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(54) **Solid shielded electrical conductors and tubes with integrated solid shielded electrical conductors**

(57) Electrical conductor (12), having a rod-like longitudinal shape extending parallel to a longitudinal axis. The conductor (12) comprises a solid inner part (15) being electrically conducting, having a flat cross-section perpendicular to the longitudinal axis and a rod-like longitudinal shape with a surface extending parallel to the longitudinal axis. The conductor (12) further comprises an insulating layer (16) closely surrounding the surface of the inner part (15), and a shielding layer (17) surrounding the insulating layer (16).

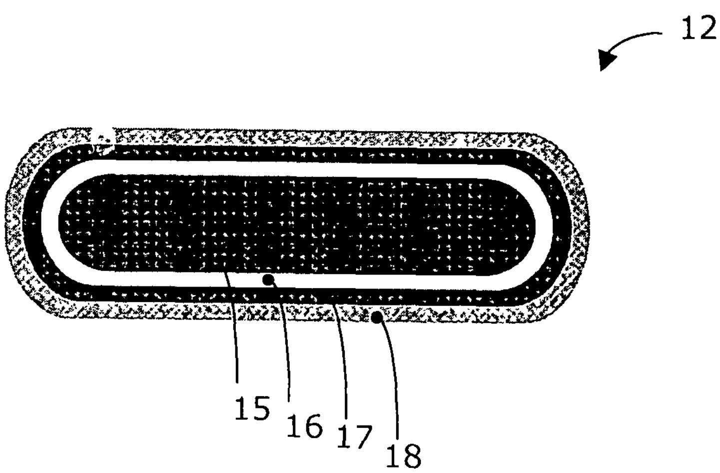

Fig. 3

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Description

[0001] The present invention concerns a solid shielded electrical conductor for integration into the wall of a tube, various tube-shaped elements with embedded solid shielded electrical conductors, and several applications using such tube-shaped elements.

BACKGROUND OF THE INVENTION

[0002] There are many different applications where tube- or pipe-shaped longitudinal structures with embedded electrical conductors are required. Drilling and pumping devices inside a drilling well, for example, being supplied and controlled by electricity from outside the well allow resources to be exploited more efficiently and safely. During a conventional drilling process, the drill bit inside the drilling well has to be cooled and the drilling mud has to be removed from the well. Therefore, in drilling technology tubes are employed in which cooling fluids are pressed down to the drill bit in the well. Usually, the drilling mud is transported along the outside of the tube toward the surface. Up to now, when supplying a down hole electric device (e.g., a drilling motor or pump), a separate cable is installed inside the tube. The handling of such a cable on site is quite difficult and the cable inside the tube reduces the cross-section being available for feeding cooling fluid into the well. Due to the cable inside the tube the hydraulic pressure is lower and the cooling is less efficient. It is quite often also a problem that the cable gets damaged, and it is quite costly to remove and replace such a cable.

[0003] A possibility to overcome some of these problems is to integrate electrical conductors into the tube wall. However, in order to maximize the flow rate of the coolant and/or the flow rate of the fluid removing the drill waste, the dimension of the tube wall has to be minimized. For practical and economical reasons several tube segments are connected together when drilling deep wells. Therefore a reliable mechanical and electrical connection between two tube segments has to be provided.

[0004] Conventional tubes for the kind of applications described so far comprise standard insulated conductors of circular cross-section. By integrating conductors with circular cross-section into the tube wall, several limiting problems arise: using few large diameter conductors (cf. Fig. 1B) results in a thick tube wall but few contacts at the connector that interconnects two tube segments; using many conductors (cf. Fig. 1A) with small diameter results in thinner tube walls, but a larger number of electrical contacts is needed at the connector between two segments.

[0005] Two examples of conventional tube-shaped elements are depicted in Figs. 1A and 1B. The Fig. 1A shows the cross-section of a tube 1 where many thin and flexible conductors with circular cross-section are embedded in the tube's wall 2. In Fig. 1B another approach is shown where fewer conductors with circular cross-section are integrated into the wall 6 of the tube 5. An example of such a tube is addressed in the UK patent application GB 2258940-A.

[0006] Flat, shielded conductors exist in many variations, but all of them have more than one individual conductor. Most of the tube wall integrated conductors known in the art employ unshielded power conductors.

[0007] Some embodiments are known where tubes with three conductors are used with a high resistive carbon fiber shield covering all conductors together. An example is disclosed in the published PCT-patent application WO 01/75263-A1, as published on 11 October 2001. Each of the three flexible conductors spans an angle of about 100°. The flexible conductors comprise conductive filaments. The high resistive carbon fiber shield is not able to reduce high electric fields adequately and therefore the risk of sparking to grounded or floating parts due to induced high voltage still exists.

[0008] A strip-like cable is presented in the UK patent application GB 2228613-A. The cable comprises several signal conductors being together enclosed by an insulating material. A conductive layer is formed on the insulating material.

[0009] A flat coaxial cable is disclosed in the patent abstract of Japan under the application number 11103741, application date 12 April 1999. A center round conductor is covered by an insulating covering. An electro-conductive foil is situated at the outside of the insulating covering.

[0010] It is an object of the present invention to provide a conductor that avoids or reduces the disadvantages of known conductors.

[0011] It is an object of the present invention to provide a tube-shaped element with conductors that avoids or reduces the disadvantages of known approaches.

[0012] It is another object of the present invention to provide systems making use of the tube-shaped element with conductors, according to the present invention.

SUMMARY OF THE INVENTION

[0013] The present invention concerns electrical conductors, having a rod-like longitudinal shape The conductor comprises a solid inner part being electrically conducting, with a flat cross-section and a rod-like longitudinal shape. The solid inner part is closely surrounded by an insulating layer, and a shielding layer is provided that surrounds the insulating layer.

[0014] The present invention further concerns tube-shaped elements having a wall that defines an inner cylindrical opening extending parallel to the longitudinal axis of the tube-shaped element. Electrical conductors are arranged in the tube wall. Each of the conductors comprises a flat, solid inner part that is electrically conducting. An insulating layer surrounds the inner part and a shielding layer is provided that surrounds the insulating layer.

[0015] Various advantageous embodiments are claimed in the dependent claims.

[0016] It is an advantage of the present invention that the conductors are well suited for energy as well as signal (data) transmission. The shielding of the conductors allows to prevent sparking. The conductors according to the present invention are thus well suited for use in an explosive environment. The shape of the conductors can be very well matched to the limited space in the tube wall. The invention allows to more freely design the tube and to optimize the mechanical and other properties of the tube walls. Using the embedded conductors, in accordance with the present invention, it is possible to achieve filling factors that are higher than the filling factors that can be achieved using conventional individually shielded conductors with circular cross-section, for example.

[0017] It is a further advantage of the invention that the shielding of the flat electrical conductors reduces the electromagnetic interferences of the conductor with respect to external equipment and vice versa. The shielding furthermore protects service personal working with the inventive tube elements from electrical shocks. The danger of high electric field induced sparking towards external floating or grounded parts is reduced dramatically by the present invention. Due to the individual shielding layer on each conductor, the signal to noise ratio of high frequency signals transmitted through the flat conductors is much higher than the signal to noise ratio observed at non-shielded conductors.

