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# (54) COVERAGE-TYPE DEEP-SEA MUD VOLCANO-ASSOCIATED NATURAL GAS HYDRATE EXPLOITATION SYSTEM AND METHOD

(57) The invention discloses a coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system and method, which are mainly applied to submarine mud volcano-associated superficial massive hydrates and exploit natural gas hydrates through a coverage-type heat-insulation heating method according to the occurrence characteristics of deep-sea mud volcano-associated hydrates, based on a specially-designed gas isolation and heat insulation cover and thermal electrodes. Decomposed hydrates flow into a production well via perforated holes of the production well under the effect of a pressure difference at the bottom of the well, and a depressurization device is disposed in the production well to further decompose the hydrates. This technical solution can effectively overcome the defects of small heating range, high energy consumption and low output rate of a heating-type hydrate exploitation method, greatly improve the exploitation efficiency and effectively avoid possible environmental risks and eco-catastrophes caused by large-area excavation on the seabed of existing methods; in addition, solar energy is used on the site, so that the cost is low, environmental friendliness is realized, large-scale efficient and economical exploitation of the hydrates is realized, the application prospect is broad, and the application value is high.

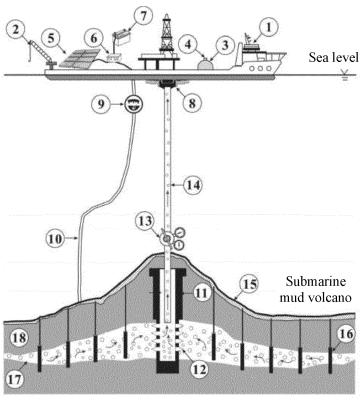


FIG. 1

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## Description

### BACKGROUND OF THE INVENTION

Technical Field

**[0001]** The invention belongs to the technical field of exploration and exploitation of submarine natural gas hydrate resources, in particular to a coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system and method.

Description of Related Art

**[0002]** Natural gas hydrates (also referred to as "combustible ice") are ice-like crystalline compounds formed by hydrocarbon gases such as methane and water in a high-pressure environment. Natural gas hydrates in the sea include deep diffused natural gas hydrates and superficial leaky natural gas hydrates according to the gas migration and accumulation manner, the burial depth and the genetic model. Wherein, the superficial leaky hydrates are closely associated with many special geologic bodies such as mud diaper, mud volcanoes and gas chimneys.

**[0003]** Superficial hydrates associated with mud volcanoes are well developed in many sea areas, and these mud volcanoes with a diameter of several meters to hundreds of meters protrude over the seabed by several meters to tens of meters and are rich of huge high-saturability hydrates. According to investigation, the reservoir of methane in a single mud volcano in Nankai Trough reaches one billion cubic meters, and tens to hundreds of such mud volcanoes are usually developed in groups. For example, 1742 superficial hydrate geologic bodies have been found in Japan sea, and most of these superficial hydrate geologic bodies are associated with mud volcanoes. Mud volcano-associated superficial hydrates are expected to play the same important role as the deep diffused hydrates in hydrate industrialization because of their extensive distribution on the seabed, small burial depth and thick and laminar occurrence manner, and have immeasurable resource significance.

**[0004]** At present, many superficial hydrate exploitation methods have been put forward, such as the well-known solid fluidization method and the robot mining method. However, no corresponding method is available yet for superficial hydrates associated with mud volcanoes. Meanwhile, although the solid fluidization method is simple and practicable, large-area excavation needs to be carried out on the seabed, which may result in eco-catastrophes and environmental disasters in a wide region, so the risk is uncontrollable. The robot mining method may also result in environmental risks due to seabed excavation in spite of its novel idea, and because of the high technical difficulties and other difficulties of robot mining, it has not yet been implemented up to now in the seabed mining field including exploration of submarine manganese nodule crusts and metal sulfide, which indicates that the seabed robot is still a conceptual design for current mining and remains far off being put into industrial production.

**[0005]** Considering the special structures of the deep-sea mud volcano-associated natural gas hydrates such as shallow occurrence positions and even exposure to the surface of the seabed, centralized occurrence scopes, moundy tops protruding out of the surface of the seabed, and gas channels developed at the center, there is an urgent need for a targeted exploitation technique.

### BRIEF SUMMARY OF THE INVENTION

**[0006]** The invention provides a coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system and method, which are mainly applied to submarine mud volcano-associated superficial massive hydrates and adopt a coverage-type heat-insulation heating method to exploit the hydrates according to the occurrence characteristics of the deep-sea mud volcano-associated hydrates.

