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CA 2585211 A1 2006/05/18

(21) **2 585 211**

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

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(86) Date de dépôt PCT/PCT Filing Date: 2005/10/17
(87) Date publication PCT/PCT Publication Date: 2006/05/18
(85) Entrée phase nationale/National Entry: 2007/04/24
(86) N° demande PCT/PCT Application No.: US 2005/037245
(87) N° publication PCT/PCT Publication No.: 2006/052392
(30) Priorité/Priority: 2004/11/05 (US60/625,388)

(51) Cl.Int./Int.Cl. *F17C 13/00* (2006.01), *F17C 5/04* (2006.01), *F17C 7/04* (2006.01)

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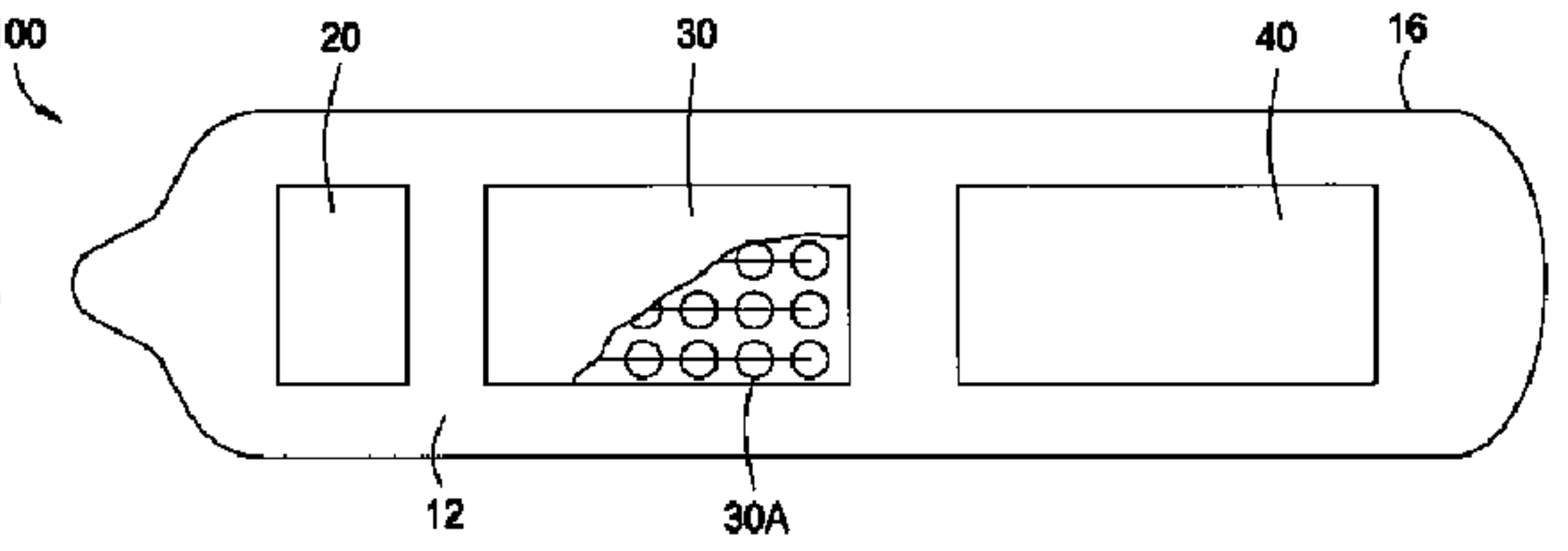
(54) Titre : MOYEN DE TRANSPORT POUR LE GAZ NATUREL LIQUEFIE ET PROCEDE DE TRANSPORT D'HYDROCARBURES
(54) Title: LNG TRANSPORTATION VESSEL AND METHOD FOR TRANSPORTING HYDROCARBONS