[0018] It is yet another advantage of the present invention that at connection points were two tube segments are connected, fewer contacts have to be made than with conventional tubes comprising many conductors with circular cross-section (considering equal total conductor cross-section and single electrical insulated feed-through).

[0019] The inventive tubes have the advantage that they - due to the combination of high temperature electrical insulation and chemical protection - can be employed in harsh environments, like drilling wells, for example.

Brief description of the drawings

[0020] For a more complete description of the present invention and for further objects and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1A	is a schematic representation of the cross-section of a conventional tube with many non-shielded, round conductors;
FIG. 1B	is a schematic representation of the cross-section of a conventional tube with few non-shielded, round conductors;
FIG. 2	is a schematic representation of the cross-section of a first tube-shaped element with electrical conductors, according to the present invention;
FIG. 3	is a schematic representation of the cross-section of a first electrical conductor, according to the present invention;
FIG. 4	is a schematic representation of the cross-section of a second tube-shaped element with electrical conductors, according to the present invention;
FIG. 5	is a schematic representation of the cross-section of a third tube-shaped element with electrical conductors, according to the present invention;
FIG. 6	is a schematic representation of the cross-section of a fourth tube-shaped element with electrical conductors, according to the present invention;
FIG. 7	is a schematic representation of the cross-section of another electrical conductor being embedded in a tube wall, according to the present invention;
FIG. 8A - FIG. 8C	are schematic representations various arrangements of electrical conductors, according to the present invention;
FIG. 9A - FIG. 9H	are schematic representations of the cross-section of various inner parts, according to the

present invention;

FIG. 10 is a schematic representation of the cross-section of a tube-shaped element with a first connector, according to the present invention;

FIG. 11 is a schematic representation of the cross-section of two tube-shaped elements with common connectors, according to the present invention;

FIG. 12 is a schematic representation of an application example showing how two tube-shaped elements with connectors can be employed in accordance with the present invention;

FIG. 13 is a schematic representation of the cross-section through the wall of a tube-shaped element with one electrical conductor, according to the present invention;

FIG. 14A - FIG. 14B are two schematic representations of wrapped layers, according to the present invention;

DETAILED DESCRIPTION

[0021] The present invention concerns tube-shaped elements 10, as illustrated in Fig. 2, having a wall 11 defining an inner cylindrical opening 13 that extends parallel to the longitudinal axis 14 of the tube-shaped element 10. In most cases, the wall 11 has a circular (as in Fig. 2) or oval cross-section and is arranged concentrically with respect to the element's longitudinal axis 14. According to the present invention, the tube-shaped element 10 comprises a plurality of longitudinally extending rod-shaped electrical conductors 12.

[0022] These conductors 12 may be arranged essentially parallel to the longitudinal axis 14 in the wall 11, or the conductors 12 may have a helical shape or a wave shape extending parallel to the longitudinal axis 14. The conductors 12 comprise a flat, solid inner part 15 (illustrated as solid black element) that is electrically conducting, an insulating layer 16 (illustrated as white layer) that closely surrounds the inner part 15, and a shielding layer 17 (illustrated as solid black layer). The embodiment in Fig. 2 comprises n=8 conductors 12, for example.

[0023] A first embodiment of an electrical conductor in accordance with the present invention is illustrated in Fig. 3. In the present example, the conductor 12 comprises a solid inner part 15 (illustrated as solid black element) that is electrically conducting. The solid inner part 15 has a flat cross-section perpendicular to the conductor's longitudinal axis and a rod-like longitudinal shape with a surface extending parallel to the longitudinal axis. The solid inner part 15 may comprise copper, for instance. The inner part 15 is closely surrounded by an insulating layer 16 (illustrated as white layer). This layer is also referred to as interior layer. An intermediate layer 17 (illustrated as black layer) covers the interior layer 16. An exterior layer 18 is situated at the outside (illustrated as gray layer). The three layers 16, 17, 18 can each serve a different purpose. In the present example, the interior layer 16 comprises an insulating material, the intermediate layer 17 may comprise a metal (e.g., copper) that serves as an electrical shielding layer. The exterior layer 18 may comprise a material that protects the other layers and the inner part against chemicals, for example.

[0024] Another tube-shaped element 20 is illustrated in Fig. 4. The tube 20 has a wall 21 defining an inner cylindrical opening 23 that extends parallel to the longitudinal axis 24 of the tube-shaped element 20. The tube-shaped element 20 comprises a plurality of electrical conductors 22 that are arranged essentially parallel to the longitudinal axis 24 in the wall 21. Each of the conductors 22 comprise a flat, solid inner part 25 (illustrated as solid black element) that is electrically conducting, an insulating layer 26 (illustrated as white layer) that closely surrounds the inner part 25, and a thin shielding layer (this thin shielding layer is not visible in Fig. 4). The embodiment in Fig. 4 comprises n=8 conductors 22, for example. The tube wall 21 comprises two (metallic) layers 27 and 28. The materials of these layers 27 and 28 may be selected in order

- to protect the tube 20 against chemicals,
- to serve as an overall shield against electromagnetic radiation,
- to reduce mechanical stress or strain on the individual conductors 22,
- to prevent gas diffusion from the outside or from the interior 23 into the tube wall 21,
- to suppress interferences,
- to serve as signaling or data lines, etc.

[0025] Contrary to the flat conductors 12 in Figs. 2 and 3, the conductors 22 in Fig. 4 just comprises two layers, namely an insulating layer 26 and a thin shielding layer.

[0026] A further embodiment is illustrated in Fig. 5. A tube-shaped element 30 is shown that comprises n=8 flat conductors 32. The tube 30 has a wall 31 defining an inner cylindrical opening 33 that extends parallel to the longitudinal axis 34 of the tube-shaped element 30. The tube-shaped element 30 comprises a plurality of electrical conductors 32 that are arranged essentially parallel to the longitudinal axis 34 in the wall 31. Each of the conductors 32 comprise a flat, solid inner part 35 (illustrated as solid black element) that is electrically conducting, an insulating layer 36 (illustrated as white layer) that encloses closely surrounds the inner part 35, and a shielding layer 37 (illustrated as solid black layer). The exterior layer 37 may be covered by a material that allows the conductors 32 to be more easily embedded inside the tube wall 31.

[0027] Fig. 6 shows the cross-section of another tube-shaped element 40, according to the present invention. The tube-shaped element 40 comprises n=8 flat conductors 42. The tube 40 has a wall 41 defining an inner cylindrical opening 43 that extends parallel to the longitudinal axis 44 of the tube-shaped element 40. The tube-shaped element 40 comprises a plurality of electrical conductors 42 that are arranged essentially parallel to the longitudinal axis 44 in the wall 41. Each of the conductors 42 comprise a flat, solid inner part 45 (illustrated as solid black element) that is electrically conducting, a very thin insulating layer (not visible in Fig. 6), and a very thin shielding layer (not visible in Fig. 6, too) that both surround the inner part 45. The tube wall 41 comprises two layers 47 and 48 (e.g., carbon layers) that define an interior section 49 inside the wall 41. This interior section 49 may be filled with an insulating material.

