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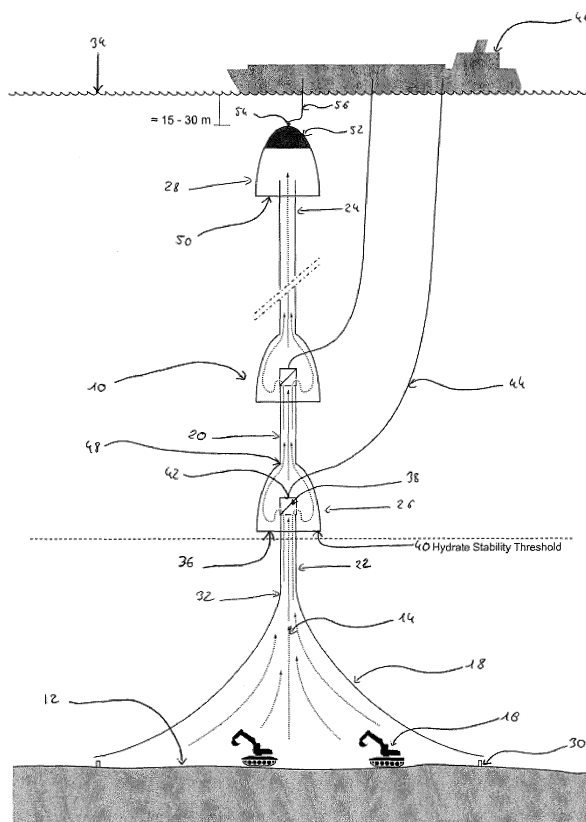
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(54) **A device for collecting methane gas**

(57) The present invention concerns a device for collecting methane gas from underwater methane hydrate deposits and the uses thereof. The present invention also

refers to a method for collecting methane gas from underwater methane hydrate deposits.

Fig. 1



Description

Technical field

[0001] The present invention generally relates to a device for extracting methane gas from underwater methane sources. This device is particularly useful for collecting methane gas coming from underwater methane hydrate deposits. The present invention also generally relates to a method for extracting methane gas from underwater sources.

Background Art

[0002] Methane hydrates, also called hydromethane, natural gas hydrate or just gas hydrate, is a solid compound in which a large amount of methane (CH_4) is trapped within a crystal structure of water, forming a solid similar to ice. Significant deposits of methane hydrates are estimated as at least an order of magnitude larger than all known natural gas reserves worldwide. They represent the world's largest source of untapped fossil energy and are widely distributed across the world.

[0003] Methane hydrates represent a huge potential energy source that could reshape global energy market. Additionally, clean burning natural gas from hydrates could displace coal and oil consumption, especially in developing energy hungry economies like China and India, yielding important climate benefits and cleaner air.

[0004] Methane hydrates occur both in deep sedimentary structures and as outcrops on the ocean floor. Indeed, methane hydrates are formed by migration of gas along geological faults, followed by precipitation or crystallization on contact with cold sea water. One liter of solid methane hydrate contains about 168 liters of methane gas. In contrast to conventional natural gas, methane hydrates exist only in definite pressure-temperature conditions (stability zone). At conditions outside the stability zone, methane does not form "methane ice".

[0005] Except on the upper continental slopes, the sea-floor of most of the world's oceans lies within the hydrate stability zone. Onshore, stability conditions are met almost exclusively in areas with thick permafrost. It is believed that most of the global gas hydrates occur in the uppermost few hundreds of meters of sediments at ocean water depths greater than 500 meters and close to continental margins.

[0006] The nature, the dispersion and the location of the hydrates pose difficult technical problems to their exploitation. Given that it is virtually impossible to extract and bring to surface the solid hydrates as such, all practical exploitation methods aim in locally decomposing the hydrates so as to cause the dissociation of the methane molecules from the water matrix and to form the methane gas.

[0007] Several methods for decomposing the methane hydrates have already been disclosed. In particular, most of the known methods involve either the heating or the

depressurization of the methane hydrate deposits in order to gasify the methane gas. All these methods require substantial quantities of energy, often more than the energy content of the extracted methane gas. Moreover, they can only be applied at very specific geological formations, where sedimentary hydrate deposits in relatively high concentrations are found below impermeable layers.

[0008] Document US 2007/0267220 describes a method and apparatus for extracting methane gas from methane hydrate. In particular, this method involves the use of a laser apparatus for heating the methane hydrate in order to gasify the methane gas.

[0009] Document WO 2011072963 relates to a method for converting methane hydrates to methane gas. In particular, the decomposition of the methane hydrates results from contacting the extracted methane hydrates with warm water. This method requires the implementation of an underwater processing station wherein the water is heated.

[0010] Document US 7,322,409B2 describes a system for dissociating the methane gas from the methane hydrates. This system comprises two electrodes fed by an energy source. Each electrode is disposed within a region of formation of methane hydrates on the ocean floor. The difference of voltage across the first and the second electrodes leads to the production of heat energy which is sufficient to thermally react with the methane hydrates thereby releasing methane gas.

[0011] Document US 6,973,968B2 refers to a method of natural gas production. This method comprises the use of an oxidizer fluid and the supply of fuel which are at higher pressure than the methane hydrate. The heating of the methane hydrate leads to its dissociation in methane gas and water. Carbon dioxide may also be used.

[0012] Another approach proposes to gasify the methane hydrate by chemical inhibition. This method involves the injection of certain organic or ionic compounds that inhibit the gas hydrate stability.

[0013] All these known methods are either of low efficiency as they require the supply of important amounts of external energy for gasifying the methane hydrates or they are applicable to very particular cases.