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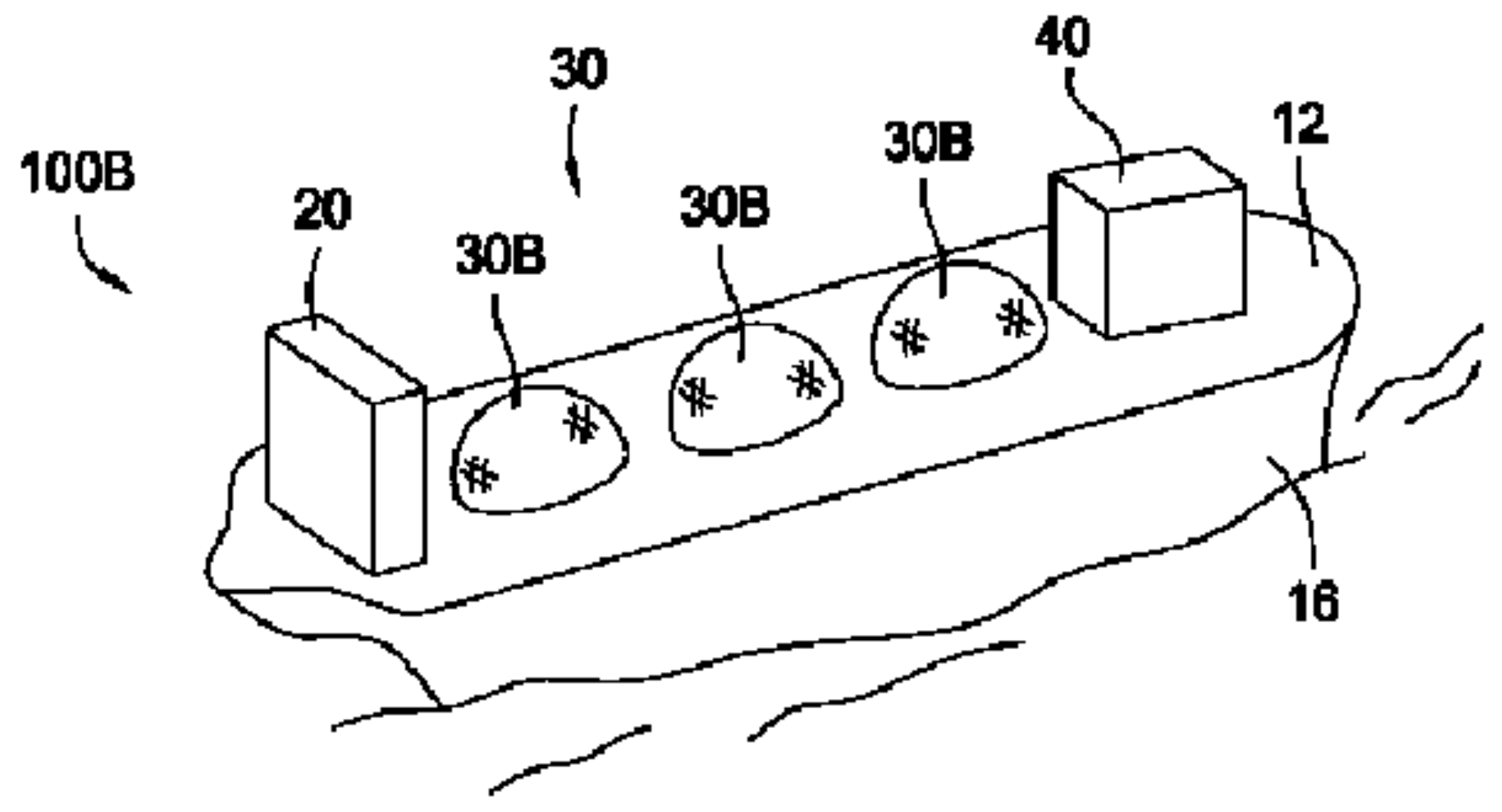

