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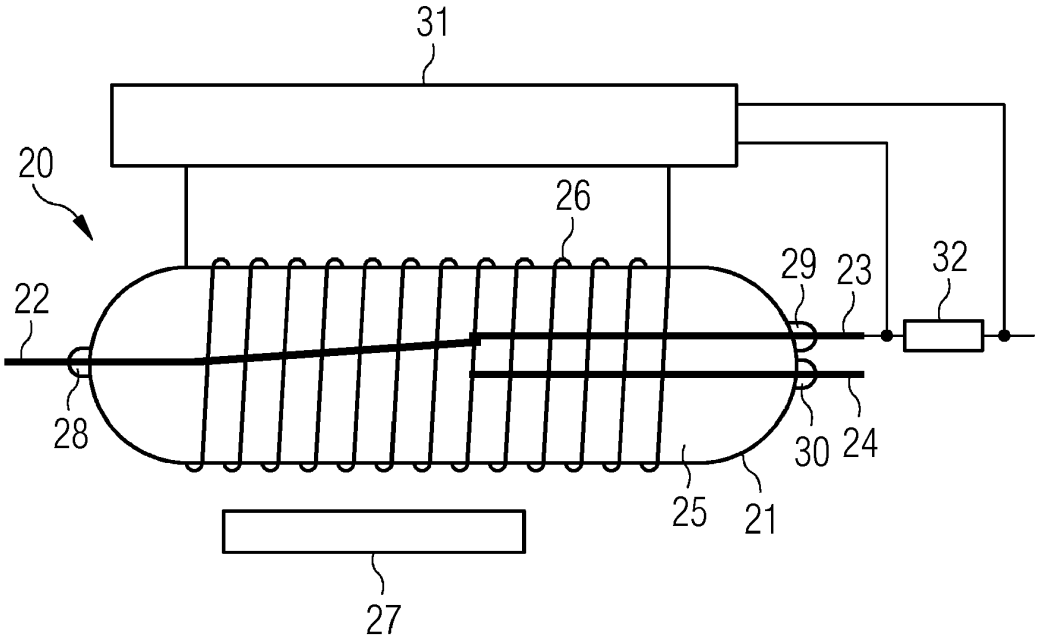
(54) **SUBSEA FUSE DEVICE**

(57) The present invention relates to a subsea fuse device (20) comprising a housing (21), a bistable switch configured to be selectively switched by applying a magnetic field, and a coil (26) configured to generate the magnetic field depending on an electrical current flowing through the bistable switch. The fuse housing (21) comprises a one-piece outer envelope which completely encloses a hollow space (25) and provides a first feedthrough opening (28) and a second feedthrough opening (29). The bistable switch is arranged within the hollow space (25) of the fuse housing (21) and a first terminal wire (22) of the bistable switch is extending through the first feedthrough opening (28) and a second terminal wire (23) of the bistable switch is extending through the second feedthrough opening (29). The terminal wires (22, 23) are in contact with their corresponding feedthrough openings (28, 29) and seal the corresponding feedthrough opening (28, 29).

FIG 2



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Description

Field of the invention

[0001] The present invention relates to a subsea fuse device which may be used in subsea equipment for protecting electrical and electronic circuits. Furthermore, the present invention relates to a subsea device comprising an electric circuitry comprising the subsea fuse device.

Background of the invention

[0002] In subsea applications, for example subsea oil production, subsea devices may be used which may comprise electric and electronic circuitry. The subsea devices may be arranged in a depth of several hundred or several thousand meters, for example in a depth of up to or even in excess of 3000 m. A subsea device may comprise a housing or enclosure for protecting the interior of the subsea device from harsh environments outside the subsea device. The housing or enclosure is also called subsea canister. The subsea device may be pressure compensated such that the inside pressure essentially corresponds to an environmental pressure outside the subsea device. Depending on the depth in which the subsea device is located, the environmental pressure may be in the range of one to a few hundred bars, for example 300 bar in a depth of 3000 m. The Enclosure of the pressure compensated subsea device may be filled with a fluid, for example oil, which may be pressurized with ambient pressure. Consequently, a high ambient pressure may also act on the electric or electronic circuitry arranged within the subsea device.

[0003] Fuses are used in electronic and electrical circuitry to protect partial circuits, so-called sub-circuits, from overload and short circuits. A usual fuse may work by melting or vaporizing a conductive element arranged within the fuse.

[0004] Melting or vaporizing the conductive element of the fuse breaks a current to a protected sub-circuit thus isolating the sub-circuit from the rest of the circuit or system.