**[0007]** The invention is realized through the following technical solution:

A coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system comprises an engineering ship support unit, a power supply unit, a drilling and casing unit and a gas isolation and heat insulation unit, wherein the engineering ship support unit provides basic hardware support for hydrate exploitation and realizes a collection of natural gas hydrates, and the power supply unit is connected to the gas isolation and heat insulation unit through a power supply cable;

The gas isolation and heat insulation unit is regularly laid on a mud volcano , covers the mud volcano and comprises a gas isolation and heat insulation cover connected to the power supply unit, wherein the gas isolation and heat insulation cover sequentially comprises, from bottom to top, a heat-conducting aluminum foil layer, a carbon fiber heating wire layer, an asbestos heat insulation layer and a heat-proof gas isolation layer and supplies heat into a sediment layer to heat a natural gas hydrate reservoir.

**[0008]** Furthermore, the gas isolation and heat insulation unit further comprises thermal electrodes which are disposed at positions with a high hydrate saturability and a large thickness, the thermal electrodes and the carbon fiber heating wire layer of the gas isolation and heat insulation cover adopt two independent power supply circuits, and the power supply circuit of the thermal electrodes is separately buried between the asbestos heat insulation layer and the heat-proof gas isolation layer.

**[0009]** Furthermore, a safe unhooking system is disposed at a joint of an exploitation mother ship and the natural gas transport pipe to handle a sudden severe

weather or other disastrous events to avoid risks and guarantee operation safety.

**[0010]** Furthermore, the power supply unit comprises a solar heating panel, a photoelectric converter and a storage battery which are disposed on the engineering ship support unit, and solar energy or electricity in the storage battery is transmitted into the gas isolation and heat insulation cover and the thermal electrodes through the power supply unit to heat the hydrates.

**[0011]** Furthermore, the engineering ship support unit comprises the exploitation mother ship, a hoisting mechanism and a natural gas storage device, a flow control valve is disposed on the natural gas storage device, a temperature-pressure sensor is disposed on the power supply cable, and the operating state of the system is determined and controlled according to system information collected by the temperature-pressure sensor and the flow control valve, so that safe and efficient operation of the system is guaranteed.

**[0012]** The invention further provides an exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system, comprising the following steps:

First, determining a central conduit of the mud volcano, drilling a well in the central conduit of the mud volcano, and disposing a casing pipe and perforated holes in the central conduit of the mud volcano;

Second, disposing the gas isolation and heat insulation unit on a flank of the mud volcano, wherein the gas isolation and heat insulation unit comprises the gas isolation and heat insulation cover and thermal electrodes, and the gas isolation and heat insulation cover sequentially comprises, from bottom to top, a heat-conducting aluminum foil layer, the carbon fiber heating wire layer, the asbestos heat insulation layer and the heat-proof gas isolation layer;

Third, heating hydrates by means of the ship-borne power supply unit; and

Fourth, collecting gas in the production well, and storing the collected gas on an engineering ship.

**[0013]** Furthermore, in the first step, the position of the central conduit of the mud volcano is targeted according to the position of a cold spring vent determined by a two-dimensional multi-channel seismic section explanation result and a submarine image.

**[0014]** Furthermore, the first step is implemented specifically through the following sub-steps:

Drilling the well in the central conduit of the mud volcano through a deepwater drilling technique, wherein the drilled well penetrates through a sediment covering layer above natural gas, stretches into a hydrate reservoir and ends at bed rock of the mud volcano, so that the production well is formed; and

Mounting the casing pipe, forming the perforated holes in the hydrate reservoir to guide water and gas generated by decomposing the hydrates, and disposing the depressurization control valve in the production well to combine heat production and depressurization to decompose the hydrates more sufficiently.

**[0015]** Furthermore, the second step is implemented specifically through the following steps:

Drilling holes at position, with a high hydrate saturability and a large thickness, of the flank of the mud volcano, and placing the thermal electrodes in the holes;

then, regularly placing the gas isolation and heat insulation cover on the mud volcano by means of an engineering underwater robot, and connecting the gas isolation and heat insulation cover to the thermal electrodes placed in the drilled holes, wherein an opening is formed in a position, corresponding to a central hole of the mud volcano, of the gas isolation and heat insulation cover.

**[0016]** Furthermore, in the fourth step, after gas released by the hydrates flows into the production well via the perforated holes, the gas is delivered into a natural gas storage device on an exploitation mother ship through the natural gas transport pipe, and a safe unhooking system is disposed at a joint of the natural gas transport pipe and the exploitation mother ship to handle a sudden severe weather or other disastrous events.