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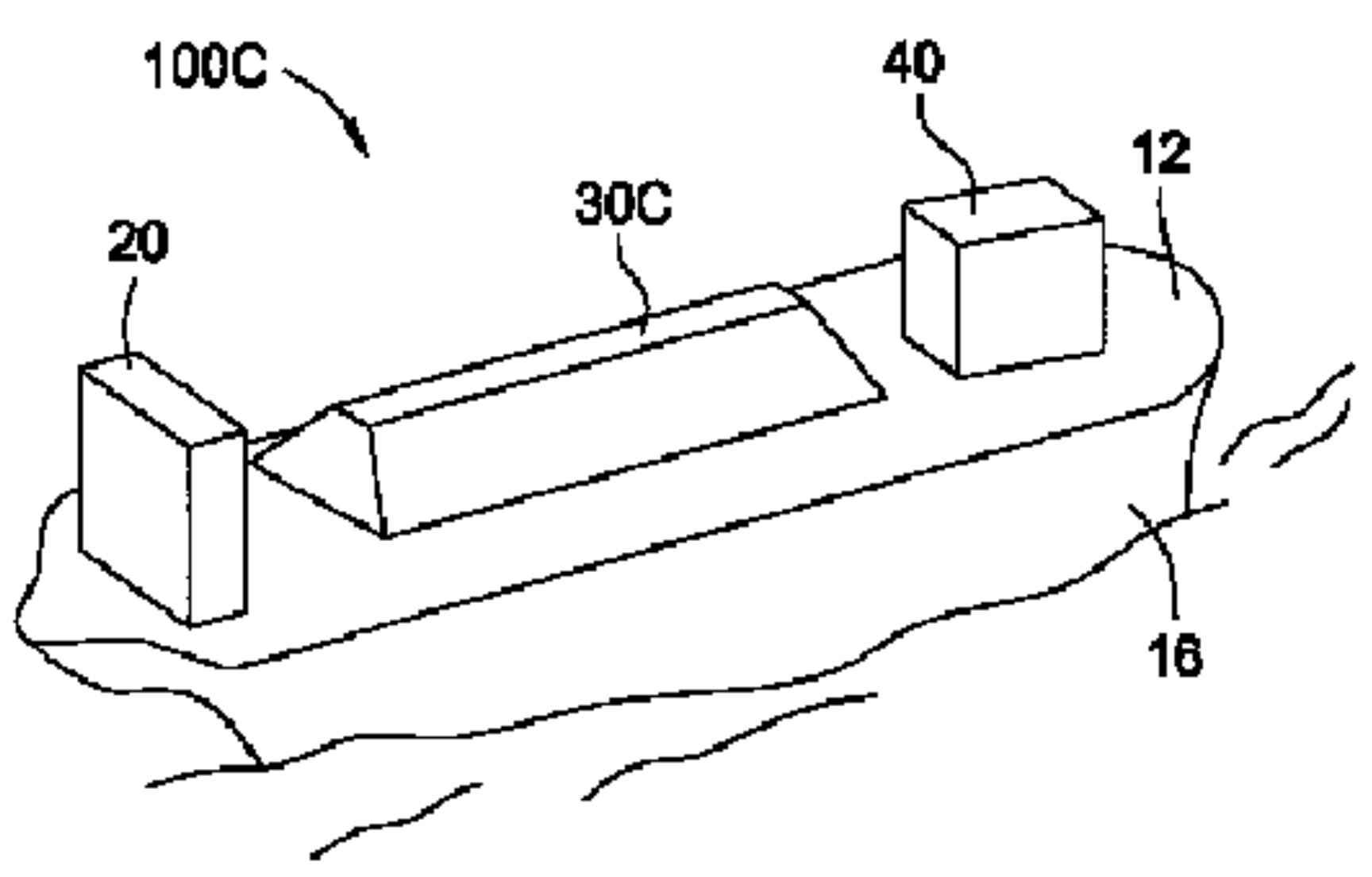