[0028] Details of another embodiment are depicted in Fig. 7. The wall 51 of a tube-shaped element is illustrated. The wall 51 comprises longitudinal trenches 59 at the outer periphery being in the present example oriented essentially parallel to the longitudinal axis of the tube-shaped element. The shape of the trenches 59 is designed so that the conductors 55, 56, 57 can be placed at least partially inside these trenches 59. The conductor in the present embodiment comprises a solid inner part 55 serving as conductor, an insulating layer 56, and a shielding layer 57. In the present example, the trench 59 has a rectangular cross-section in the plane that is perpendicular to the longitudinal axis of the tube-shaped element. The width of the trench 59 is chosen such that the conductor 55, 56, 57 can be easily inserted into the trench 59. As illustrated in Fig. 7, the conductors 55, 56, 57 may be held in place by filling the trenches 59 with a resin 58 (e.g., an epoxy resin or a phenol, or urethane resin), or glue, or PPS, or the like. For most applications, at least one additional layer 52 is formed to cover the conductors 55, 56, 57 and the trenches 59.

[0029] The tube-shaped elements according to the present invention may have cylindrical as well as tapered tube walls. The tube-shaped elements can be made with varying thickness of walls lengthwise. The tube's cross-section may be circular, oval, or polygonal. One example of a tube-shaped element 60 is schematically illustrated in Fig. 8A. The tube-shaped element 60.1 comprises a tube wall 61 that is arranged concentrically around the longitudinal axis 64. Two of the n conductors 62 are visible in this Figure. These conductors 62 are arranged essentially parallel to the longitudinal axis 64.

[0030] Another embodiment is depicted in Fig. 8B. A tube-shaped element 60.2 is shown. The tube-shaped element 60.2 comprises a tube wall 65 that is arranged concentrically around the longitudinal axis 64. One conductor 66 is shown in this Figure. The conductor has a helical shape extending around the longitudinal axis 64. The angle β may be $-90° < \beta < +90°$.

[0031] Yet another embodiment is illustrated in Fig. 8C. The tube-shaped element 60.3 comprises a wave-shaped conductor 69. The conductors 62, 66, 69 may be embedded in the tube wall 61, 65, 68 by adding a layer around the tube wall 61, 65, 68. The tube-shaped elements 60.1, 60.2, 60.3 and the conductors 62, 66, 69 are not drawn to scale.

[0032] Various cross-sections of the inner parts 71.1 - 71.8 of the flat conductors, according to the present invention, are schematically illustrated in Figs. 9A - 9H. The inner parts 71.1 - 71.6 have a tube wall adapted shape. The flat inner part 71.6 comprises a through hole 72. A fiber can be embedded in this through hole 72, for example. By sending light through this fiber, it is possible to detect whether the respective conductor is damaged. The fiber can also be used for communication purposes. All the inner parts 71.1 - 71.8 are well suited for tube wall integration in accordance with the present invention. Preferably, the flat cross-section has a width w and a thickness t, with w being greater than two times t (cf. Fig. 7).

[0033] A first connector 83, according to the present invention, is schematically depicted in Fig. 10. The connector 83 sits at the end of a tube segment comprising n flat solid conductors 82 embedded in a tube wall 81. Two conductors 82 are visible in Fig. 10. Each conductor comprises a flat solid inner part 85 (illustrated in black), an insulation layer 87 (illustrated in white), and a shielding layer 88 (illustrated in black). The flat solid inner part 85 is connected by a bridge element 89. Depending on the application the bridge element 89 may connect two or more of the n conductors 82. A contact pin 90 is provided. This contact pin 90 is connected to the bridge element 89 and allows to establish a contact to a connector of a subsequent tube segment (not shown in Fig. 10). The first connector 83 allows several of the n flat solid inner parts 85 to be combined into one contact pin 90. This approach allows to reduce the number of necessary connector contacts. Due to the high electric fields between the flat solid inner parts 85 and the shielding layers 88, the electrical stress control has to be designed appropriately. In the present example, a conductive bridge 80 is provided inside the connector 83. This bridge (also referred to as shielding connection) connects the shielding layers 88. This approach allows all shielding layers to be kept at the same potential, e.g., ground potential.

[0034] Another connector 93, according to the present invention, is schematically depicted in Fig. 11. Two connectors 93 are shown that allow to connect the tube segments 101 and 102. There is a separate feed through for each conductor

92. The conductors 92 in Fig. 11 are embedded in a tube wall 91 and each conductor 92 comprise a flat solid inner part 95 (illustrated in black), an insulation layer 97 (illustrated in white), and a shielding layer 98 (illustrated in black). The connector design is much simpler than the one described in connection with Fig. 10. The electrical stress control can be realized more easily and a higher insulation level can be achieved.

[0035] The connectors according to the present invention are preferably protected against pollution and condensation. Means can be employed to seal the part of the connectors (e.g., by using a connector case) where the contact is made between the conductors of subsequent tube segments.

[0036] The conductors of the tube-shaped elements according to the present invention may be employed as electrical power and/or data conductors (e.g., for data transmission and signaling purposes) and may be combined with a fiber-optic sensing and monitoring system, in order to enable the permanent monitoring of the element's integrity. The monitoring system allows to recognize problems at an early stage.

[0037] In one embodiment, the tube-shaped elements 101 with integrated conductors are designed for electric pumping applications. The set-up is schematically illustrated in Fig. 12. The tube-shaped elements 101 are corrosion and pressure resistant und thus well suited for such applications. Two tube-shaped elements 101 are connected by connectors 93. The inner structure 103 (liner) of the tube-shaped elements 101 (illustrated as dark gray pipe), is connected to the (submergible) pump 105. The pump 105 transports a liquid (e.g., water or oil) from the bottom of the well up to the surface, as indicated by the arrow 107. The conductors 104 can be used to connected a power supply 106 to a down hole pump 105, as schematically indicated in Fig. 12. In addition, it is possible to install a down hole permanent (gauge) monitoring system using some of the conductors inside the tube-shaped elements 101. In case of changing down hole conditions the system allows quick reactions and if necessary interventions.

[0038] In an alternative embodiment high frequency signals are modulated onto the power supply signal. Employing a filter unit, the high frequency signals can be recovered. This approach allows to use the conductors for power supply and data transmission purposes at the same time.

[0039] In another embodiment, the tube-shaped element with integrated conductors is designed for electric drilling applications. The tube-shaped element is high-temperature, corrosion and fatigue resistant und thus well suited to withstand the very high mechanical forces and the hot and hostile down hole conditions. The conductors can be connected to a hydraulically actuated sliding sleeve or a down hole electric drilling motor for example. It is also possible to install a down hole monitoring system (e.g., employing a set of sensors) using the conductors inside the tube-shaped element. In case of changing down hole conditions the system allows quick reactions and if necessary interventions.