Technical problem

[0014] It is an object of the present invention to provide a device and a method for collecting methane gas from underwater methane hydrates deposits, in particular a device which is applicable to a wide range of underwater hydrate deposits, sedimentary or outcrops, and which requires only limited external energy input for gasifying and collecting methane gas from the methane hydrates.

[0015] This object is achieved by a device as claimed in claim 1 and a method as claimed in claim 14.

General Description of the Invention

[0016] According to a first aspect, the present invention provides a device for collecting methane gas from underwater methane hydrates deposits, which device comprises:

- a collector for being placed over an underwater methane hydrate deposits area for collecting a mixture (or a slurry) comprising potential gas (such as leaking methane gas from seabed), liquids, sediments and methane hydrates rising from the underwater methane hydrate deposits area due to the gravity;
- a riser tube having a lower end in communication with the collector for transferring the mixture of gas (such as methane gas), liquids, sediments and methane hydrates toward the sea surface;
- a buoyant buffer reservoir configured for being maintained submerged at a predetermined depth under the sea surface, said submerged buffer reservoir being in communication with the upper end of said riser tube for receiving the collected mixture.

[0017] This device is also characterized in that the riser tube comprises one or a plurality of bell-shaped separator(s). The at least one bell-shaped separator is arranged along the length of the riser tube and at a depth being located above the hydrate stability threshold. The methane hydrate stability threshold defines the limit between the state of methane hydrate and the state of methane gas. The methane hydrate stability threshold corresponds to a specific pressure limit reached at a specific depth and for a specific temperature. Thus, when reaching the at least one bell-shaped separator (located above the hydrates stability threshold), at least a part of the methane hydrates (which have been collected from the underwater methane hydrates deposits area) comprised within the mixture has been converted in methane gas and water. The bell-shaped separator generally comprises an open bottom wherein the riser tube penetrates. The at least one bell-shaped separator is configured in its interior to separate the gas and in particular the methane gas from the mixture of liquids, sediments and methane hydrates discharged by the riser tube.

[0018] Contrary to the known devices, the device according to the present invention does not require the supply of large amounts of additional external energy to gasify the methane hydrates in methane gas. In fact, the present device is designed in such a way so as to guide the excavated methane hydrates, which are lighter than water, along any methane gas or other hydrocarbons seeping out from the seabed, upwards, above the hydrate stability zone, where the methane hydrates are gradually converted into methane gas. In fact, the device according to the present invention does not require the

supply of any external energy source other than that required by the mechanical stirring and/or excavating equipment useful to detach the methane hydrates from the sediments. In particular, the device according to the present invention does not require the supply of any additional energy (except the one required by the mining equipment) to move the mixture collected within the device and to gasify the methane hydrates in methane gas.

[0019] The gasification of the methane hydrates is gravity driven only. This is possible since the density of the methane hydrates is lower than water. The methane hydrate blocks may be easily detached from the underwater methane hydrates area by stirring or excavating the upper sediments zone (few tens of meters). This operation is implemented under the collector of the device. As methane hydrates are slightly lighter than seawater, when the upper sediments layer is mobilized, they tend to surface from the seafloor and then rise slowly through the apex of the collector inside the riser tube due to gravity. Then, the mixture comprising gas (for example methane gas), sediments, methane hydrates, and liquids travels upwards inside the riser tube, toward conditions beyond the hydrate stability threshold (HST), until reaching the first bell-shaped separator of a succession of bell-shaped separators (or possibly the only bell-shaped separator). This leads to the gradual dissociation of the methane gas from water. However, the device is preferably designed in such a way that the generated methane gas cannot, within the distance remaining till the next bell-shaped separator, acquire significant speed so as to compromise the structural stability of the device.

[0020] At least one of the bell-shaped separators is located above the methane hydrate stability threshold. As a result, the hydrostatic pressure within the bell-shaped separator(s) is inferior to that required for keeping the methane and water in methane hydrate forms. The methane gas formed is separated from the mixture and evacuated from the bell-shaped separator(s) through transfer tubes for example gas transfer tubes, connected to a vessel such as compressed natural gas carrier (CNG) vessel. The separated methane gas is compressed and stored at shuttle compressed natural gas carrier vessel. Any remaining solid methane hydrates continue to travel upwards the riser tube, with the mixture, until reaching the next bell-shaped separator. The formed gas is again separated and evacuated. This separation and evacuation of the generated methane gas can be repeated as many times as necessary to gasify the whole quantity of methane hydrates.

[0021] The mixture collected from the underwater methane hydrate deposits area may comprise gas (such as leaking gas, in particular leaking methane gas), liquids, sediments and methane hydrates. The gas collected within the mixture may come from a leak located near or within the methane hydrate deposits area. The liquids comprised within the mixture may include water and potential hydrocarbons, which are lighter than the water. The sediments may also include sediments hydrocar-

bons in solid state. Any potential hydrocarbons comprised within the mixture are channeled through the successive bell-shaped separators and the riser tube toward the buoyant buffer reservoir. Then, the possible hydrocarbons are separated from water by gravity and accumulate in the top of buoyant buffer reservoir from where they are periodically recuperated by for example shuttle tanker.