**[0017]** Compared with the prior art, the invention has the following advantages and beneficial effects:

1) The gas isolation and heat insulation cover can be laid freely according to the shape of the mud volcano, has a good gas leakage prevention capacity to prevent gas generated by decomposing the hydrates from leaking from the flank, and can realize uniform heating; heat-insulation treatment is carried out between the gas isolation layer and the heating layer with asbestos materials, so that the heating layer only supplies heat to the hydrates below to minimize energy consumption;

2) Moreover, multiple thermal electrodes are disposed at the position with a high hydrate saturability and a large thickness and are effectively connected to heating elements of the gas isolation and heat insulation cover, and each thermal electrode can penetrate to a required depth according to the actual depth of the hydrates to further heat the hydrates in a target region, so that the decomposed hydrates can flow into the production well via the perforated holes of the production well under the effect of a pressure difference at the bottom of the well.

**[0018]** By adoption of this solution, the defects of small heating range, high energy consumption and low output rate of a heating-type hydrate exploitation method are

overcome, and the exploitation efficiency can be greatly improved; moreover, possible environmental risks and eco-catastrophes caused by large-area excavation on the seabed of existing methods are avoided; large-scale efficient and economical exploitation of the hydrates can be realized, the application prospect is broad, and the application value is high.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

**[0019]**

FIG. 1 is a schematic diagram of a coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system in an embodiment of the invention;

FIG. 2 is a structural diagram of a gas isolation and heat insulation cover in an embodiment of the invention;

Wherein: 1, exploitation mother ship; 2, hoisting mechanism; 3, natural gas storage device; 4, flow control valve; 5, solar heating panel; 6, photoelectric converter; 7, storage battery; 8, safe unhooking system; 9, temperature-pressure sensor; 10, power supply cable; 11, production well; 12, perforated hole; 13, depressurization control valve; 14, natural gas transport pipe; 15, gas isolation and heat insulation cover; 16, thermal electrode; 17, hydrate reservoir; 18, sediment layer; 151, heat-conducting aluminum foil layer; 152, carbon fiber heating wire layer; 153, asbestos heat insulation layer; 154, heat-proof gas isolation layer.

## DETAILED DESCRIPTION OF THE INVENTION

**[0020]** To gain a clearer understanding of the above purposes, features and advantages of the invention, the invention will be further explained below in conjunction with the drawings and embodiments. Many specific details are expounded in the following description for a comprehensive appreciation of the invention. But the invention can also be implemented in other ways different from those mentioned herein. Therefore, the invention is not limited to the specific embodiments disclosed below.

**[0021]** The invention provides a coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system and method, which are mainly applied to submarine mud volcano-associated superficial massive hydrates and exploit natural gas hydrates through a heating method based on a specially-designed gas isolation and heat insulation cover and thermal electrodes. Decomposed hydrates flow into a production well via perforated holes of the production well under the effect of a pressure difference at the bottom of the well, and a depressurization device is disposed in the production well to further decompose the hydrates to complete thermal production of the volcano-associated hydrates; moreover, to reduce energy consumption and improve economical efficiency, solar power generation is used to heat the thermal electrodes, and a ship-borne autonomous power supply device is used in rainy days or at night when the solar energy conversion efficiency is insufficient, so that stable and continuous production is guaranteed.

Embodiment 1

**[0022]** This embodiment provides a coverage-type exploitation system for thermal production of submarine deep-sea mud volcano-associated natural gas hydrates. When it is determined in the resource exploration stage that a hydrate reservoir 17 in a submarine mud volcano is located below a sediment layer 18, this system and relevant techniques can be used to exploit hydrates to obtain natural gas. Specifically, as shown in FIG. 1:

The exploitation system comprises an engineering ship support unit, a power supply unit, a drilling and casing unit and a gas isolation and heat insulation unit, wherein the engineering ship support unit comprises an exploitation mother ship 1, a hoisting mechanism 2, a natural gas storage device 3 and a safe unhooking system 8, a flow control valve 4 is disposed on the natural gas storage device 3, and the safe unhooking system is able to immediately separate the exploitation mother ship from other underwater systems in case of a sudden severe weather or other disastrous events to allow the exploitation mother ship to leave a working site to avoid risks and allow other systems to stay on a seabed; after the weather returns to normal or the disastrous events are eliminated, the exploitation mother ship can return to the site and continue to work after being connected to the underwater systems through an unhooking device.