[0040] A tube-shaped element according to the present invention can be used for driving a tunnel in soil, ice or rock, for example. The tube-shaped element is part of a drill bit assembly that is rotatable. The inner opening of the tube-shaped element enables the removal of drill waste from the drill bit front through said opening toward the rear end.

[0041] The tube-shaped element may comprise an auxiliary tube allowing compressed air or water to be guided into the tunnel during drilling. The compressed air or water causes the soil, ice or rock to move through the inner opening toward the end of the tube-shaped element.

[0042] The tube-shaped elements according to the invention are well suited for use in combination with electric equipment, like sensors, valves, cameras, pumps, drilling heads, drilling motors, and so forth. The invention is particularly well suited for usage in the oil or gas drilling business, electric cable laying, horizontal or vertical controlled drilling, electric energy transmission, (geo)thermal heating systems and energy exploration, combined gas supply and electric energy transmission, etc. Due to the usage of individually shielded conductors, a deployment in critical environments (e.g., in explosive environment such as oil platform, gas drilling, gas supply, etc.) is possible.

[0043] The flat inner part preferably has a cross-section with the following dimensions (thickness t and width w): $1\text{mm} < t < 10\text{mm}$, $2\text{mm} < w < 50\text{mm}$. The inner part comprises a metal, preferably copper or aluminum. According to the present invention, the tube wall comprises $3 < n < 22$ conductors.

[0044] According to the present invention, the insulating layer (interior layer) typically has a thickness between 0.1mm and 2mm. Preferably, the thickness is between 0.2mm and 1mm. A Kapton™ or Mica™ film may be used as insulating material, for example. Likewise, the insulating material may comprise Kapton™ Polyimid and/or Teflon™. Well suited is a Kapton-Teflon FEP sandwich foil, as offered by Du Pont. Such a sandwich foil may comprise two Teflon™ layers and one Kapton layer, for instance.

[0045] In a preferred embodiment, strips of an insulating foil (e.g., a Kapton-Teflon FEP sandwich foil) are wrapped around the inner part. If one provides sufficient overlap when wrapping the foil around the inner part, a tight enclosure can be obtained. An overlap can be obtained by choosing an appropriate slope when wrapping a single strip 120 around the inner part, as schematically indicated in fig. 14A. Another approach, illustrated in Fig. 14B, allows to obtain sufficient overlap by using two layers 121 and 122 of insulating foil strips, whereby the second layer 122 is shifted with respect to the first layer 121.

[0046] A conductive coating may be employed as shielding layer. Each conductor as used herein has such an individual shielding layer. The thickness is typically between 0.1mm and 2mm. Preferably, the thickness is between 0.2mm and 1mm. Copper or Cablolam copper is suited as shielding material. The Cablolam copper may comprise a copper layer and a PET (Polyethylenterephtalat) layer.

[0047] It is advantageous to apply one or more layers to the outside of the tube wall 111, as illustrated in Fig. 13. The thickness *tw* of the tube wall 111 typically is between 2mm and 50mm, and preferably between 3mm and 20mm. The layer 114 may have a thickness *t1* between 1mm and 20mm, and preferably between 3mm and 10mm. The layer 115 may have a thickness *t2* between 0.5mm and 10mm, and preferably between 1mm and 3mm. The total thickness of the tube wall 111 plus all additional layers 114, 115 is thus between 3.5mm and 80mm, and preferably between 8mm and 36mm.

[0048] The tube wall may comprise reinforcing fibers, such as carbon, glass or aramid, and a matrix material supporting the fibers. The tube wall may also comprise an embedded steel layer.

[0049] The overall diameter of a tube-shaped element in accordance with the present invention may be between 30mm and 500mm. Preferably, the diameter is between 50mm and 200mm.

[0050] It is an advantage of the tube-shaped elements according to the present invention that the layers (e.g., 16, 17, and/or 18) surrounding the flat inner part of the conductors provide for an effective protection against mechanical forces, pressure, humidity, chemicals, heat, and so forth. The layers are liquid tight and, if necessary can also be made gas tight.

[0051] Before integrating the flat solid conductors into a tube wall, one may pre-test each of the conductors. It is for example possible to conduct electrical pre-testing steps before tube wall integration. This pre-testing is possible since the shielding layer can act as counter electrode being closely spaced apart from the conducting inner part.

[0052] It is advantage of those embodiments where the conductors as well as the tube wall comprise protective layers (cf. Figs. 4 and 6) that due to this built-in redundancy the reliability and robustness of these tube-shaped elements can be improved compared to conventional designs as illustrated in Figs. 1 and 2, for example.

[0053] For applications where high torsion and/or bending forces act on the tube-shaped elements, care has to be taken that the various layers inside the tube wall bond optimal. This is a problem for chemical and high temperature resistant materials (like Teflon™), since these materials generally do not bond optimally to neighboring layers. The tube-shaped elements 10 and 30, illustrated in Figs. 2 and 5, have the advantage that the structure of the tube walls 11, 31 is more stable since no shielding layers or the like are integrated into these tube walls. The design of the wall structure is almost completely independent from the design of the solid conductors. A chemically resistant layer can be applied to the solid conductors without having much of an impact on the mechanical properties of the tube wall as a whole. Chemical resistant layers can be used to protect the conductors that do not bond well to the material of the tube wall.

[0054] It is a further advantage of the invention that even if one conductor is attacked by a chemical or gas, the other conductors remain intact (redundancy concept).

[0055] Due to the fact that individually shielded conductors are integrated into a tube wall, the cross talk between neighboring conductors is reduced compared to arrangements where many unshielded or jointly shielded conductors are embedded in the tube wall.

[0056] Due to its well conducting individual shielding layers, the present invention is very well suited for use on oil-platforms or in other sensitive areas where protection against explosion is of utmost importance. A solid copper conductor in accordance with the present invention is able to conduct higher currents than a copper braid. The tubes according to the present invention can also be used in the exploration and winning of oil and gas.

[0057] The inventive conductors and/or tube-shaped elements with integrated conductors can be used for the transmission of electrical power. The invention is well suited for special applications where efficient cooling is required. Examples of such applications are magnetic levitation systems (e.g., a magnetic levitation train), supra-conducting systems, and the like.

[0058] The invention is also suited for supplying caves, buildings and other facilities with gas and/or water and with electric power. This can all be done using just one tube-shaped element.

[0059] The tube-shaped element in accordance with the present invention can be used as oil and/or gas pipelines. The conductors provide power to intermediate pump stations that are required when long distances are to be bridged by a pipeline.

[0060] The invention set standards for quality, ease of use and durability.

Claims

1. Electrical conductor (12; 22; 32; 82; 92; 112), having a rod-like longitudinal shape extending parallel to a longitudinal axis, comprising

   - a solid inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95) being electrically conducting, having a flat cross-section perpendicular to the longitudinal axis and a rod-like longitudinal shape with a surface extending parallel

to the longitudinal axis,
- an insulating layer (16; 26; 36; 56; 87; 97; 120; 121, 122) closely surrounding the surface of the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95), and
- a shielding layer (17; 37; 57; 88; 98) surrounding the insulating layer (16; 26; 36; 56; 87; 97; 120; 121, 122).