[0022] The device according to the present invention shows the advantages of being cost-effective to operate and relatively easy to implement since it does not require the use and the installation of high pressure equipment or external energy sources to move (or to transfer) the methane hydrates through the device and to gasify the methane hydrates. As a result, components such as heating means, depressurized means or chemical compounds are not required within the present device, which saves costs and increases the reliability of the device. In fact, the supply of external energy is only required for the stirring and/or excavating means (such as mining equipments) implemented to detach the methane hydrates from the sediments. However, although it is not required, the present device may be used in combination with devices including heating means or depressurization means to gasify the methane hydrates. In addition, there is no need for an offshore platform arrangement to be permanently installed for the collecting procedure. In fact, the methane gas can be directly collected from the bell-shaped separators through gas transfer tubes by a vessel (for example compressed natural gas carrier vessel). The device is self-supportive as it is attached to the seaground at the periphery of the collector. In addition, another significant advantage is that as the device is located at a depth below the sea surface, it is relatively insensitive to adverse weather conditions.

[0023] The methane hydrate physical properties are well known. There is a pressure vs. temperature state diagram that determines the necessary minimum pressure for hydrates to be stable at each given temperature. Thus, the hydrates stability threshold is determined accurately by considering the temperature profile of the water column above the underwater methane hydrates area.

[0024] The underwater methane hydrate deposits area is covered by the collector of the device. Thus, when stirring and excavating the upper sediments zone of this area with stirring and/or excavating equipment (such as mining equipment), the methane hydrates rising from the sediments are confined in a reduced zone (namely under the device) and cannot spread everywhere. Furthermore, this avoids the release of the methane gas, which is a potent greenhouse gas, to the atmosphere when extracting the methane hydrates. The collector allows covering a large area if necessary. Preferably, the collector corresponds to a large inverted funnel dome-shaped element (or dome shape). As a result, the methane hydrates, together with any gas (such as leaking methane gas from seabed) or other hydrocarbons (liquids or potentially

even solid particles), converge toward its apex due to gravity.

[0025] Advantageously, the bottom of said collector is positioned proximate to said underwater methane hydrate deposits area. In a preferred embodiment, the collector comprises a plurality of anchoring means for anchoring said collector to the ground. The anchoring means may be distributed at the periphery of said collector. Anchoring means can preferably consist from standard suction anchors or from gravity driven torpedo shaped anchors that are dropped from the sea surface so as to penetrate deep into the sea floor. Further anchoring means can be provided if needed to attach the upper structures of the riser tube or the bell-shaped separator via for example wires or cables.

[0026] In a preferred embodiment, the collector has about its apex an opening to which the lower end of the riser tube is connected. The opening is thus located in the area where the collected methane hydrates converge due to the dome shape of the collector. Thus, this allows transferring the collected methane hydrates to the riser tube through the opening by the effect of gravity. Preferably, the collector is made of impermeable light soft fabric. Advantageously, the diameter of the collector at its largest part, close to the seabed, is comprised between 100 m and 500 m.

[0027] The riser tube transfers the collected mixture comprising gas (such as methane gas), methane hydrates, liquids and sediments from the opening located at the apex of the collector to the buoyant buffer reservoir via the bell-shaped separator(s) due to gravity. In particular, it is designed so as the collected mixture of gas (such as methane gas), liquids, sediments and methane hydrates is transferred from said collector to said at least one bell-shaped separator through said riser tube due to gravity. The methane gas is separated from the liquids and sediments by the bell-shaped separators and the potential hydrocarbons (liquids or possibly solids) are separated from other liquids (such as water) and from potential remaining sediments by gravity within the buoyant buffer reservoir.

[0028] In a preferred embodiment, the riser tube has an inner diameter comprised between 0.5 meters and 5 meters, preferably between 1 meter and 2 meters.

[0029] The device may comprise one or a plurality of bell shaped separator(s). The bell-shaped separator(s) comprise(s) an open bottom. Their open bottom may be completely or partially open. The open bottom should at least comprise an opening in order to communicate with the riser tube. At least one of the, preferably most of the bell-shaped separator(s) has/have to be located at a depth above the hydrate stability threshold, such that at least a part of the methane hydrates is gasified when reaching it/them. The flow of mixture within the riser tube is enhanced due to effect of the gradual generation of methane gas that, due to its significantly lower density, tends to rise rapidly and expand, due to the drop of hydrostatic pressure, inside the riser tube. Preferably, one

of the bell-shaped separator(s) may be located between about 5 meters to 20 meters, more preferably between about 7 meters to 15 meters above the hydrate stability threshold. Ideally, one bell-shaped separator is located about ten meters above the hydrates stability threshold so that any gas generated from the rising methane hydrates cannot acquire sufficient velocity and compromise the structural stability of the system. The prime function of the bell-shaped separator is to separate and evacuate through a dedicated gas transfer tube the methane gas generated in the portion of the riser tube between the bell-shaped separator and the collector apex or the previous bell-shaped separator. Preferably, the bell-shaped separator(s) is/are located between the collector and the buoyant buffer reservoir. The number of the required bell-shaped separators and their exact position depend on methane hydrate quantity and their dissociation rate.

[0030] According to a specific embodiment, the device according to the present invention may also comprise one or several bell-shaped separator(s) under the hydrate stability threshold. This could be useful for example if the seabed is substantially deeper (200 meters or more) than the hydrate stability threshold and if gas leaks (for example methane gas leaks) are present at the sea floor. Then, this at least one bell shaped separator below the hydrate stability threshold, preferably located from 10 meters to 20 meters above the collector dome apex, allows to separate from the flow the methane gas leaking from the seabed and evacuates it towards the sea surface, where it can be collected for example on a compressed natural gas carrier vessel, together with the methane gas generated from the methane hydrate dissociation higher in the riser tube.

[0031] Hence, thank to the particular design of the present device, it is possible to control the speed of the flow of mixture within the device, evacuating the gas leaking (such for example methane gas leaking) from the seabed or the gas generated from the dissociation of the rising methane hydrates in steps, before it acquires velocity that can compromise the stability of the device.