[0005] When using such a fuse in subsea device, the fuse may fail to protect sub-circuits when being used in oil at high ambient pressure, for example at 300 bars. Additionally, the oil which is typically used as an isolating dielectric fluid, may be contaminated by the melted of vaporized conductive element of the fuse. This may influence the insulating properties of the oil which are depending on the cleanliness of the oil.

[0006] Therefore, there is a need for a fuse for subsea devices which reliably breaks a current in an oil-filled subsea device at high pressures and which does not contaminate surrounding oil when breaking the current.

Summary of the invention

[0007] According to the present invention, this object is achieved by a subsea fuse device and a subsea device as defined in the independent claims. The dependent claims define embodiments of the present invention.

[0008] A subsea fuse device according to the present invention comprises a fuse housing, a bistable switch and a coil. The bistable switch is configured to be selectively switched into a first switching state and second switching state by applying a magnetic field. The coil is configured to generate the magnetic field depending on an electrical current flowing through the bistable switch. The fuse housing comprises a one piece outer envelope which completely encloses a hollow space and provides a first feed through opening and a second feedthrough opening. The bistable switch is arranged within the hollow space of the fuse housing. A first terminal wire of the bistable switch is extending through the first feedthrough opening and a second terminal wire of the bistable switch is extending through the second feedthrough opening. An electrical current, which is to be interrupted in case of a failure or overcurrent condition, may be transmitted via the first and second terminal wires in the first switching state and may be interrupted in the second switching state. At the first feedthrough opening, an outer circumferential surface of the first terminal wire is in contact with an inner circumferential surface of the first feedthrough opening and seals the first feedthrough opening. At the second feedthrough opening, an outer circumferential surface of the second terminal wire is in contact with an inner circumferential surface of the second feedthrough opening and seals the second feedthrough opening.

[0009] Thus, the interior of the fuse housing comprising the bistable switch is completely sealed from an outside of the fuse housing. Consequently, the bistable switch is not in contact with a fluid surrounding the fuse housing, for example a dielectric fluid or oil. Furthermore, the interior of the fuse housing is protected from high pressure outside the fuse housing. Operation of the bistable switch inside the fuse housing may become reliable and an isolating dielectric fluid outside the fuse housing may not be contaminated by loss of contact material of the bistable switch when the bistable switch is switching. As the fuse housing is formed as a one piece outer envelope, a reliable tightness of the fuse housing can be achieved even at high environmental pressure. The first switching state may comprise a closed switching state of the bistable switch and the second switching state may comprise an open switching state of the bistable switch. Via the magnetic field generated by the coil, the bistable switch may selectively be switched over into the open switching state or the closed switching state and may remain in the corresponding switching state even if the magnetic field is removed. A circuit to be protected by the subsea fuse device may be supplied with an electric current via the bistable switch in its closed switching state. The bistable switch remains in its closed switching state even if no magnetic field is applied. In case of a failure, the coil may be controlled to generate a magnetic field to switchover the bistable switch into its open switching state which

breaks the electric current to the circuit to be protected. The bistable switch remains in its open switching state even if the magnetic field is removed thus breaking reliably the electric current to the circuit.

[0010] For re-activating the subsea fuse device, that means for switching over the bistable switch into its closed switching state, a further magnetic field may be applied, for example from the coil energized in reverse direction.

[0011] According to an embodiment, the coil is arranged outside the outer envelope. By arranging the coil outside the outer envelope instead of inside the outer envelope, no additional feedthroughs for providing the coil with electrical energy are needed. Thus, a hermetical sealing of the outer envelope may be improved and a dimension of the outer envelope may be reduced which may facilitate the robustness of the outer envelope against high external pressure in subsea environment.

[0012] According to a further embodiment, the outer envelope has a tubular form and the first and second feedthrough openings are arranged at opposite ends of the tubular envelope. The tubular form supports a high stability of the fuse housing against high external pressure in subsea environment.

[0013] Additionally, the outer envelope may be hermetically sealed apart from the first and second feedthrough openings. Consequently, the hollow space within the outer envelope may be filled with gas or air with a pressure independent from a pressure outside the outer envelope, for example with a pressure far below an operating pressure in subsea environments. For example, a pressure of approximately one bar may be present in the hollow space. According to another embodiment, the hermetically sealed outer envelope may be evacuated. Due to the preset pressure inside the outer envelope a reliable operation of the bistable switch may be enabled.

[0014] According to another embodiment, the outer envelope is made of an electrically isolating material. The electrically isolating material may comprise for example glass, ceramics or resin. In the open switching state of the bistable switch the whole fuse device reliably breaks an electrical current to an electrical circuit or sub-circuit protected by the subsea fuse device.