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(57) Abrégé/Abstract:
A vessel for transporting liquefied natural gas is provided. The vessel generally includes a gas transfer system for on-loading and off-loading natural gas to and from the vessel at essentially ambient temperature. The vessel further includes a gas processing facility

(57) Abrégé(suite)/Abstract(continued):
for selectively providing liquefaction and regasification of the natural gas. The vessel also includes a containment structure for containing the liquefied natural gas during transport. The vessel may be a marine vessel or a barge vessel for transporting LNG over water, or a trailer vessel for transporting LNG overÞthe-road. A method for transporting LNG is also provided, that provides on-loading of natural gas onto a vessel, condensing the natural gas, storing the gas on the vessel in liquefied form, transporting the gas to an import terminal, vaporizing the gas, and off-loading the gas at the terminal.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 May 2006 (18.05.2006)

PCT

(10) International Publication Number
WO 2006/052392 A3

(51) International Patent Classification:
F17C 13/00 (2006.01) ***F17C 7/04*** (2006.01)
F17C 5/04 (2006.01)

(21) International Application Number:
PCT/US2005/037245

(22) International Filing Date: 17 October 2005 (17.10.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/625,388 5 November 2004 (05.11.2004) US

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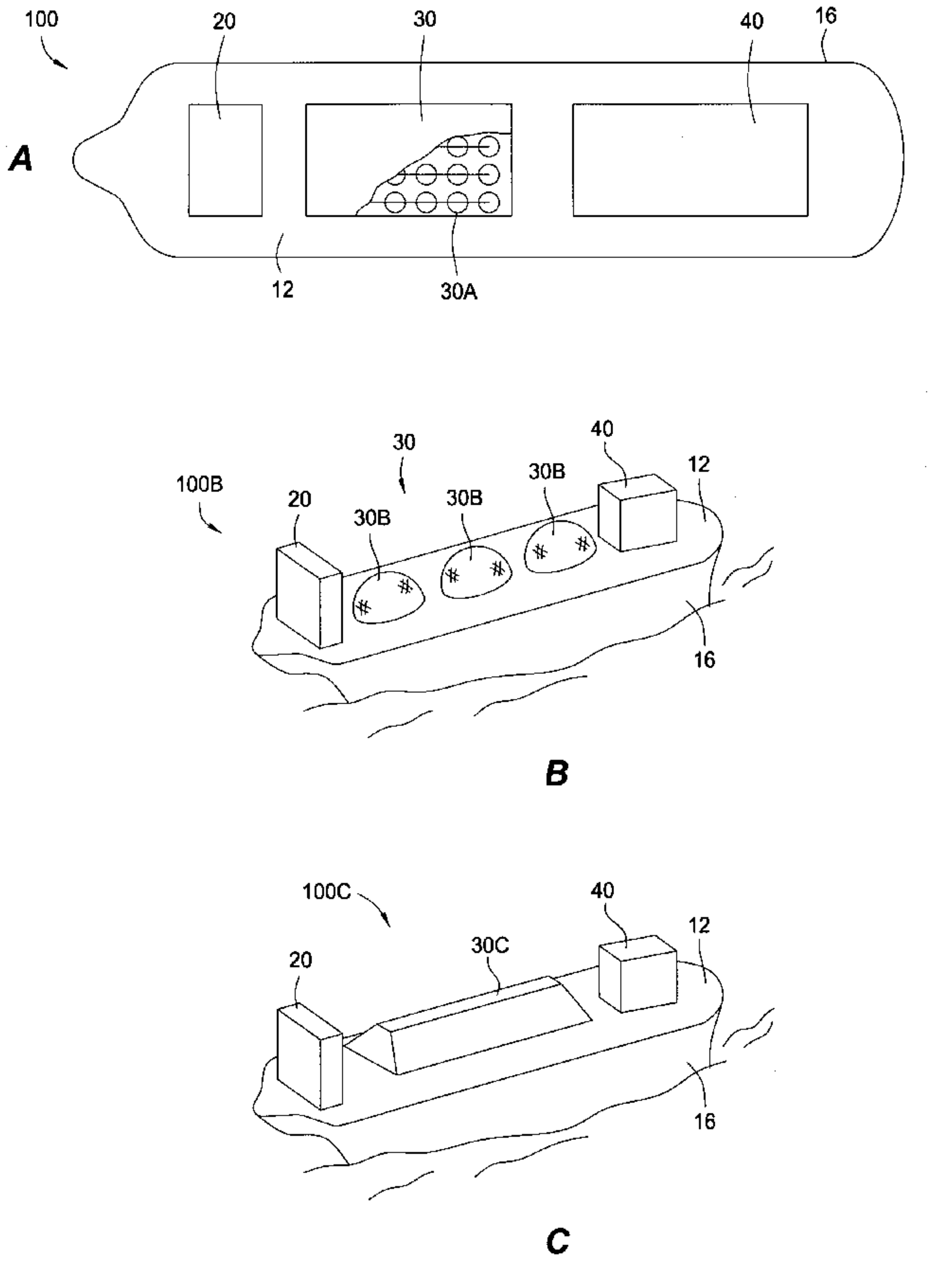
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,