[0032] When the device comprises a plurality of bell-shaped separators, this plurality of bell shaped separators is arranged at variable or regular intervals possibly along the length of the riser tube. The bell-shaped separators are in fact arranged preferably in a serial manner along the length of the riser tube and preferably along the length of at least a portion of the riser tube. It also means that the bell-shaped separators are separated from each other by a part of riser tube. The number and the distance between each other depend among others on the gas separation and the expected flow acceleration. Preferably, the bell-shaped separators are spaced by between 10 meters and 100 meters and preferably by 30 meters. The succession of bell-shaped separators is useful to prevent compromising the structural stability of the system since the methane gas is gradually evacuated all along the length of the riser tube.

[0033] The bell-shaped separator(s) communicate(s)

with the riser tube so that the mixture of liquids, sediments, (remaining) methane hydrates and gas (methane gas) flows upwardly through the bell-shaped separator(s). At least a part of the sediments and at least a part of the liquids may be evacuated through the open bottom of the bell-shaped separator(s).

[0034] Preferably, the bell-shaped separator(s) is/are made of steel or from reinforced fabric. Advantageously, the bell-shaped separator(s) comprise(s) a gas separator unit. This gas separator unit communicates with the riser tube and is designed so as to separate and evacuate the methane gas from the flow mixture. The mixture passes within the gas separator unit. The gaseous part of the flow is separated from the liquid by the gas separator unit and, successively, evacuated through dedicated gas transfer tubes towards the sea surface. According to a preferred embodiment, the gas separator unit comprises a number of gas permeable surfaces arranged in such a way so as let the gas pass through while deviating the liquid flow. The number and dimensions of the gas-permeable surfaces depends upon the expected quantity of the methane gas. The bell-shaped separator may comprise a gas evacuation port through which the separated methane gas is evacuated. The gas evacuation port can be connected to a gas transfer tube which channels the methane gas toward the sea surface, for example towards a compressed natural gas carrier vessel. The shape of the bell-shaped separator allows the remaining mixture (namely the mixture which remains after the separation of the methane gas) to converge toward the apex of the bell-shaped separator which communicates with the riser tube (for example through an opening). Thus, the bell shape of the bell-shaped separator optimizes the move of the mixture upwardly within the device.

[0035] After going through (all) the bell-shaped separator(s), channeled through the riser tube, any liquids (or potential lighter solid particles) lighter than water present are transferred by gravity upwards, towards the sea surface until reaching the submerged buoyant buffer reservoir. The buoyant buffer reservoir may also be called a buffer bell. In fact, this buoyant buffer reservoir may preferably show a bell shape. The buoyant buffer reservoir is different from the bell-shaped separator. The buoyant buffer reservoir is designed to collect liquids (and possibly remaining sediments or lighter solid particles) but is not intended to separate or to store gas. This buoyant buffer reservoir is preferably located few tens of meters below the sea surface. The buoyant buffer reservoir is located between 10 meters and 50 meters below the sea surface, preferably between 15 meters and 25 meters below the sea surface. This buoyant buffer reservoir is useful for separating the potential hydrocarbons (liquids or even solids) from the water. The hydrocarbons are lighter than water and thus tend to accumulate at the top of the buoyant buffer reservoir while the heavier water escapes through the open bottom of the buoyant buffer reservoir due to gravity. Thus, in addition to the methane gas, the present device also allows collecting any even-

tual hydrocarbons (fluids such as oil, or petroleum or other substances lighter than water) escaping / released from the hydrate deposits area. The shape of the buffer buoyant reservoir allows the liquids converging to the top of the buffer buoyant reservoir and thus optimizing the separation of lighter liquids than water (or possibly lighter solids) due to gravity.

[0036] As a result, the device, according to the invention, also prevents the release of liquid pollutants to the sea. Advantageously, the device can be used to collect both the methane gas and the hydrocarbons (for example liquid hydrocarbons). The device can be used to collect the methane generated from the hydrate dissociation as well as the methane released by leaks in the seabed, like for example underwater mud volcanoes or leaking offshore installations. In particular, it can also be used to collect hydrocarbons leaking naturally from the seabed or leaking from a damaged offshore installation or leaking from a sunken shipwreck.

[0037] Preferably the buoyant buffer reservoir is designed to act as a terminal buoy. Advantageously, the buoyant buffer reservoir comprises a closed outer chamber, which serves to provide the necessary minimum buoyancy so as to keep the device in tension under all conditions. Advantageously, the buoyant buffer reservoir comprises also an inner chamber with an open bottom, which communicates with the upper end of the riser tube. This open bottom allows the riser tube penetrating into said inner chamber in order to discharge the up flowing mixture. The open-bottom may be completely or partially open. The open-bottom of the buoyant buffer reservoir should comprise at least two openings to communicate with the riser tube and the surrounding seawater. Advantageously, the closed outer chamber of the buffer buoyant reservoir is made of steel of sufficient strength to resist the operating hydrostatic pressure without any significant deformation. In a preferred embodiment, the closed outer chamber is of annular form on which is attached the open inner chamber. The open inner chamber does not have to resist any hydrostatic pressure differential, thus it can be made either from steel, aluminum, plastic or reinforced fabric.

[0038] In a preferred embodiment, the submerged buoyant buffer reservoir comprises a drainage port through which the chamber can be emptied by pumping. The hydrocarbon extracted is then transferred to for example a shuttle tanker through a transfer tube. The chamber of the buoyant buffer reservoir may have a capacity comprises between 1,000 to 20,000 m³ or more.