2. Electrical conductor (12; 22; 32; 82; 92; 112) according to claim 1, **characterized in that** the flat cross-section has a width *w* and a thickness *t*, with *w* being greater than two times *t*.

3. Electrical conductor (12; 22; 32; 82; 92; 112) according to claim 1 or 2, **characterized in that** the flat cross-section is approximately rectangular.

4. Electrical conductor (12; 22; 32; 82; 92; 112) according to claim 1, 2 or 3, **characterized in that** the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95) comprises copper or aluminum.

5. Electrical conductor (12; 22; 32; 82; 92; 112) according to one of the preceding claims, **characterized in that** the flat inner part (15) is surrounded by a plurality of layers (16, 17, 18), one of the plurality of layers serving as layer (18) that provides for a protection against chemicals and/or humidity.

6. Electrical conductor (12; 22; 32; 82; 92; 112) according to one of the preceding claims, **characterized in that** the shielding layer (17; 37; 57; 88; 98) is a metallic shielding layer employed to reduce electromagnetic interferences and/or to prevent sparking.

7. Electrical conductor (12; 22; 32; 82; 92; 112) according to one of the preceding claims, **characterized in that** at least the insulating layer (16; 26; 36; 56; 87; 97; 120; 121, 122) is formed by wrapping a band around the surface of the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95), whereby the band partially overlaps.

8. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) having a wall (11; 21; 31; 41; 51; 61; 65; 68; 81; 91; 111) defining an inner cylindrical opening (13; 23; 33; 43) extending parallel to a longitudinal axis (14; 24; 34; 44; 64) of the tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) and comprising a plurality of longitudinal electrical conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112), wherein each of the conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112) comprises

- a longitudinal solid inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95) being electrically conducting, having a flat cross-section perpendicular to the inner part's longitudinal axis and a surface extending essentially parallel to the inner part's longitudinal axis,
- an insulating layer (16; 26; 36; 56; 87; 97; 120; 121, 122) closely surrounding the surface of the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95), and
- a shielding layer (17; 37; 57; 88; 98) surrounding the insulating layer (16; 26; 36; 56; 87; 97; 120; 121, 122).

9. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to claim 8, **characterized in that** the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95) has a cross-section being approximately rectangular, whereby the conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112) are arranged tangentially in the wall (11; 21; 31; 41; 51; 61; 65; 68; 81; 91; 111).

10. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to claim 8, **characterized in that** the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95) comprises copper or aluminum.

11. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to claim 8, 9 or 10, comprising *n* conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112), with $n > 3$.

12. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to claim 11, whereby the *n* conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112) are arranged in a regular pattern.

13. Tube-shaped element (10) according to one of the claims 8 - 12, **characterized in that** the flat inner part (15) is surrounded by a plurality of layers (16, 17, 18), one of the plurality of layers serving as layer (18) that provides for a protection against chemicals and/or humidity.

14. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to claim 8 or 9, whereby the shielding layer (17; 37; 57; 88; 98) is a metallic shielding layer employed to reduce electromagnetic interferences between adjacent conductors (12; 22; 32; 42; 55, 56; 62; 66; 69; 82; 92; 104; 112) and/or to prevent sparking.

15. Tube-shaped element (10; 20; 30; 40; 60.1; 60.2; 60.3; 101, 102) according to one of the claims 8 - 14, **characterized in that** at least the insulating layer (120; 121, 122) is formed by wrapping a band around the surface of the inner part (15; 25; 35; 45; 55; 71.1 - 71.8; 85; 95).

16. Tube-shaped element according to one of the claims 8 - 15, **characterized in that** the wall (51) comprises longitudinal trenches (59) extending essentially parallel to the tube's longitudinal axis, whereby the shape of the trenches (59) is designed so that the conductors (55, 56, 57) can be placed at least partially in these trenches (59).

17. Tube-shaped element according to one of the claims 8 - 16, **characterized in that** the wall comprises several layers (111, 114, 115).

18. Tube-shaped element according to one of the claims 8 - 17 being designed to serve as drilling tube where during a drilling process solid or fluid material travels through the inner cylindrical opening.

19. Tube-shaped element (101) according to one of the claims 8 - 17 being designed to be used in connection with a pump (105).

20. Tube-shaped element (101) according to one of the claims 8 - 17 being designed to be used in an environment where protection against explosions is required.