[Continued on next page]

(54) Title: LNG TRANSPORTATION VESSEL AND METHOD FOR TRANSPORTING HYDROCARBONS



(57) Abstract: A vessel for transporting liquefied natural gas is provided. The vessel generally includes a gas transfer system for on-loading and off-loading natural gas to and from the vessel at essentially ambient temperature. The vessel further includes a gas processing facility for selectively providing liquefaction and regasification of the natural gas. The vessel also includes a containment structure for containing the liquefied natural gas during transport. The vessel may be a marine vessel or a barge vessel for transporting LNG over water, or a trailer vessel for transporting LNG overthe-road. A method for transporting LNG is also provided, that provides on-loading of natural gas onto a vessel, condensing the natural gas, storing the gas on the vessel in liquefied form, transporting the gas to an import terminal, vaporizing the gas, and off-loading the gas at the terminal.

WO 2006/052392 A3

ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
27 July 2006

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

LNG TRANSPORTATION VESSEL AND METHOD FOR TRANSPORTING HYDROCARBONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application 60/625,388, filed 5 November, 2004.

BACKGROUND

Field of the Inventions

[0002] Embodiments of the present invention generally relate to the transportation of hydrocarbons. More particularly, embodiments of the present invention relate to an integrated design for a liquefied natural gas transportation vessel. In addition, embodiments of the present invention relate to a method for combining liquefaction, transportation and regasification processes.

Description of Related Art

[0003] Clean burning natural gas has become the fuel of choice in many industrial and consumer markets around the world. However, natural gas sources are often located in remote locations relative to the commercial markets desiring the gas. This means that the natural gas must sometimes be produced in remote geographic locations, and then transported across oceans using large-volume marine vessels.

[0004] To maximize gas volumes for transportation, the gas may be taken through a liquefaction process. The liquefied natural gas ("LNG") is formed by chilling very light hydrocarbons, e.g., gases containing methane, to approximately -160° C. The liquefied gas may be stored at ambient pressure in special, cryogenic tanks disposed on large ships. Alternatively, LNG may be liquefied at an increased pressure and at a warmer temperature, i.e., above -160° C, in which case it is known as Pressurized LNG ("PLNG"). For purposes of the present disclosure, PLNG and LNG may be referred to collectively as "LNG."