[0015] In case the outer envelope is made of glass material, the subsea fuse device may be manufactured as described below. The first terminal wire of the bistable switch may be passed through one end of the glass tube such that the first terminal wire ends at a central section of the glass tube in its longitudinal direction. The second terminal wire of the bistable switch may be passed through the opposite end of the glass tube such that the second terminal wire also ends at the central section of the glass tube in its longitudinal direction. The end of the first and second terminal wires in the central section of the glass tube may be overlapping such that they may be brought into contact. The first terminal wire may be made of a magnetisable material such that it may be elastically bent within the glass tube by applying a magnetic field. The ends of the glass tube are heated so that they seal around the first and second terminal wires, respectively. For example, infrared absorbing glass may be used such that an infrared heat source can concentrate the heat in the small sealing zone of the glass tube. The thermal coefficients of expansion of the glass material and the first and the second terminal wires may be similar to prevent breaking the glass to metal seal. The glass may contain no volatile components such as lead oxide and fluorides to support the isolating property.

[0016] According to an embodiment, the bistable switch and the coil are coupled in series connection. An electric power supply current to a circuit or sub-circuit protected by the subsea fuse device may be fed through the series connection of the bistable switch and the coil. Under normal operation conditions of the circuit or sub-circuit the electric current may be lower than in case of a short circuit or a failure of the circuit or sub-circuit. The coil may be dimensioned such that the electric current at normal operation conditions does not generate a magnetic field which is sufficiently large to switch the bistable switch from the closed switching state to the open switching state. However, the much higher electrical current in case of a short circuit or a failure may generate a sufficiently high magnetic field to cause a switchover of the bistable switch from the closed switching state to the open switching state. Thus, a reliable protection of the circuit or sub-circuit can be provided without additional circuitry.

[0017] According to another embodiment, the subsea fuse device comprises a control unit which is configured to determine an electrical current through the bistable switch and to control the magnetic field generated by the coil depending on the electrical current through the bistable switch. The electrical current through the bistable switch may be determined as it is known in the art. For example, a voltage drop over a resistor, a so-called shunt, in a series connection with the bistable switch may be determined. As another example, a magnetic field induced by the electric current through the first and second terminal wires of the bistable switch may be determined with a magnetic field sensor, and the electric current may be calculated based on information from the magnetic field sensor. The determined electrical current through the bistable switch may be compared with a threshold value and in case the determined electrical current exceeds the threshold value, the control unit may control or activate the coil to generate a magnetic field to switch the bistable switch from the closed switching state to the open switching state. The threshold value may be configurable via a control input of the control unit. Thus, the subsea fuse device may be used to protect a wide variety of circuits and sub-circuits.

[0018] According to a further embodiment, the subsea fuse device comprises furthermore a magnet configured to provide a magnetic field which pretensions the bistable switch into one of the first and second switching states. In combination with the magnetic field generated by the

coil the bistable property of the bistable switch may be achieved.

[0019] According to an embodiment, the bistable switch of the subsea fuse device comprises a changeover switch. The bistable changeover switch comprises a third terminal wire. For example, in the first switching state, the first terminal wire may be in contact with the second terminal wire, and in the second switching state the first terminal wire may be in contact with the third terminal wire. The outer envelope provides a third feedthrough opening through which the third terminal wire of the bistable changeover switch is extending. At the third feedthrough opening, an outer circumferential surface of the third terminal wire is in contact with an inner circumferential surface of the third feedthrough opening and seals the third feedthrough opening. In the second switching state, the third terminal wire may be used to indicate that the subsea fuse device has broken the connection between the first terminal wire and the second terminal wire. Furthermore, in case of the above-described series connection of the coil and the bistable switch, the third terminal wire may be used to provide an electrical current for switching back the bistable switch after the bistable switch has opened the connection between the first terminal wire and the second terminal wire.

[0020] According to another aspect of the present invention, a subsea device is provided which comprises an enclosure and an electric circuitry arranged within the enclosure. The electric circuitry comprises the above described subsea fuse device for protecting the electric circuitry from overcurrent or short circuit.

[0021] According to an embodiment, the enclosure of the subsea device is filled with a fluid, for example a dielectric fluid or oil, and comprises a volume and pressure compensator which balances the pressure inside the enclosure to the pressure prevailing in an environment of the enclosure. In other words, the subsea device is pressure compensated and the fluid filled into the enclosure is pressure compensated, which means that the fluid filled into the enclosure is pressurized with essentially the same pressure prevailing outside the subsea device. For example, in a subsea environment in a depth of for example 3000 m, the prevailing pressure may be approximately 300 bars. The electric circuitry inside the enclosure may be reliably protected from overcurrent by the use the of the subsea fuse device which is also pressurized as the bistable switch inside the subsea fuse device is completely sealed from this environmental pressure and is operating at a preset pressure of for example one bar or even less, for example in an evacuated state.