**[0023]** The power supply unit comprises a solar heating panel 5, a photoelectric converter 6 and a storage battery 7 which are disposed on the engineering ship support unit, the power supply unit is connected to the gas isolation and heat insulation unit through a power supply cable 10, a temperature-pressure sensor 9 is disposed on the power supply cable 10, solar energy or electricity in the storage battery is transmitted into the gas isolation and heat insulation cover and thermal electrodes through the power supply unit to heat the hydrates, and system information is automatically collected by the temperature-pressure sensor 9 and the flow control valve 4 to determine the operating state of the system and to control the operation of a valve in time to guarantee safe and efficient operation of the system;

The drilling and casing unit comprises a production well 11, perforated holes 12 and a natural gas transport pipe 14, wherein the perforated holes 12 are formed in a hydrate enrichment layer in the production well 11 to better guide the hydrates to release fluid, and a depressurization control valve 13 is disposed at an appropriate position of the natural gas transport pipe 14 to combine pressurization and thermal production to guarantee smooth output of the natural gas hydrates. A well is preferably

drilled in a central conduit of the mud volcano, which is an important passage for material exchange between mud volcano fluid and the outside and has a good lateral circulation condition; after the hydrates are heated to be decomposed, gas will migrate into the central conduit to be collected; and specifically, the position of the central conduit of the mud volcano can be targeted according to the position of a cold spring vent determined by a two-dimensional multi-channel seismic section explanation result and a submarine image.

**[0024]** The gas isolation and heat insulation unit can only supply heat into the sediment layer, including the gas isolation and heat insulation cover 15 and the thermal electrodes 16; the gas isolation and heat insulation cover 15 is a special heating body and sequentially comprises, from bottom to top, a heat-conducting aluminum foil layer 151, a carbon fiber heating wire layer 152, an asbestos heat insulation layer 153 and a heat-proof gas isolation layer 154. The heat-conducting aluminum foil layer 151 has a flame-retarding and heat-conducting function, thus facilitating heat transfer to the sediment layer below; the carbon fiber heating wire 152 is made of carbon fiber materials and is disposed in the gas isolation and heat insulation cover in an S shape, a hollow square shape or a wavy shape; the asbestos heat insulation layer 153 is subjected to heat-insulation treatment with asbestos materials to supply heat only into the sediment layer to efficiently and uniformly heat the natural gas hydrate reservoir; a heat-proof plastic film (made of polysulfone plastic and capable of being used under 100-180°C for a long time) is laid on the surface of the heat-insulating asbestos layer to serve as the heat-proof gas isolation layer 154 to endow the device with a gas leakage prevention function, so that gas generated by decomposing the hydrates will not leak to the ocean or the atmosphere via a covering layer; moreover, the four layers have food flexibility and can be bent freely according to the shape of the mud volcano without compromising the using effect.

**[0025]** In addition, to avoid contradictions that may be caused by different heating powers, the thermal electrodes 16 and carbon fiber heating wires of the gas isolation and heat insulation cover 15 adopt independent power supply circuits; during construction, the circuit of the thermal electrodes is separately buried between the heat insulation layer and the gas isolation layer of the gas isolation and heat insulation cover 15, so that an opening does not need to be additionally formed in the gas isolation and heat insulation cover 15 anymore, the construction difficulty will not be increased, and the risk of gas leakage is avoided; during exploitation, power is supplied to the thermal electrodes separately, and the heating efficiency is controlled through a temperature control switch to satisfy the heating requirements of hydrates with different thicknesses.

**[0026]** According to this embodiment, a coverage-type heat-insulation heating method is adopted according to the occurrence characteristics of deep-sea mud volcano hydrates; the gas isolation and heat insulation cover can be laid freely according to the shape of the mud volcano, has a good gas leakage prevention capacity to prevent gas generated by decomposing the hydrates n from leaking from the flank, and can realize uniform heating; heat-insulation treatment is carried out between the gas isolation layer and the heating layer with asbestos materials, so that the heating layer only supplies heat to the hydrates below to minimize energy consumption; moreover, multiple thermal electrodes are disposed at the position with a high hydrate saturability and a large thickness and are effectively connected to heating elements of the gas isolation and heat insulation cover, and each thermal electrode can penetrate to a required depth according to the actual depth of the hydrates to further heat the hydrates in a target region, so that the decomposed hydrates can flow into the production well via the perforated holes of the production well under the effect of a pressure difference at the bottom of the well.

Embodiment 2

**[0027]** This embodiment provides a corresponding exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system disclosed in Embodiment 1. The exploitation method specifically comprises the following steps:

First, the central conduit of the mud volcano is determined, a well is drilled in the central conduit of the mud volcano, and a casing pipe and the perforated holes are disposed in the central conduit of the mud volcano;

The exploitation mother ship 1 is sailed to the hydrate region of the mud volcano, the well is drilled in the conduit of the mud volcano-associated hydrates through a deepwater drilling technique, and the well penetrates through a sediment covering layer 18 above natural gas, stretches into a hydrate reservoir 17 and finally ends at bed rock of the mud volcano, so that the production well 11 is formed; then the casing pipe is mounted, the perforated holes 12 are drilled in the hydrate reservoir to guide water and gas generated by decomposing the hydrates, and the depressurization control valve 13 is disposed in the production well, so that thermal production and decompression are combined to decompose the hydrates more sufficiently.