[0005] The transportation of LNG to the importing nation or locale is expensive. As currently developed, gas is taken through a liquefaction process at a location proximate the point of production. This means that a large gathering and liquefaction center is erected in the producing country. Alternatively, the liquefaction process may take place offshore on a platform or vessel, such as a floating production, storage and offloading (FPSO) vessel. From there, the hydrocarbon product is loaded in its liquefied state onto marine transport vessels. Such vessels are known as LNG tankers.

[0006] Upon arrival at a destination country, the LNG product is offloaded at a receiving terminal. The receiving terminal may be onshore or "near shore" relative to the importing nation. In some cases, the gas is temporarily maintained in storage in its chilled and liquefied state. Liquefaction enables larger volumes of gas to be stored in insulated tanks until introduced into the gas grid, or delivered to a customer. In some instances, the chilled gas is transported in specially insulated vessels on the back of a trailer and hauled over-the-road to markets. In some instances, the imported LNG is "vaporized" into the grid for the market.

[0007] LNG technology generally requires large investments of capital and resources at the export and import terminals. It also requires cryogenic transfer of liquids at each end. In many locations, natural gas resources are present in insufficient quantities to justify the expense of building a gas liquefaction processing facility in the producing country or at the producing site. In addition, the transfer of cryogenic material, particularly from an FPSO, is difficult. Alternatively, consumer demand at the importing location may not economically justify the fabrication of a regasification facility. Therefore, there is a need for an integrated vessel that is capable of receiving a light hydrocarbon product at an export terminal of a producing country, chilling the gas to a liquefied state, and then transporting the gas to a location in greater proximity to the desired market. In addition, there is a need for a vessel that is capable of regasifying the light hydrocarbon upon arrival at a location for offloading, or import terminal. There is further a need for such a vessel that travels the oceans, on a river, or over the road.

[0008] Additional information relating to LNG liquefaction, transportation, and/or regasification technology can be found in U.S. patent no. 5,878,814 (to Breivik et al.), DE 32 00 958 (Linde AG), U.S. patent no. 5,025,860 (to Mandrin et al.), U.S. patent no. 6,517,286 (to Latchem), WO 2004/081441 (Conversion Gas Imports), US2003/185631 (Bliault et al.), WO 2004/000638 (ABB Lummus Global, Inc.), U.S. patent no. 3,766,583 (to Phelps), US2003/182948 (Nierenberg), US 2002/174662 (Frimm et al.), and U.S. patent no. 6,089,022 (to Zednik et al.).

SUMMARY

[0009] First, a method for transporting liquefied natural gas is provided. The method includes the steps of on-loading natural gas in a substantially gaseous phase onto a vessel at a first location; cooling the natural gas on the vessel so as to convert it substantially into liquefied natural gas; storing the liquefied gas in an insulated container; transporting the liquefied natural gas on the vessel from the first location to a second location; heating the liquefied natural gas on the vessel so as to reconvert it back into a substantially gaseous phase; and off-loading the natural gas from the vessel at the second location. Preferably, the steps of cooling the natural gas and heating the liquefied natural gas are each accomplished by using a gas processing facility. More preferably, the same gas processing facility is used for both cooling (liquefying) the natural gas and heating the liquefied natural gas.

[0010] The method for transporting LNG may be accomplished on a variety of vessels. Examples include a marine vessel, a barge vessel, and an over-the-road trailer vessel.

[0011] In another aspect, a method is provided for transporting liquefied natural gas on a vessel. The method generally comprises the steps of providing a gas transfer system for the vessel; on-loading the natural gas onto the vessel through the gas transfer system, the natural gas being in essentially a gaseous phase; providing a gas processing facility on the vessel, the gas processing facility selectively cooling and heating the natural gas; flowing the natural gas through the gas processing facility so as to cool the natural gas to a lower temperature where the natural gas is in a substantially liquefied phase, and providing a containment structure on the vessel for containing the liquefied natural gas during transport.