[0022] Although specific features are described in the above summary and the following detailed description in connection with specific embodiments and aspects of the present invention, it is to be understood that the features of the embodiments and aspects may be combined with each other unless specifically noted otherwise.

Brief description of the drawings

[0023] The present invention will now be described in more detail with reference to the accompanying drawings.

Figure 1 shows schematically a subsea device according to an embodiment of the present invention.

Figure 2 shows schematically a subsea fuse device according to an embodiment of the present invention.

Figure 3 shows schematically a subsea fuse device according to another embodiment of the present invention.

Detailed description of the drawings

[0024] In the following, exemplary embodiments of the invention will be described in more detail. It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other unless specifically noted otherwise. Same reference signs in the various drawings refer to similar or identical components and a repetitive description of these components may be omitted.

[0025] Figure 1 shows a subsea device 10, for example a subsea canister, which may be arranged in a subsea environment for housing electrical components or an electric circuitry 11. A data and energy supply connection 12 may be provided for communicating with other components arranged in other subsea devices and for supplying the electric circuitry 11 with electrical energy. The data and energy supply connection 12 may extend from an interior of the subsea device 10 to an exterior of the subsea device 10. The subsea device 10 may be arranged and operated in a deep sea environment, for example in a depth of up to 3000 m or even deeper. Hence, the subsea device 10 comprises an enclosure 13 which protects the interior of the enclosure 13 from the environment, for example from salt water.

[0026] For dealing with the high pressures present in deep sea environments, one of the following constructions of subsea devices may commonly be used. As one alternative, a pressure resistant enclosure may be provided, which has a close to atmosphere internal pressure. This enables the use of conventional electric and electronic components inside the enclosure. Such enclosures need to have relatively thick and robust walls and are therefore bulky and heavy, since they have to withstand high differential pressures. As another alternative, pressurized or pressure compensated enclosures may be used. Pressure compensated enclosures comprise a volume/pressure compensator which balances the pressure inside the enclosure to the pressure prevailing in the ambient seawater. The enclosure 13 shown in Fig. 1 comprises such a volume/pressure compensator indicat-

ed by reference sign 14. The pressure compensated enclosure 13 may be filled with a fluid 17, for example oil or a dielectric fluid, and components operated inside the pressure compensated enclosure 13 are made to be operable under high pressure conditions. The pressure/volume compensator 14 compensates variations in the volume of the fluid 17 filling the enclosure 13, which may occur due to variations in ambient pressure or due to variations in temperature of the fluid 17. Temperature changes may be caused by deployment of the subsea device at the subsea location or by internal heating, for example due to electric losses.

[0027] The electric circuitry 11 may comprise partial or sub-circuits 15 and 16. Some of the sub-circuits 15 and 16 may have to be protected from overload, overcurrent or short circuits. Therefore, in the power supply connection 12 to the sub-circuit 15, a subsea fuse device 20 is provided. The electric circuitry 11 may comprise for example a printed circuit board on which the subsea fuse device 20 as well as the sub-circuits 15 and 16 are arranged. The electric circuitry 11 may comprise further subsea fuse devices for protecting further sub-circuits which are not shown in Fig. 1 for clarity reasons.

[0028] The interior of the enclosure 13 may be filled with fluid 17, for example an isolating dielectric oil. Consequently, the subsea fuse device 20 may be surrounded by the fluid 17 and may be in direct contact with the fluid 17. Due to the pressure compensation of the enclosure 13 via the pressure compensator 14, the fluid 17 may be pressurized at essentially the same pressure as it is prevailing outside the enclosure 13. In subsea applications, this pressure may be for example a few hundred bars. Therefore, the subsea fuse device 20 has to be capable of operating reliably under these high pressure conditions.

[0029] Fig. 2 shows an embodiment of the subsea fuse device 20 of Fig. 1 in more detail. The subsea fuse device 20 comprises a fuse housing 21 and the bistable switch comprising a first terminal wire 22, a second terminal wire 23 and an optional third terminal wire 24. The fuse housing 21 may have a tubular form and may be made of a glass tube. In general, the fuse housing 21 may be made as a one-piece outer envelope, which completely encloses a hollow space 25 in which at least a part of each of the terminal wires 22 to 24 is arranged. At the ends of the tubular housing 21 in the longitudinal direction, feedthrough openings for the terminal wires 22 to 24 are provided. The housing 22 has a first feedthrough opening 28 at the left-hand side, and a second feedthrough opening 29 as well as a third feedthrough opening 30 at the right-hand side. The first terminal wire 22 is extending through the first feedthrough opening 28. The second terminal wire 23 is extending through the second feedthrough opening 29. The third terminal wire 24 is extending through the third feedthrough opening 30. At the first feedthrough opening 28, an outer circumferential surface of the first terminal wire 22 is in direct contact with an inner circumferential surface of the first feedthrough opening 28 and seals the first feedthrough opening 28. At the second feedthrough opening 29, an outer circumferential surface of the second terminal wire 23 is in direct contact with an inner circumferential surface of the second feedthrough opening 29 and seals the second feedthrough opening 29. Likewise, at the third feedthrough opening 30, an outer circumferential surface of the third terminal wire 24 is in direct contact with an inner circumferential surface of the third feedthrough opening 30 and seals the third feedthrough opening 30. Due to the direct contact, no additional sealing means are needed. Furthermore, the terminal wires 22 to 24 are held in position by the feedthrough openings.