**[0028]** Second, the gas isolation and heat insulation cover is disposed on the flank of the mud volcano by means of an engineering robot;

Holes are drilled in positions, with a high hydrate saturability and a large thickness, of the flank of the mud volcano, and the thermal electrodes 16 are placed into the holes. Then, the gas isolation and heat insulation cover 15 is regularly disposed on the mud volcano by means of the engineering underwater robot and is connected to the thermal electrodes 16 placed into the holes. An open-

ing is formed in the position, corresponding to a central hole of the mud volcano, of the gas isolation and heat insulation cover 15. In this way, construction of the gas isolation and heat insulation unit is completed.

**[0029]** Third, the hydrates are heated by the ship-borne power supply unit (the solar panel and the standby storage battery);

Solar energy collected by the solar heating panel 5 of the exploitation mother ship 1 is converted into electric energy by the photoelectric converter 6, and the electric energy is transmitted to the volcano gas isolation and heat insulation cover 15 on the seabed. The gas isolation and heat insulation 15 and the integrated thermal electrodes 16 supply power to heat the natural gas hydrates. In rainy days or at night when the power of electric energy generated by the whole solar system cannot meet exploitation requirements, the ship-borne storage battery 7 is started to supply power to guarantee that the whole production process is stable and continuous.

**[0030]** Fourth, gas in the production well is collected and is stored on the ship;

After gas released by the hydrates flows into the production well 11 via the perforated holes 12, the gas can be delivered into the natural gas storage device 3 on the exploitation mother ship through the natural gas transport pipe 14 so as to be stored. The depressurization control valve 13 is disposed on the natural gas transport pipe, so that the risk of instrument damage caused by an excessively high pressure in the gas accumulation process is prevented; the pressure can be decreased properly to combine thermal production and depressurization to prompt the hydrate exploitation efficiency to be improved.

**[0031]** It should be noted that in the whole exploitation process, the full-course operation is safety monitored by means of automatic control and feedback of the entire system. For example, system information is automatically collected by the temperature-pressure sensor 9 and the flow control valve 4 to determine the operating state of the system and to control the operation of the valve in time to switch the operating mode, so that the working requirements under different conditions are met, and safe and efficient operation of the system is guaranteed.

**[0032]** According to the invention, a coverage-type heat-insulation heating method is adopted according to the occurrence characteristics of deep-sea mud volcano hydrates, so that the defects of small heating range, high energy consumption and low output rate of a heating-type hydrate exploitation method are overcome, and the exploitation efficiency can be greatly improved; moreover, possible environmental risks and eco-catastrophes caused by large-area excavation on the seabed of existing methods are avoided; in addition, solar energy is used on the site, so that the cost is low, environmental friendliness is realized, and in use, the system is driven by standby electricity stored on the ship at night and in rainy days by controlling the pressure condition of the gas well. By adoption of these measures, large-scale efficient and economical exploitation of the hydrates can be realized, and the application prospect is broad.

**[0033]** The aforesaid embodiments are merely preferred ones of the invention and are not intended to limit the invention in any forms. Any skilled in the art can make alterations or transformations according to the technical contents disclosed above to obtain equivalent embodiments applied to other fields. Any simple modifications and equivalent alternations and transformations of the above embodiments obtained based on the technical principle of the invention without departing from the contents of the technical solution of the invention still fall within the protection scope of the technical solution of the invention.

## Claims

1. A coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system, comprising an engineering ship support unit, a power supply unit, a drilling and casing unit and a gas isolation and heat insulation unit, wherein the engineering ship support unit provides basic hardware support for hydrate exploitation and realizes a collection of natural gas hydrates, and the power supply unit is connected to the gas isolation and heat insulation unit through a power supply cable (10);
   the drilling and casing unit comprises a production well (11), perforated holes (12) and a natural gas transport pipe (14), wherein the perforated holes (12) are formed in a hydrate enrichment layer in the production well (11), the natural gas transport pipe (14) has an end disposed in the production well (11) and an end connected to the engineering ship support unit, and a depressurization control valve (13) is disposed on the natural gas transport pipe (14);
   the gas isolation and heat insulation unit is regularly laid on a mud volcano, covers the mud volcano and comprises a gas isolation and heat insulation cover (15) connected to the power supply unit, wherein the gas isolation and heat insulation cover (15) sequentially comprises, from bottom to top, a heat-conducting aluminum foil layer (151), a carbon fiber heating wire layer (152), an asbestos heat insulation layer (153) and a heat-proof gas isolation layer (154) and supplies heat into a sediment layer to heat a natural gas hydrate reservoir;
   the gas isolation and heat insulation unit further comprises thermal electrodes (16) which are disposed at positions with a high hydrate saturability and a large thickness, the thermal electrodes (16) and the carbon fiber heating wire layer (152) adopt two independent power supply circuits, and the power supply circuit of the thermal electrodes (16) is separately buried between the asbestos heat insulation layer (153) and the heat-proof gas isolation layer (154).