[0039] Due to the specific design of the device according to the present invention, the flow of the mixture and thus the structural stability of the device may be easily controlled by several means such as, among others:

- Regulating the activity of the stirring and/or excavating means (such as mining equipment) under the dome collector,

- Regulating the number and the position of the bell shaped separators,
- Regulating the configuration of the gas separator units and the open bottom of the inner chamber at each bell shaped separator.

[0040] According to another aspect, the invention also proposes a method for collecting methane gas from underwater methane hydrate deposits. The method comprises the steps of

- Stirring and excavating the upper sediments zone of an underwater methane hydrates deposits area in order to detach the methane hydrates from the sediment and cause them to rise upward due to the gravity,
- Channelling the mixture of the methane hydrates as well as potential gas (for example leaking methane gas from seabed), liquids, and sediments upwardly, toward the sea surface, so as to exceed the hydrate stability threshold leading to the gasification of at least a part of the methane hydrates in methane gas,
- Separating the methane gas from the mixture (liquids and the sediments),
- Transferring the separated methane gas toward the sea surface.

[0041] The method according to the present invention does not require the supply of any additional energy to gasify the methane hydrates in order to obtain methane gas other than the mechanical energy needed to stir / excavate the seabed under the collector dome. The gasification of the methane hydrates in methane gas is due to the pressure drop as they rise upwards due to gravity. In addition, the method according to the present invention does not require any external energy source to transfer the mixture upwardly through the device. An energy source must be supplied only for stirring and/or excavating the upper zone of the sediments in order to detach the methane hydrates.

[0042] Preferably, the method according to the invention includes the step of channeling the mixture of the methane hydrates as well as potential gas (leaking methane gas), liquids, and sediments upwards, towards the buoyant buffer reservoir, through a series of bell-shaped separators. As the methane hydrates move upwards they reach the hydrate stability threshold and start dissociating transforming gradually in water and methane gas. Preferably, the separated methane gas is channeled to a compressed natural gas carrier vessel. According to an embodiment, the method according to the present invention includes the step of separating and temporarily storing any leaking hydrocarbons or other pollutants lighter than seawater present within the mixture, to the buoyant buffer reservoir, close to the sea surface. Advantageously, the collected hydrocarbons are transferred to a shuttle tanker.

[0043] In a preferred embodiment, the method for collecting methane gas involves the use of a device according to the present invention.

[0044] Preferably, the method comprises the following steps:

- Setting up a device according to the present invention over an underwater methane hydrate deposits area,
- Stirring and excavating the upper sediments zone of an underwater methane hydrates area in order to cause the methane hydrates to rise upward due to the gravity through the collector until reaching the apex of the collector inside the riser tube,
- Channeling the mixture of potential gas (such as leaking gas for example leaking methane gas from seabed), liquids, methane hydrates and sediments upwardly within the riser tube until exceeding the hydrate stability threshold leading to the gasification of at least a part of the methane hydrates in methane gas,
- Separating the methane gas from the mixture (liquids and sediments) in at least one bell-shaped separator,
- Transferring the methane gas from the bell-shaped separators to the sea surface by at least one gas transfer tube in communication with the bell-shaped separator(s).

[0045] Advantageously, the method also comprises a step of channeling the remaining mixture via the riser tube until reaching a buoyant buffer reservoir wherein the hydrocarbons are separated from the water by gravity.

[0046] Preferably, the method comprises the step of extracting periodically the hydrocarbons (liquids or solids) accumulated at the top of the buoyant buffer reservoir through transfer tube towards for example shuttle tankers.

[0047] All the embodiments previously described may be combined within reason.

Brief Description of the Drawings

[0048] Further details and advantages of the present invention will be apparent from the following detailed description of a not limiting embodiment with reference to the attached drawing, wherein:

- Fig. 1 is a plan view of one embodiment of the device according to the present invention.

Description of Preferred Embodiments

[0049] Fig.1 shows a preferred embodiment of a device 10 for collecting methane gas in accordance with the present invention. Reference 12 indicates underwater

methane hydrates deposits area. In the most general case, a mixture 14 of methane hydrates, gas (leaking methane gas), hydrocarbons (for example liquid hydrocarbons) and sediment particles rises upwardly under the action of the mining equipment (or stirring and/or excavating equipment) 16 from the underwater methane hydrate deposits area 12.

[0050] The device 10 comprises a collector 18 in form of a deployable inverted funnel dome-shaped element, a riser tube 20, a plurality of bell-shaped separators 26, and a buoyant buffer reservoir (or bell buffer) 28. The lower end of the riser tube 22 is connected to the apex of the inverted funnel dome-shaped element (collector 18). The upper end of the riser tube 24 is connected to the submerged buoyant buffer reservoir 28. The plurality of bell-shaped separators 26 is arranged along the length of the riser tube 20 in a serial manner.

[0051] The mining equipment 16 stirs and excavates the upper sediments zone of this area 12 so that the methane hydrates, present within this sediment zone and which are lighter than the water, are caused to rise upwards due to the gravity. Eventual leaking gas (such as leaking methane gas) as well as other liquid or solid hydrocarbons are also mobilized. Under the action of the buoyancy, the methane hydrates and other mobilized lighter than water substances comprised within the upper sediments zone travel upward and converge to the apex of the collector 18 in form of an inverted funnel dome-shaped element and enter the riser tube 20 wherein they ascend towards the sea surface 34. In fact, a mixture 14 of methane hydrates, liquids, gas (methane gas) and sediments is caused to rise upward from the underwater methane hydrate area and is channeled through the device 10. In addition to water, the liquids comprised within the mixture 14 may also include liquid or solid hydrocarbons. The collector 18, which comprises an inverted funnel dome shaped element should be installed so as to cover the whole interesting methane hydrate deposits area 12. The collector 18 in form of an inverted funnel dome shaped element is anchored to the seabed through several anchoring means 30.