[0030] Inside the housing 21, the terminal wires 22 to 24 compose a changeover switch. The second and third terminal wires 23 and 24 may be arranged in parallel with a gap between them. The first terminal wire 22 may be arranged such that its end tip inside the housing 21 may contact selectively one of the end tips of the second and third terminal wires 23 and 24. Thus, depending on the position of the first terminal wire 22, an electrical contact may be provided either between terminal wires 22 and 23 or between terminal wires 22 and 24. The changeover switch may be a bistable changeover switch. Bistable means that after applying a force for moving the changeover switch into one of the switching states, the switch remains in this switching state even if no further actuating force is provided. The changeover switch shown in Fig. 2 may be actuated by applying a magnetic force. The magnetic force may be generated by a coil 26 which may be energized with an electrical current to provide the magnetic force. Additionally, a permanent magnet 27 may be arranged as shown in Fig. 2 for providing a permanent magnetic field. The bistable property of the changeover switch may be achieved as described in the following.

[0031] The first terminal wire 22 may be made of a magnetic material. Furthermore, the first terminal wire 22 may be mechanically pre-tensioned into the direction of the second terminal wire 23 such that the first terminal wire 22 is pressed against the second terminal wire 23 as shown in Fig. 2 if no further force is acting thereon. Due to the magnetic property of the first terminal wire 22, the first terminal wire 22 is pulled into the direction of the permanent magnet 27. However, the magnetic force of the permanent magnet 27 is selected to be not sufficient to move the first terminal wire 22 away from the second terminal wire 23 against the pretension. When a magnetic field is generated by the coil 26, this magnetic field may cooperate with the magnetic field of the permanent magnet 27 such that an enlarged resulting magnetic field is acting on the first terminal wire 22. This enlarged resulting magnetic field may be sufficient to move the first terminal wire 22 away from the second terminal wire 23 and in contact with the third terminal wire 24. When the coil 26 is de-energized, the first terminal wire 22 is held in its current position in contact with the third terminal wire 24 by the magnetic field of the permanent magnet 27. Due

to the shorter distance between the first terminal wire 22 and the permanent magnet 27 in this position, the magnetic field of the permanent magnet 27 is sufficient to keep the first terminal wire 22 in this position against the mechanical pretension of the first terminal wire 22. For switching the first terminal wire 22 back into contact with the second terminal wire 23, a reverse magnetic field may be generated by the coil 26 such that a lowered resulting magnetic field is acting on the first terminal wire 22. The lowered resulting magnetic field enables that the first terminal wire 22 is moving back into contact with the second terminal wire 23 due to its mechanical pretension.

[0032] An electric current through the coil 26 maybe controlled by a control unit 31 based on an electric current flowing through the subsea fuse device 20 to the sub-circuit 15. For example, an energy supply current is flowing through the first terminal wire 22 and the second terminal wire 23 to the sub-circuit 15. For measuring the electrical current flowing into the sub-circuit 15, a resistor 32 may be provided in the connection between the second terminal wire 23 and the sub-circuit 15. A voltage drop over the resistor 32 indicates the electrical current flowing into the sub-circuit 15. The control unit 31 may compare the determined electrical current flowing into the sub-circuit 15 with a threshold value and may energize the coil 26 if the threshold value is exceeded. As a result, the current flow through the subsea fuse device 20 is interrupted.

[0033] The control unit 31 may comprise a further input for configuring the threshold value for activating the coil. Furthermore, the control unit 31 may comprise a configuration input for receiving a command to re-establish the electrical current flow between the first terminal wire 22 and the second terminal wire 23. When receiving such a command to re-establish the electrical current flow, the control unit 31 may energize the coil 26 in a reverse direction to move the first terminal wire 22 into contact with the second terminal wire 23 as described above. Thus, the sub-circuit 15 may be protected reliably from overcurrent and short circuit.