2. The coverage-type deep-sea mud volcano-associ-

ated natural gas hydrate exploitation system according to Claim 1, wherein a safe unhooking system (8) is disposed at a joint of an exploitation mother ship (1) and the natural gas transport pipe (14) to handle a sudden severe weather or other disastrous events.

**3.** The coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 1, wherein the power supply unit comprises a solar heating panel (5), a photoelectric converter (6) and a storage battery (7) which are disposed on the engineering ship support unit, and solar energy or electricity in the storage battery is transmitted into the gas isolation and heat insulation cover (15) and the thermal electrodes (16) through the power supply unit to heat the hydrates.

**4.** The coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 2, wherein the engineering ship support unit comprises the exploitation mother ship (1), a hoisting mechanism (2) and a natural gas storage device (3), a flow control valve (4) is disposed on the natural gas storage device (3), a temperature-pressure sensor (9) is disposed on the power supply cable (10), and an operating state of the system is determined and controlled according to system information collected by the temperature-pressure sensor (9) and the flow control valve (4).

**5.** An exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 1, comprising the following steps:

1) determining a central conduit of the mud volcano, drilling a well in the central conduit of the mud volcano, and disposing a casing pipe and the perforated holes in the central conduit of the mud volcano;
2) disposing the gas isolation and heat insulation unit on a flank of the mud volcano, wherein the gas isolation and heat insulation unit comprises the gas isolation and heat insulation cover (15) and the thermal electrodes (16), and the gas isolation and heat insulation cover (15) sequentially comprises, from bottom to top, the heat-conducting aluminum foil layer (151), the carbon fiber heating wire layer (152), the asbestos heat insulation layer(153) and the heat-proof gas isolation layer (154);
3) heating the hydrates by means of the ship-borne power supply unit; and
4) collecting gas in the production well, and storing the collected gas on an engineering ship.

**6.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein in Step 1), the position of the central conduit of the mud volcano is targeted according to the position of a cold spring vent determined by a two-dimensional multi-channel seismic section explanation result and a submarine image.

**7.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein Step 1) is implemented specifically through the following sub-steps:

drilling the well in the central conduit of the mud volcano through a deepwater drilling technique, wherein the drilled well penetrates through a sediment covering layer (18) above natural gas, stretches into a hydrate reservoir (17) and ends at bed rock of the mud volcano, so that the production well (11) is formed; and
mounting the casing pipe, forming the perforated holes (12) in the hydrate reservoir to guide water and gas generated by decomposing the hydrates, and disposing the depressurization control valve (13) in the production well (11) to combine heat production and depressurization to decompose the hydrates more sufficiently.

**8.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein Step 2) is implemented specifically through the following sub-steps:
drilling holes at position, with a high hydrate saturability and a large thickness, of the flank of the mud volcano, and placing the thermal electrodes (16) in the holes; then, regularly placing the gas isolation and heat insulation cover (15) on the mud volcano by means of an engineering underwater robot, and connecting the gas isolation and heat insulation cover (15) to the thermal electrodes (16) placed in the drilled holes, wherein an opening is formed in a position, corresponding to a central hole of the mud volcano, of the gas isolation and heat insulation cover (15).

**9.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein in Step 4), after gas released by the hydrates flows into the production well (11) via the perforated holes (12), the gas is delivered into a natural gas storage device (3) on an exploitation mother ship through the natural gas transport pipe (14), and a safe unhooking system (8) is disposed at a joint of the natural gas transport pipe (14) and the exploitation mother ship to handle a sudden severe weather or other disastrous events.

Amended claims in accordance with Rule 137(2) EPC.