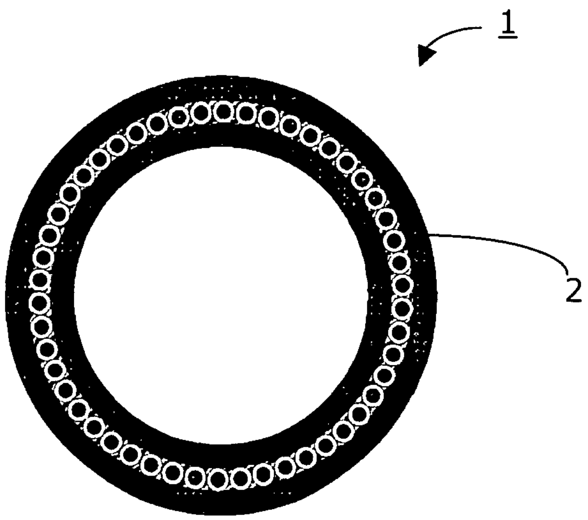


Fig. 1A

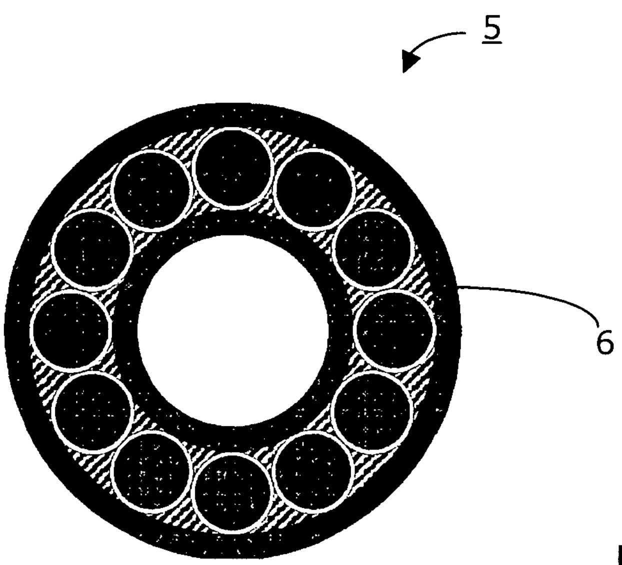


Fig. 1B

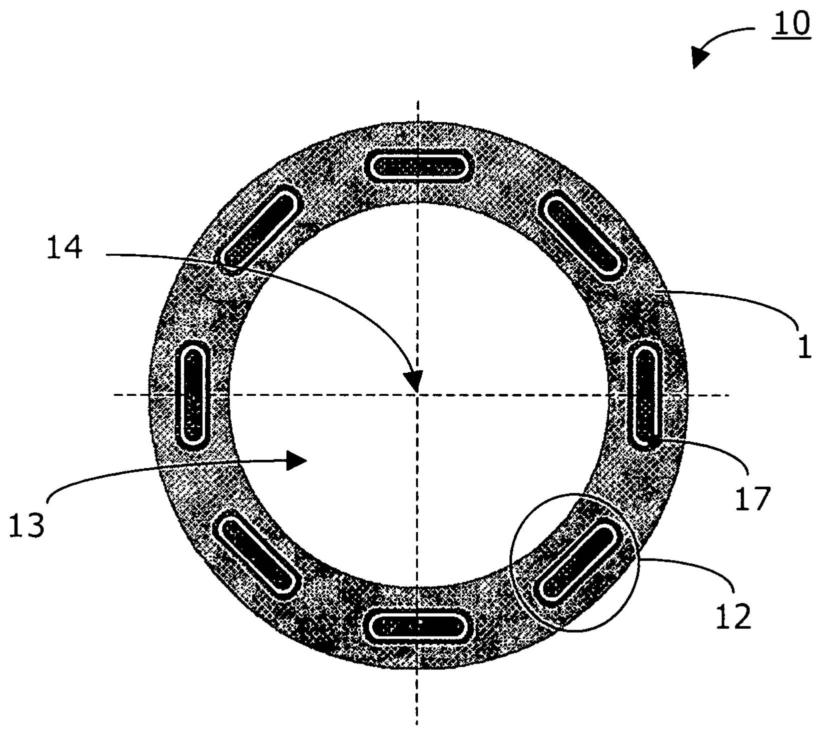


Fig. 2

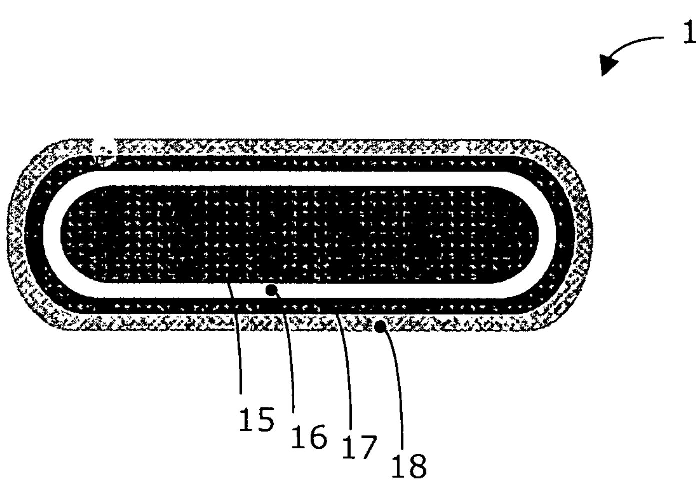


Fig. 3

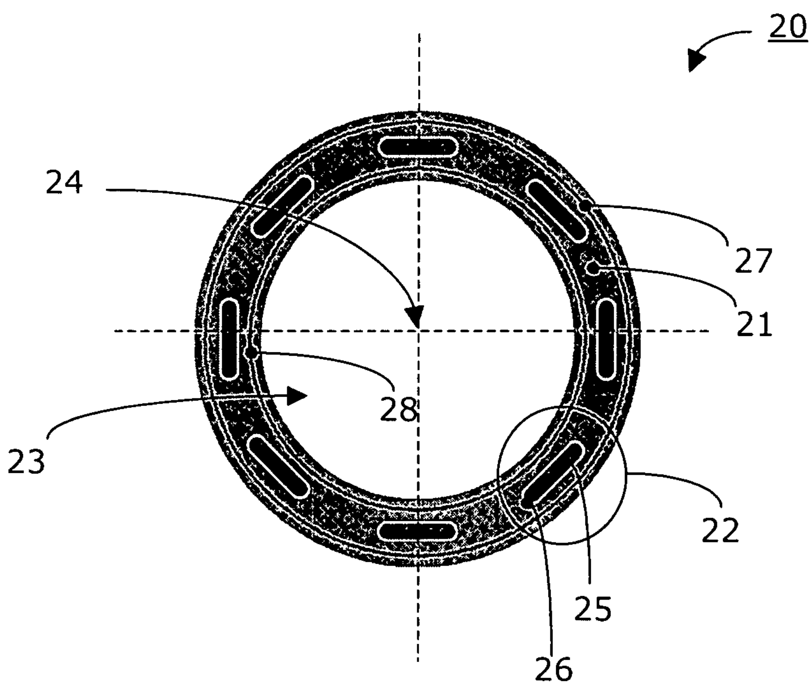
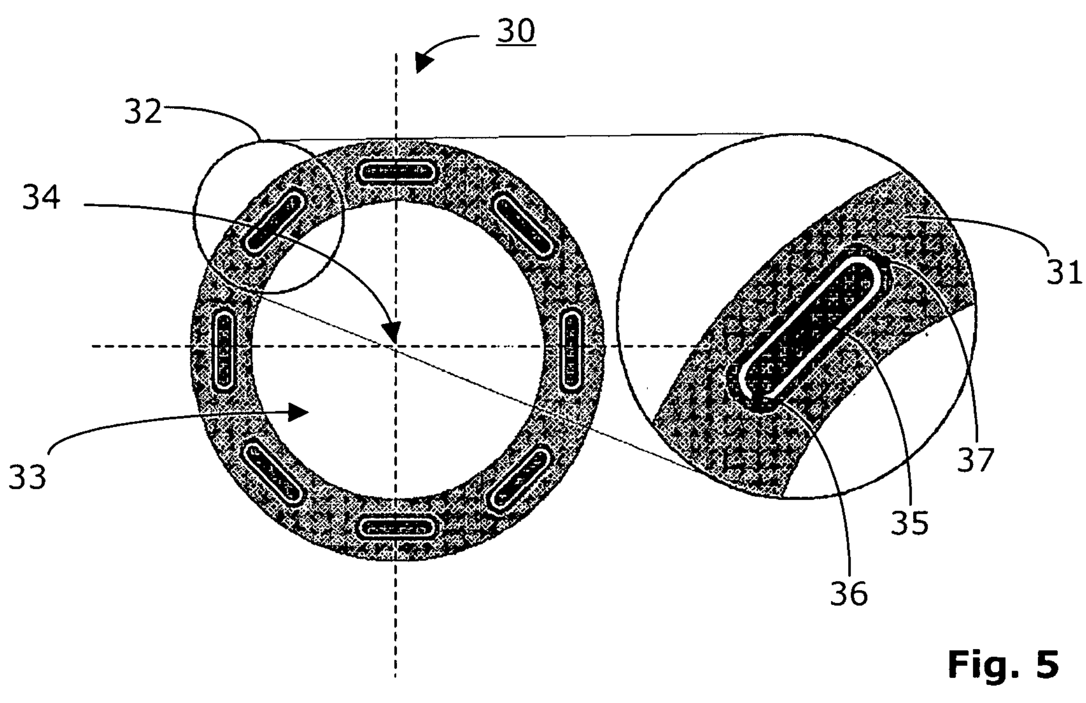