[0034] As the whole fuse housing 21 is sealed including the feedthrough openings 28 to 30, the bistable switch may be operated under predefined pressure conditions, for example at a pressure of 1 atm or in a vacuum inside the housing 21. Furthermore, the fluid 17 outside the fuse housing 21 may not be contaminated by switching operations of the bistable switch within the housing 21, for example by a loss of material of the terminal wires 22 to 24 when being switched. Finally, the tubular form of the housing 21 provides a significant pressure resistance such that the subsea fuse device 20 may be used in the above-described high pressure environment without breaking.

[0035] The fuse housing 21 may be made of glass. The glass tube may be bonded onto the metallic terminal wires 22 to 24 ensuring a sealed tube. For example, during production of the subsea fuse device 20, the terminal wires 22 to 24 may be arranged in a glass tube with open ends. Each end of the glass tube is heated such that it seals around the corresponding terminal wires 22 to 24. The ceiling areas at both ends of the glass tube are indicated in Fig. 2 by reference signs 28 to 30. Thermal expansion coefficients of the metal of the terminal wires 22 to 24 and the glass may be selected similar to prevent cracks as they cool during production. For example, those parts of the terminal wires 22 to 24 which are extending from the housing 21 may be soldered to a printed circuit board of the electric circuitry 11.

[0036] In the above-described subsea fuse device, the coil 26 is wound around the housing 21. However, this is only an example and the coil may be arranged at any other suitable position inside or outside the housing 21. However, arranging the coil outside the housing 21 avoids additional feedthroughs at the housing 21.

[0037] The terminal wires 22 and 23 may be dimensioned according to the carrying current and voltage rating. The housing 21 may be filled with gas or produced with vacuum depending on the voltage level. The terminal wires 22 to 24 may be uniform or non-uniform and may consist of one or several materials.

[0038] Fig. 3 shows another embodiment of the subsea fuse device 20. The subsea fuse device 20 of Fig. 3 does not require the control unit 31 for controlling the current through the coil 26. Instead, the operating current for energizing the sub-circuit 15 is additionally fed through the coil 26. This is accomplished by connecting the first terminal wire 22 to the coil 26 as shown in Fig. 3. A current to be supplied to the sub-circuit 15 for supplying the sub-circuit 15 with electrical energy is supplied to the second terminal wire 23 and via the connection to the first terminal wire 22 and the coil 26 to the sub-circuit 15. The number of windings of the coil 26 may be dimensioned according to a normal current flow and possible overcurrent. In detail, the windings of the coil 26 are dimensioned such that normal current does not create a magnetic field strong enough to actuate the bistable switch, but the short circuit current does. When the subsea fuse device 20 is tripped, the first terminal wire 22 is in contact with the third terminal wire 24. In this state, a reverse current may be applied to the third terminal wire to reset the subsea fuse device 20 into its operating and conducting state.

[0039] The subsea fuse device 20 enables an isolation of a faulty sub-circuit 15 in an oil-filled and pressurized environment. However, the subsea fuse device 20 may be used in other applications in subsea devices, for example for implementing redundancy and providing overcurrent protection. Using the subsea fuse device 20 may avoid an interrupted service, high-cost of replacing the oil, or a total failure of larger systems, when a fuse does not break as intended, in particular in subsea devices which are often placed in high ambient pressure environments which are inaccessible, for example at the seafloor, and which may make maintenance difficult and expensive.

Claims

1. A subsea fuse device, comprising:

   - a fuse housing (21),
   - a bistable switch configured to be selectively switched into a first switching state and a second switching state by applying a magnetic field, and
   - a coil (26) configured to generate the magnetic field depending on an electrical current flowing through the bistable switch, wherein the fuse housing (21) comprises a one-piece outer envelope which completely encloses a hollow space (25) and provides a first feedthrough opening (28) and a second feedthrough opening (29),

   wherein the bistable switch is arranged within the hollow space (25) of the fuse housing (21), wherein a first terminal wire (22) of the bistable switch is extending through the first feedthrough opening (28) and a second terminal wire (23) of the bistable switch is extending through the second feedthrough opening (29),
   wherein, at the first feedthrough opening (28), an outer circumferential surface of the first terminal wire (22) is in contact with an inner circumferential surface of the first feedthrough opening (28) and seals the first feedthrough opening (28), and
   wherein, at the second feedthrough opening (29), an outer circumferential surface of the second terminal wire (23) is in contact with an inner circumferential surface of the second feedthrough opening (29) and seals the second feedthrough opening (29).

2. The subsea fuse device according to claim 1, wherein the outer envelope is pressure resistant.

3. The subsea fuse device according to claim 1 or claim 2,
   wherein the coil (26) is arranged outside the outer envelope.