[0052] The collector 18 in form of an inverted funnel dome shaped element communicates with the lower end of the riser tube 22 through an opening (or collector-riser interface) 32. Preferably, the lower end of the riser tube 22 communicates with the collector 18 in form of an inverted funnel dome shaped element through an opening 32 located at the apex of the collector 18. As shown in Fig.1, the riser tube 20 is preferably vertically arranged above the apex of the collector 18 in form of an inverted funnel dome shaped element so that the collected mixture 14, after converging toward the apex, is transferred within the riser tube 20 and rises upwardly therein under the effect of the gravity.

[0053] When the mixture 14 travels upward the collector 18 in form of an inverted funnel dome shaped element, a part of the methane hydrates may already be gasified due to the friction. This may be beneficial since it can

accelerate the transfer of the mixture 14 within the device 10.

[0054] The riser tube 20 channels the mixture 14 upwardly within the device 10 toward the sea surface 34, namely from the apex of the collector 18 in form of an inverted funnel dome-shaped element until the submerged buoyant buffer reservoir 28. The riser tube 20 also communicates with bell-shaped separator 26 wherein the mixture 14 is discharged. The riser tube 20 allows channeling the mixture 14 and the methane gas within the whole device 10.

[0055] A plurality of bell-shaped separators is arranged along the length of the riser tube 20. It has to be noted that the device 10 may also comprise only one bell-shaped separator 26 according to a specific embodiment. The riser tube 20 penetrates within each of the bell-shaped separator 26 through the open bottom of the bell-shaped separator 36. This plurality of bell-shaped separators 26 is located along the riser tube 20 between the apex of the inverted funnel dome shaped element (collector 18) and the submerged buoyant buffer reservoir 28. In particular, this at least one or the plurality of bell-shaped separator(s) 26 is located above the hydrate stability threshold. Preferably the first bell-shaped separator is located few tens above the hydrate stability threshold. As a result, when reaching the bell-shaped separator 26, at least a part of the methane hydrates is converted in methane gas. The gasification of the methane gas gradually occurs within the device 10 according to the present invention due to gravity, without requiring the supply of an additional external energy source. If the seabed is substantially deeper (200 m or more) than the hydrate stability threshold and if methane gas leaks are present at the sea floor, then it is advantageous to have at least one bell shaped separator 26 below the hydrate stability threshold, preferably from 10 m to 20 m above the collector 18 dome apex, in order to separate from the flow the methane gas leaking from the seabed and evacuate it towards the sea surface.

[0056] The separation of the methane gas from the liquids, sediments and the potential remaining methane hydrates is carried out within the interior of the bell-shaped separators 26, which are properly configured for this. In order to efficiently separate the methane gas from the mixture 14, the bell-shaped separator 26 comprises a gas separator unit 38. The mixture 14 is caused to flow through the separator unit 38.

[0057] The bell-shaped separator 26 may be connected to the riser tube 20 through connector means 40. These connector means 40 can be for example: wires or cables. This bell-shaped separator 26 may also comprise one or several gas evacuation port(s) 42 from which the bell-shaped separator 26 may be emptied and thus the methane gas evacuated. Every gas evacuation ports 42 of the bell-shaped separator(s) 26 are connected to a gas transfer tube 44 of the bell-shaped separator 26. This gas transfer tube 44 allows channeling the methane gas toward the sea surface 34 and especially toward a col-

lecting means such as a compressed natural gas carrier vessel 46.

[0058] The step of separation of methane gas from the remaining mixture 14 may be repeated as many time as necessary. The sediments, the liquids (comprising potential hydrocarbons) and the eventual remaining methane hydrates are caused to flow upwardly within the riser tube 20 toward the next bell-shaped separator 26 if an additional separation step is necessary. In fact, the riser tube 20 also communicates with the upper part of each bell-shaped separator 26. In particular, the riser tube 20 communicates with an upper opening 48 located at the apex of the bell-shaped separator 26 toward which the remaining mixture 14 converges after the separation of at least a part of the methane gas. The bell-shaped separators 26 are connected to each other through the riser tube 20. As shown in Fig.1, parts of riser tube 20 are located between the bell-shaped separators 26. The bell-shaped separators 26 are spaced by between 10 meters and 100 meters and preferably by 30 meters. After the mixture 14 has been submitted to the last bell-shaped separator 26 (or the only one bell-shaped separator 26 according to a specific embodiment), the mixture 14 collected from the upper opening of the bell-shaped separator 48 is channeled by the riser tube 20 until reaching the buoyant buffer reservoir 28.