1. A coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system, comprising an engineering ship support unit, a power supply unit, a drilling and casing unit and a gas isolation and heat insulation unit, wherein the engineering ship support unit provides basic hardware support for hydrate exploitation and realizes a collection of natural gas hydrates,

   **characterized in that** the power supply unit is connected to the gas isolation and heat insulation unit through a power supply cable (10);
   the drilling and casing unit comprises a production well (11), perforated holes (12) and a natural gas transport pipe (14), wherein the perforated holes (12) are formed in a hydrate enrichment layer in the production well (11), the natural gas transport pipe (14) has an end disposed in the production well (11) and an end connected to the engineering ship support unit, and a depressurization control valve (13) is disposed on the natural gas transport pipe (14);
   the gas isolation and heat insulation unit is regularly laid on a mud volcano, covers the mud volcano and comprises a gas isolation and heat insulation cover (15) connected to the power supply unit, wherein the gas isolation and heat insulation cover (15) sequentially comprises, from bottom to top, a heat-conducting aluminum foil layer (151), a carbon fiber heating wire layer (152), an asbestos heat insulation layer (153) and a heat-proof gas isolation layer (154) and supplies heat into a sediment layer to heat a natural gas hydrate reservoir;
   the gas isolation and heat insulation unit further comprises thermal electrodes (16) which are disposed at positions with a high hydrate saturability and a large thickness, the thermal electrodes (16) and the carbon fiber heating wire layer (152) adopt two independent power supply circuits, and the power supply circuit of the thermal electrodes (16) is separately buried between the asbestos heat insulation layer (153) and the heat-proof gas isolation layer (154).

2. The coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 1, wherein a safe unhooking system (8) is disposed at a joint of an exploitation mother ship (1) and the natural gas transport pipe (14) to handle a sudden severe weather or other disastrous events.

3. The coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 1, wherein the power supply unit comprises a solar heating panel (5), a photoelectric converter (6) and a storage battery (7) which are disposed on the engineering ship support unit, and solar energy or electricity in the storage battery is transmitted into the gas isolation and heat insulation cover (15) and the thermal electrodes (16) through the power supply unit to heat the hydrates.

4. The coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 2, wherein the engineering ship support unit comprises the exploitation mother ship (1), a hoisting mechanism (2) and a natural gas storage device (3), a flow control valve (4) is disposed on the natural gas storage device (3), a temperature-pressure sensor (9) is disposed on the power supply cable (10), and an operating state of the system is determined and controlled according to system information collected by the temperature-pressure sensor (9) and the flow control valve (4).

5. An exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 1, comprising the following steps:

   1) determining a central conduit of the mud volcano, drilling a well in the central conduit of the mud volcano, and disposing a casing pipe and the perforated holes in the central conduit of the mud volcano;
   2) disposing the gas isolation and heat insulation unit on a flank of the mud volcano, wherein the gas isolation and heat insulation unit comprises the gas isolation and heat insulation cover (15) and the thermal electrodes (16), and the gas isolation and heat insulation cover (15) sequentially comprises, from bottom to top, the heat-conducting aluminum foil layer (151), the carbon fiber heating wire layer (152), the asbestos heat insulation layer(153) and the heat-proof gas isolation layer (154);
   3) heating the hydrates by means of the ship-borne power supply unit; and
   4) collecting gas in the production well, and storing the collected gas on an engineering ship.

6. The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein in Step 1), the position of the central conduit of the mud volcano is targeted according to the position of a cold spring vent determined by a two-dimensional multi-channel seismic section explanation result and a submarine image.