Fig. 4



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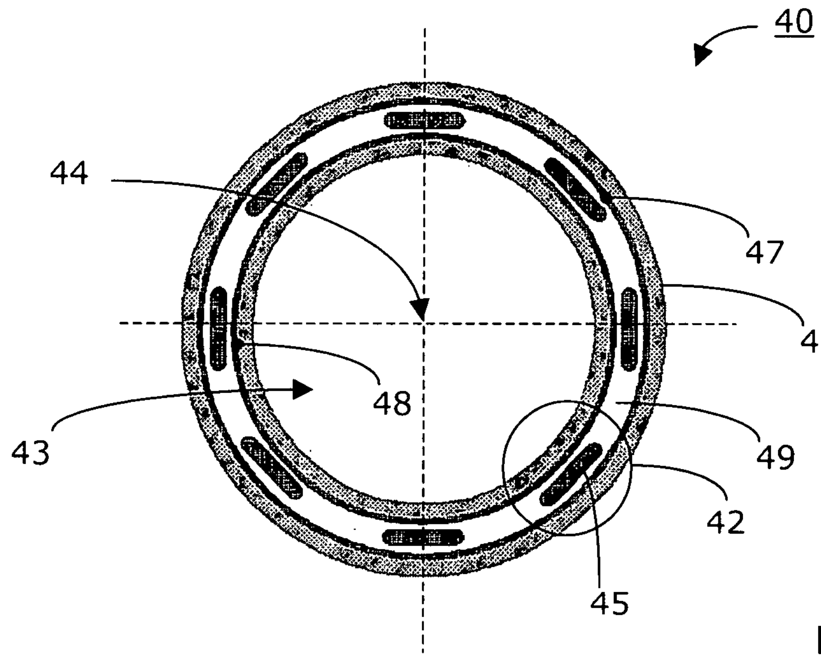