[0059] The buoyant buffer reservoir 28 comprises an open bottom 50, which communicates with the upper end of the riser tube 24. In fact, the riser tube 20 penetrates within the buoyant buffer reservoir 28 and discharges the remaining mixture 14, which has passed through the bell-shaped separators 26. The remaining mixture 14 comprises liquids (water, hydrocarbons, etc.) and sediments (such as solid particles). In particular, the remaining mixture 14 may also comprise hydrocarbons (liquid or even solid for example particles) for example such as oils, petroleum, etc... Due to the difference of gravity, the hydrocarbons (in liquid state or even in solid state) accumulate at the top of the buffer buoyant reservoir 52 and separate from the water. Thus, the present device 10 provides the advantage to separate the hydrocarbons from the water. Hence, the hydrocarbons may also be recovered from the mixture 14 collected from the upper sediments zone of the methane hydrate area. The hydrocarbons, which are accumulated at the top 52 of the buoyant buffer reservoir 28 may be collected through one or several drainage ports 54 preferably located at the upper part of the buoyant buffer reservoir 52. In order to extract the hydrocarbons from the buoyant buffer reservoir, one or several transfer tube(s) 56 is/are connected to the drainage port(s) 54 of the buoyant buffer reservoir 28. The transfer tube(s) 56 of the buoyant buffer reservoir 28 channel(s) the hydrocarbons toward the sea surface 32 and preferably to a shuttle tanker 46.

[0060] The device 10 according to the present invention presents many significant advantages. Firstly, it is very simple and does not require precise or elaborate manipulations of operations for its manufacturing or on-

site deployment. Many of its components can be manufactured and assembled by non-specialized shipyards. The riser tube 20 configuration can be implemented through a modular design, adding operational flexibility and lowering the cost. The device 10 can be operated entirely by non-specialized personnel. It is entirely passive: the flow of methane hydrates and methane gas is almost gravity driven. Once in place, it does not require regular deep-sea operations or monitoring. The device 10 is highly configurable since the riser tube 20, the bell-shaped separators 26 and the buoyant buffer reservoir 28 can be optimized. Furthermore, the device 10 can be easily and quickly installed. Other advantages are that its operation is entirely gravity driven. The device 10 does not require the use of an additional energy source to gasify the methane hydrates or to transfer the flow mixture 14 upwardly through the device 10. There is no need of heating means, depressurization means or chemical agents. The device 10 avoids complex and expensive installations, which are difficult to manage remotely. Furthermore, the operation of the device 10 is not sensitive to weather conditions.

Legend:

[0061]

10	Device	
12	Underwater methane hydrate deposits area	
14	Mixture	
16	Mining equipment	
18	Collector	
20	Riser tube	
22	Lower end of the riser tube	
24	Upper end of the riser tube	
26	Bell-shaped separator	
28	Buoyant buffer reservoir (or buffer bell)	
30	Anchoring means	
32	Opening of the collector (or collector-riser interface)	
34	Sea surface	
36	Open bottom of the Bell-shaped separator	
38	Gas separator unit	
40	Connector means	
42	Gas evacuation port	
44	Gas transfer tube	
46	Shuttle tanker or CNG carrier vessel	
48	Upper opening of the bell-shaped separator	
50	Open bottom of buoyant buffer reservoir (or buffer bell)	
52	Top of the buoyant buffer reservoir (or buffer bell)	
54	Drainage port	
56	Transfer tube	

Claims

1. A device (10) for collecting methane gas from un-

derwater methane hydrates deposits (12) comprising:

- a collector (18) for being placed over an underwater methane hydrates deposits area (12) for collecting a mixture (14) comprising potential gas, liquids, sediments and methane hydrates rising from the underwater methane hydrates deposits area (12) due to gravity;
- a riser tube (20) having a lower end (22) in communication with the collector (18) for transferring the mixture (14) of gas, liquids, sediments and methane hydrates toward the sea surface (32);
- a buoyant buffer reservoir (28) configured for being maintained submerged at a predetermined depth under the sea surface (32), said submerged buffer reservoir being in communication with the upper end of said riser tube for receiving the collected mixture (14);
- the device (10) being **characterized in that** at least one bell-shaped separator (26) is arranged along the length of the riser tube and at a depth being located above the hydrate stability threshold, said at least one bell-shaped separator (26) comprises an open bottom (36) wherein the riser tube penetrates, said bell-shaped separator (26) is arranged in its interior to separate the methane gas from the mixture (14) of liquids, sediments and methane hydrates discharged by the riser tube (20).

2. The device (10) according to claim 1, wherein it is not required the supply of any additional energy to move the mixture (14) within the device (10) and to gasify the methane hydrates in methane gas.

3. The device (10) according to claim 1 or 2, wherein the at least one bell-shaped separator (26) comprises a gas separator unit (38).

4. The device (10) according to any one of claims 1 to 3 wherein it comprises a plurality of bell-shaped separators (26) which is arranged at variable or regular intervals along the length of the riser tube (20).

5. The device (10) according to claim 4 wherein the plurality of bell-shaped separators (26) is arranged in a serial manner.

6. The device (10) according to any one of the preceding claims wherein the at least one bell-shaped separator is located between about 5 meters to 20 meters, preferably between about 7 meters to 15 meters and more preferably about ten meters above the hydrates stability threshold.