4. The subsea fuse device according to any one of the preceding claims, wherein the outer envelope has a tubular form, and wherein the first and second feedthrough openings (28, 29) are arranged at opposite ends of the tubular envelope.

5. The subsea fuse device according to any one of the preceding claims, wherein the outer envelope is hermetically sealed apart from the first and second feedthrough openings (28, 29).

6. The subsea fuse device according to any one of the preceding claims, wherein the outer envelope is made of an electrically isolating material.

7. The subsea fuse device according to any one of the preceding claims, wherein the outer envelope is made of at least one material of a group comprising:

   - glass,
   - ceramics, and
   - resin.

8. The subsea fuse device according to any one of the preceding claims, wherein the bistable switch and the coil (26) are coupled in a series connection.

9. The subsea fuse device according to any one of the preceding claims, further comprising:

   - a control unit (31) configured to determine an electrical current through the bistable switch and to control the magnetic field generated by the coil (26) depending on the electrical current through the bistable switch.

10. The subsea fuse device according to claim 9, wherein the control unit (31) comprises a control input for configuring a current threshold value, wherein the control unit (31) is configured to compare the electrical current through the bistable switch with the current threshold value and to control the magnetic field generated by the coil (26) depending on the comparison.

11. The subsea fuse device according to any one of the preceding claims, further comprising:

    - a magnet (27) configured to provide a magnetic field biasing the bistable switch into one of the first and second switching states.

12. The subsea fuse device according to any one of the preceding claims, wherein the bistable switch comprises a changeover switch,
    wherein the outer envelope provides a third feedthrough opening (30), wherein a third terminal wire (24) of the bistable changeover switch is extending through the third feedthrough opening (30),
    wherein, at the third feedthrough opening (30), an outer circumferential surface of the third terminal wire (24) is in contact with an inner circumferential surface of the third feedthrough opening (30) and seals the third feedthrough opening (30).

13. A subsea device, comprising:

    - an enclosure (13), and
    - an electric circuitry (11) arranged within the enclosure (13),

    wherein the electric circuitry (11) comprises a subsea fuse device (20) according to any one of the

preceding claims.

14. The subsea device according to claim 13, wherein the enclosure (13) is filled with a fluid (17) and comprises a volume/pressure compensator (14) which balances the pressure in the enclosure (13) to the pressure prevailing in an environment of the enclosure (13).