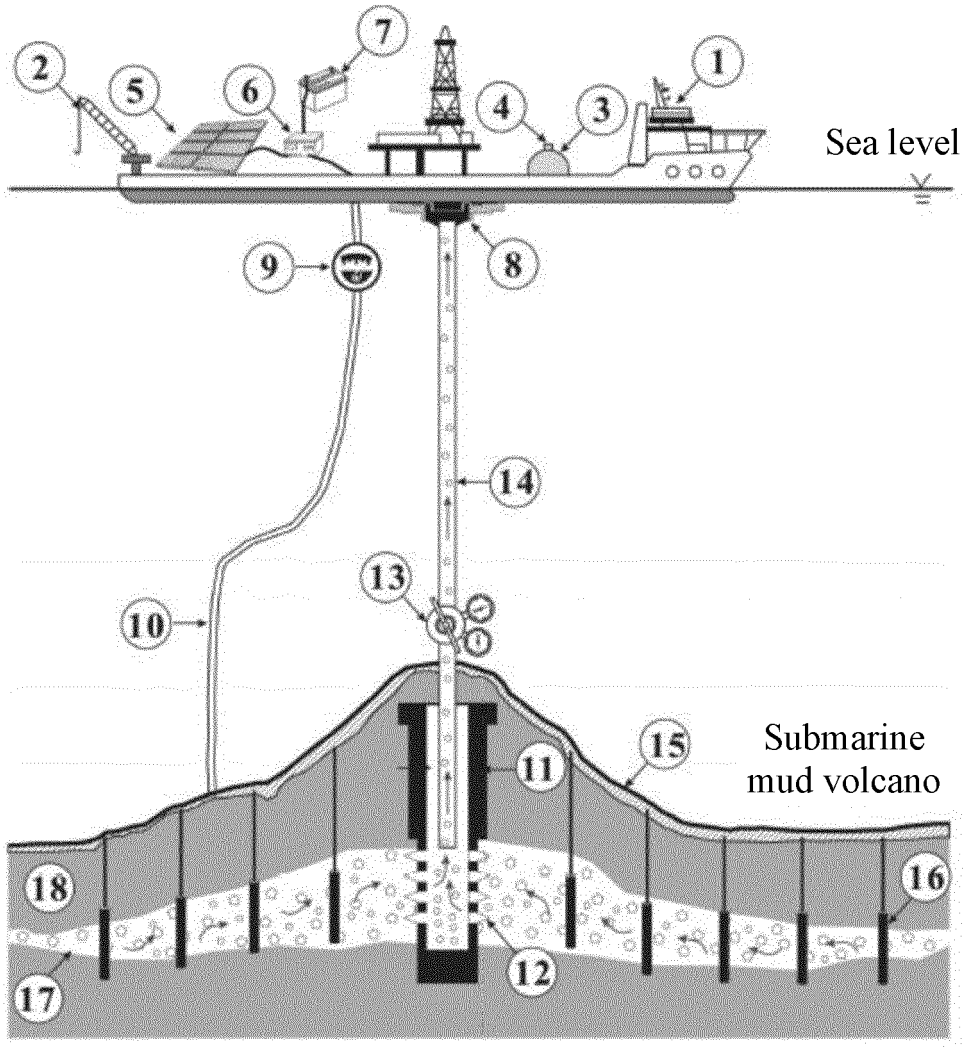
7. The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5,

wherein Step 1) is implemented specifically through the following sub-steps:

drilling the well in the central conduit of the mud volcano through a deepwater drilling technique, wherein the drilled well penetrates through a sediment covering layer (18) above natural gas, stretches into a hydrate reservoir (17) and ends at bed rock of the mud volcano, so that the production well (11) is formed; and
mounting the casing pipe, forming the perforated holes (12) in the hydrate reservoir to guide water and gas generated by decomposing the hydrates, and disposing the depressurization control valve (13) in the production well (11) to combine heat production and depressurization to decompose the hydrates more sufficiently.

**8.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein Step 2) is implemented specifically through the following sub-steps:
drilling holes at position, with a high hydrate saturability and a large thickness, of the flank of the mud volcano, and placing the thermal electrodes (16) in the holes; then, regularly placing the gas isolation and heat insulation cover (15) on the mud volcano by means of an engineering underwater robot, and connecting the gas isolation and heat insulation cover (15) to the thermal electrodes (16) placed in the drilled holes, wherein an opening is formed in a position, corresponding to a central hole of the mud volcano, of the gas isolation and heat insulation cover (15).

**9.** The exploitation method based on the coverage-type deep-sea mud volcano-associated natural gas hydrate exploitation system according to Claim 5, wherein in Step 4), after gas released by the hydrates flows into the production well (11) via the perforated holes (12), the gas is delivered into a natural gas storage device (3) on an exploitation mother ship through the natural gas transport pipe (14), and a safe unhooking system (8) is disposed at a joint of the natural gas transport pipe (14) and the exploitation mother ship to handle a sudden severe weather or other disastrous events.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Sea level
Submarine
mud volcano

FIG. 1

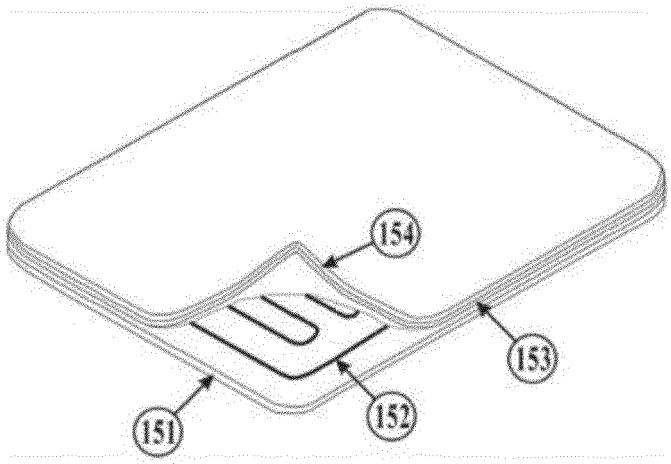
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FIG. 2

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# EUROPEAN SEARCH REPORT

Application Number
EP 20 21 1931

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The present search report has been drawn up for all claims

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| Munich | 29 April 2021 | Beran, Jiri |

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