Fig. 6

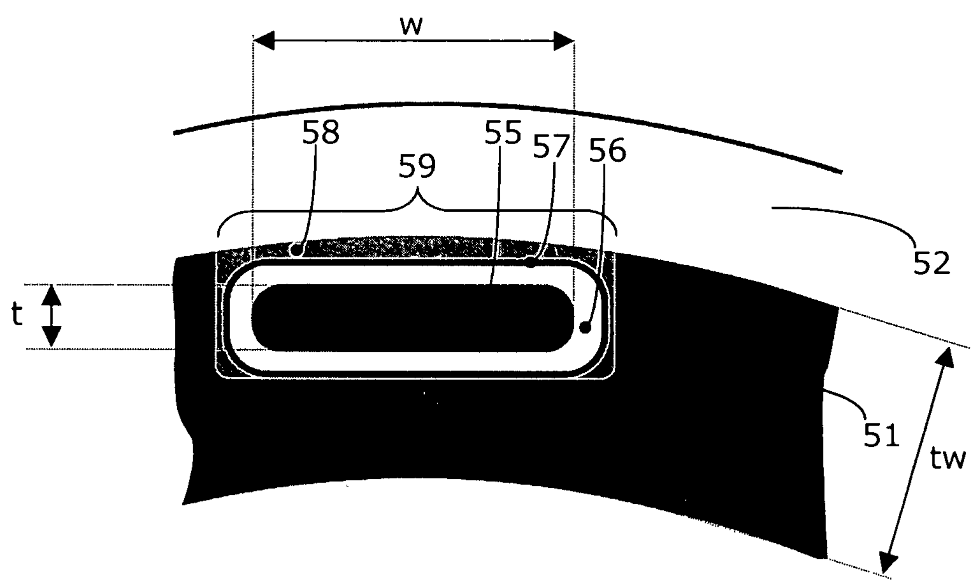

Fig. 7

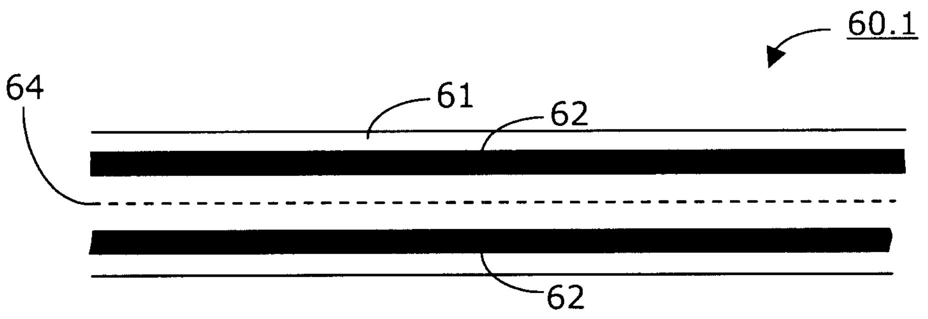

Fig. 8A

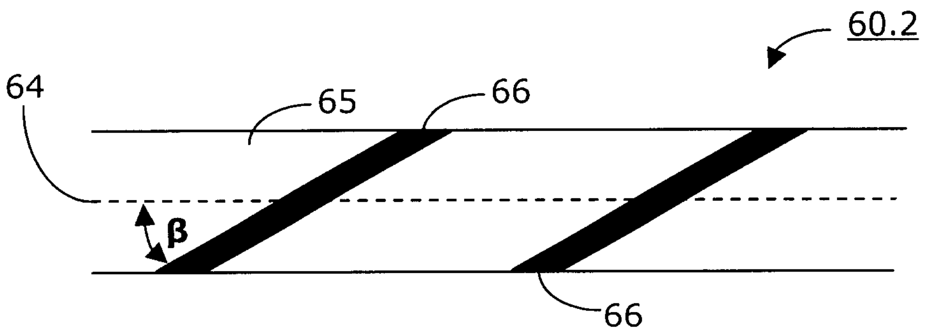

Fig. 8B

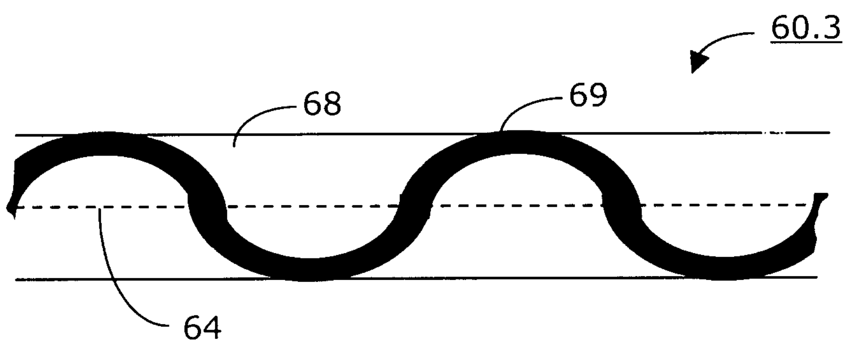

Fig. 8C

Fig. 9A

Fig. 9B

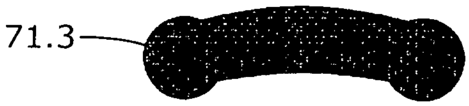

Fig. 9C

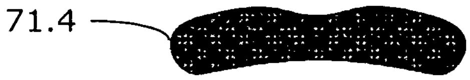

Fig. 9D

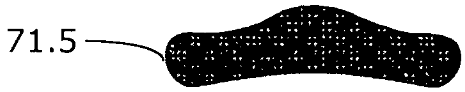

Fig. 9E

Fig. 9F

Fig. 9G

Fig. 9H

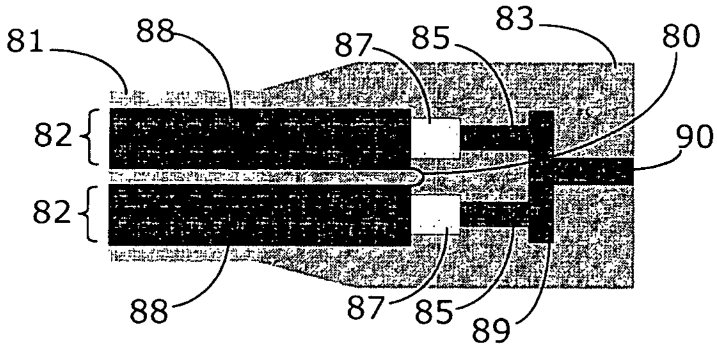

Fig. 10

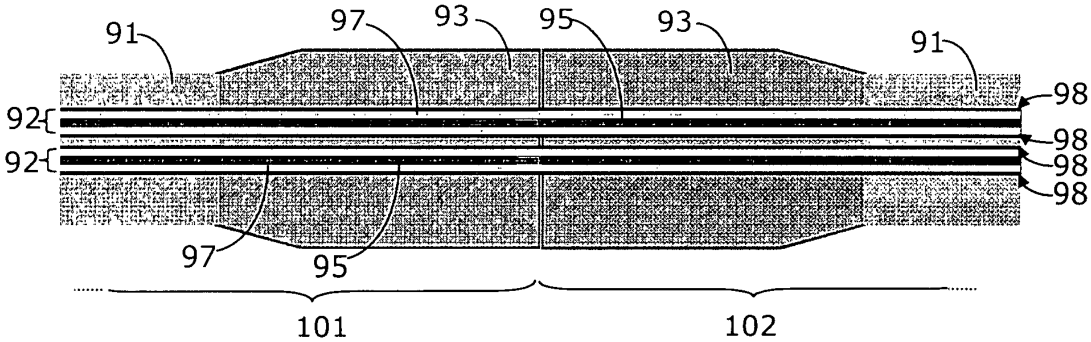
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Fig. 11

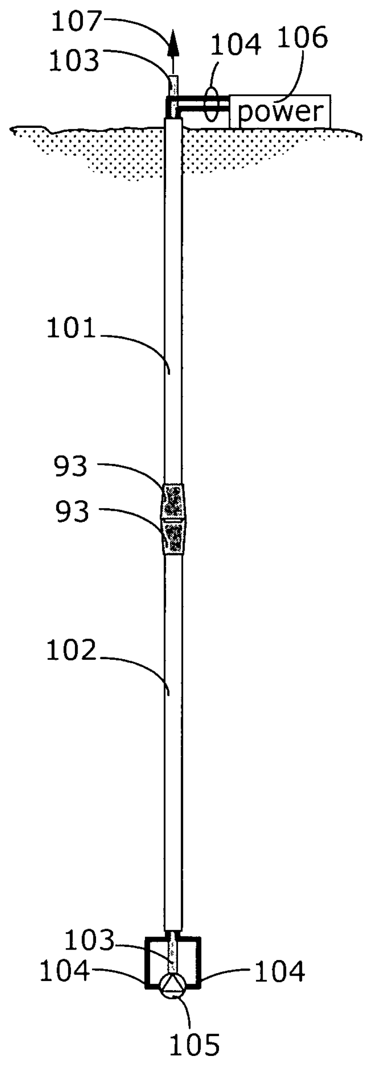
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Fig. 12

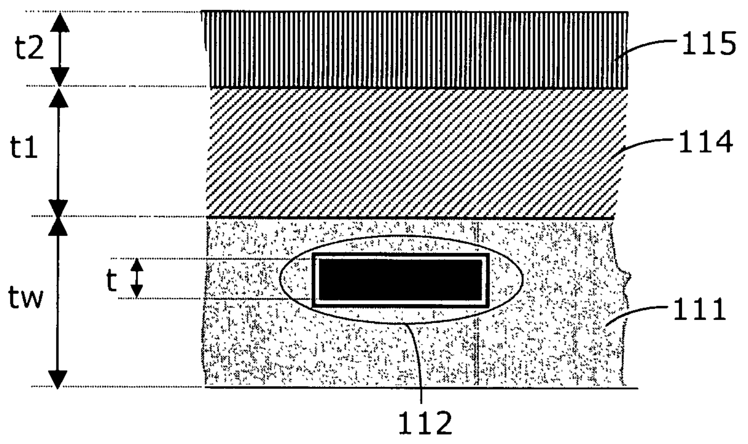

Fig. 13

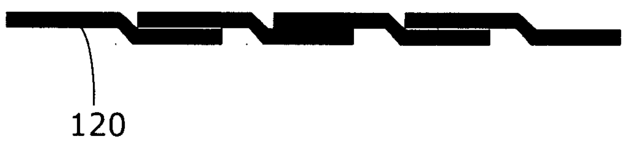

Fig. 14A

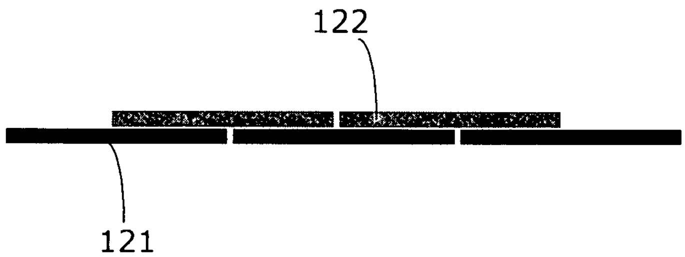

Fig. 14B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 00 8817

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.7)
A	CH 682 525 A (OPTELMA AG) 30 September 1993 (1993-09-30) * column 1, line 31 - column 2, line 33; figures 1-3 *	1-7	H01B7/00
A	DE 58 895 C (SEBASTIAN ZIANI) * page 1, column 2 - page 3, column 2; figures 1-9 *	1-7	
A	FR 2 710 923 A (MOULINEX SA) 14 April 1995 (1995-04-14) * figure 3 *	8-20	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H01B
H02G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 September 2002	Demolder, J

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82