7. The device (10) according to any one of the preced-

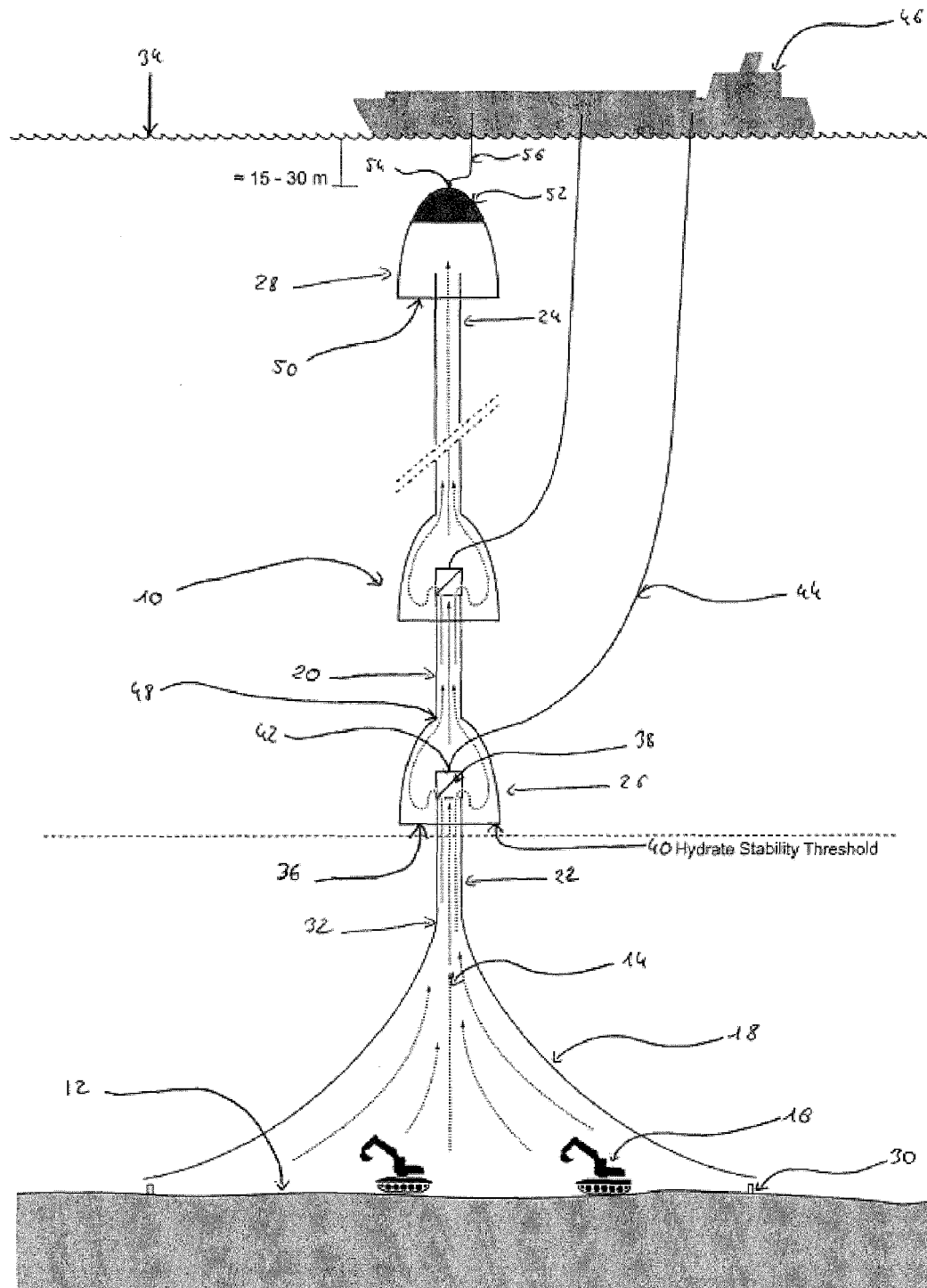
ing claims wherein the interior of the at least one bell-shaped separator (26) communicates with the riser tube (20) so as the mixture (14) of liquids, sediments, methane hydrates and gas flows upwardly through the bell-shaped separator(s) (26).

8. The device (10) according to any one of the preceding claims wherein the device comprises at least one bell-shaped separator (26) under the hydrate stability threshold, preferably about 10 meters above the upper part of the collector (18). 10
9. The device (10) according to any one of the preceding claims wherein the bell-shaped separators (26) are spaced by between 10 meters and 100 meters and preferably by 30 meters. 15
10. The device (10) according to any one of the preceding claims wherein the at least one bell-shaped separator (26) is made of steel or reinforced fabric. 20
11. The device (10) according to any one of the preceding claims wherein the at least one bell-shaped separator (26) comprises a gas evacuation port (42). 25
12. The device (10) according to any one of the preceding claims wherein the riser tube (20) has an inner diameter comprised between 0,5 meter and 5 meters, preferably between 1 meter and 2 meters. 30
13. The device (10) according to any one of the preceding claims wherein said collector (18) is in form of an inverted funnel dome-shaped element.
14. The device (10) according to any one of the preceding claims wherein the buoyant buffer reservoir (28) is located between 10 meters and 50 meters, preferably between 15 meters and 25 meters below the sea surface. 35
40
15. A method for collecting methane gas from underwater methane hydrate deposits comprising the steps of:
- stirring and excavating the upper sediments zone of an underwater methane hydrates area (12) in order to detach the methane hydrates from the sediment and to cause them to rise upward due to the gravity, 45
- channeling the mixture (14) of methane hydrates, potential gas, liquids and sediments upwardly within the riser tube (20) toward the sea surface until exceeding the hydrate stability threshold leading to the gasification of at least a part of methane hydrates in methane gas, 50
- separating the methane gas from the mixture (14), 55
- transferring the methane gas toward the sea

surface (32).

16. Use of a device (10) according to any one of claims 1 to 14 for collecting methane gas.
17. Use of a device (10) according to claim 16, for further collecting hydrocarbons.
18. Use of a device (10) according to any one of claims 16 to 17 wherein the methane gas is generated from the dissociation of the methane hydrates and/or is released by leaks in the seabed.
19. Use of a device (10) according to any one of claims 16 to 18 wherein the collected hydrocarbons are released from leaks in the seabed, from a damaged offshore installation or from a sunken shipwreck.

Fig. 1





EUROPEAN SEARCH REPORT

Application Number

EP 13 17 5822

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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