FIG 1

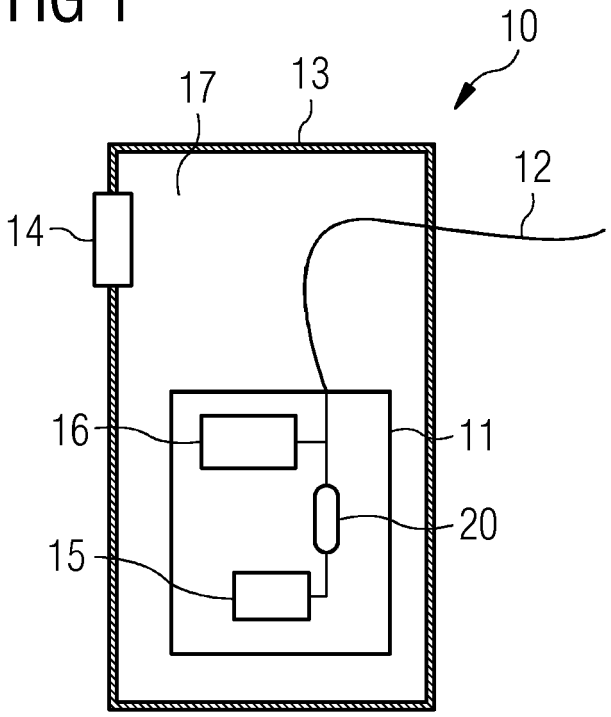


FIG 2

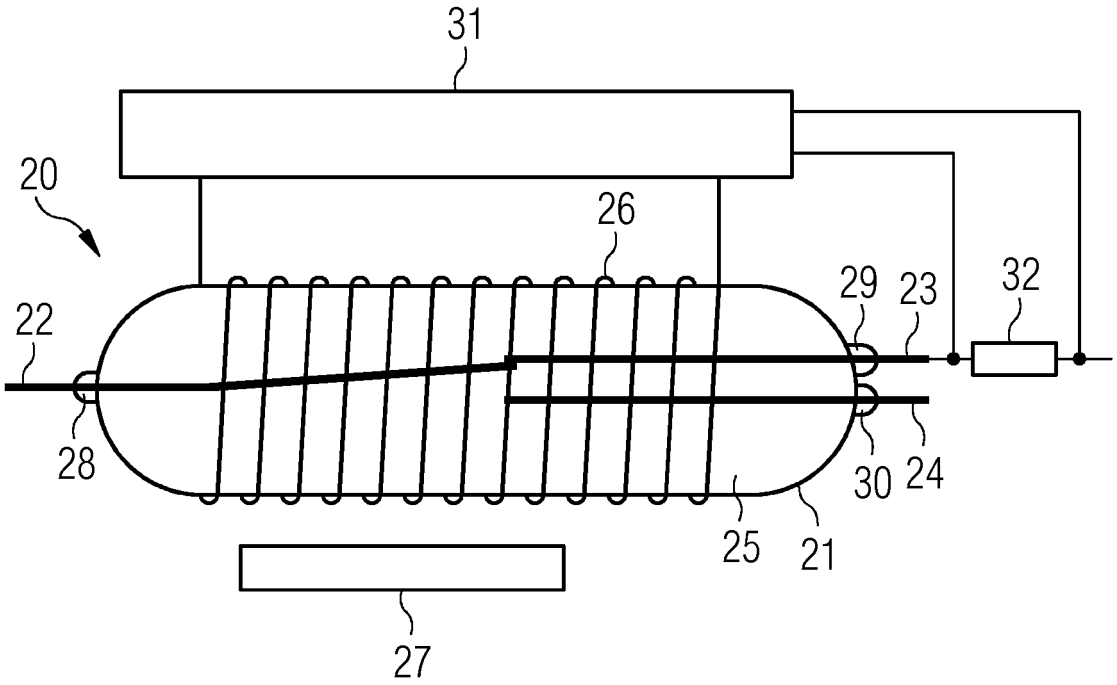
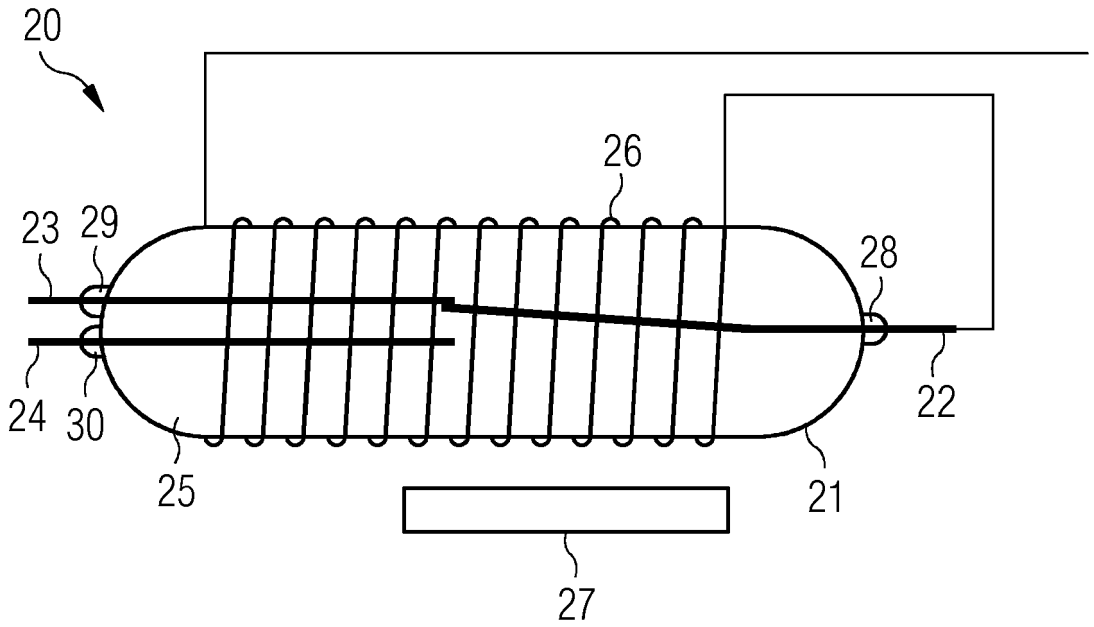


FIG 3



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EUROPEAN SEARCH REPORT

Application Number
EP 16 16 7107

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 838 104 A1 (SIEMENS AG [DE]) 18 February 2015 (2015-02-18) * paragraph [0035] - paragraph [0044] * * figure 1 *	1-14	INV. H01H77/06
A	US 4 126 841 A (MAENO CHIAKI) 21 November 1978 (1978-11-21) * column 6, line 58 - column 7, line 35 * * figure 6 *	1-14	
A	US 3 204 059 A (SAATY THEODORE N) 31 August 1965 (1965-08-31) * column 1, line 63 - column 2, line 65 * * figures 1, 2 *	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 October 2016	Fribert, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 16 7107

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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04-10-2016

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		EP 3000119 A1	30-03-2016
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82