[0012] In addition, a vessel for transporting liquefied natural gas is provided. In one embodiment, the vessel includes a gas transfer system for on-loading and off-loading natural gas to and from the vessel in its essentially gaseous phase; a gas processing facility for selectively (i) cooling the natural gas from a temperature where the natural gas is in a gaseous phase, to a lower temperature where the natural gas is in a substantially liquefied phase; and (ii) heating the natural gas from a temperature where the natural gas is in a substantially liquefied phase, to a temperature where the natural gas is converted back to its gaseous phase; a power generator for providing power to the gas processing facility; and a containment structure for containing the liquefied natural gas during transport.

[0013] The vessel again may be any type of transport vessel, including for example a marine vessel, a barge vessel, or an over-the-road trailer vessel. Where the vessel is a marine vessel, the gas transfer system may further comprise a buoyed line for placing the gas processing facility in fluid communication with a marine jumper line. Where the vessel is a land-based vessel such as a vessel on a trailer, the gas transfer system may further comprise a line for placing the gas processing facility in fluid communication with a land hose.

[0014] Where the containment structure is a marine vessel, the containment structure may be one or more Moss sphere tanks, it may be a membrane tank, or it may be a plurality of pressurized bottles in fluid communication. The plurality of bottles maintain the LNG under pressures greater than ambient.

[0015] In one aspect, the gas processing facility comprises at least one heat exchanger through which the natural gas thermally contacts a heat exchanger fluid; and at least one fluid movement device. The fluid movement device may be either a compressor or a pump.

[0016] In one arrangement, the gas processing facility cools the natural gas by providing a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid; a compressor wherein the heat exchanger fluid is compressed and temporarily warmed after flowing through the first heat exchanger; a second heat exchanger wherein the compressed heat exchanger fluid is cooled; and an expander wherein the compressed heat exchanger fluid is further cooled, and decompressed before returning through the first heat exchanger. Alternatively, the gas processing facility heats the natural gas by providing a first heat exchanger for warming the natural gas by thermal contact between the natural gas and a heat exchanger fluid; and a second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger. The heat exchanger fluid movement device may be a compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger. Alternatively, the fluid movement device is a pump disposed in line between the first and second heat exchangers for pressurizing the liquefied heat exchanger fluid.

[0017] Preferably, the power generator is configured to selectively provide power to propel the vessel when the natural gas is stored in the containment structure, and to provide power to the gas processing facility when the natural gas is being cooled or heated. Optionally, the vessel may further have an ancillary compressor for circulating and cooling the heat exchanger fluid while the vessel is transporting the LNG in order to recondense any natural gas that becomes vaporized during transport, or to generally keep the heat exchanger fluid and system equipment cool.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The following drawings are provided as an aid in understanding the various inventions described herein.

[0019] Figure 1A presents a plan view of the main deck of a fluid transportation vessel. The exemplary vessel is a marine vessel. Visible in this view are a bridge, a cargo storage area, and a gas processing facility. The cargo storage area represents one or more individual tanks within a liquefied gas containment structure.

[0020] Figure 1B presents an alternate marine vessel for transporting fluids in a temperature-controlled environment. The containment structure of the LNG transportation vessel of Figure 1B is a Moss sphere tank.

[0021] Figure 1C presents yet an additional alternate marine vessel for transporting fluids in a temperature-controlled environment. The containment structure of the LNG transportation vessel of Figure 1C is a membrane tank. The illustrative vessel is again a marine vessel.

[0022] Figure 2 is a side view of the vessel of Figure 1A. The profile of the vessel can be seen. Visible in this view is a side of the containment structure of Figure 1A.

[0023] Figure 3 presents a schematic view of the gas processing facility of Figure 1A, in one embodiment. Arrows depict the process of liquefaction for the light hydrocarbons.

[0024] Figure 4A presents another schematic view of the gas processing facility of Figure 1A. In this view, arrows depict the process of regasification for the light hydrocarbons.

[0025] Figure 4B presents an alternate arrangement for the regasification facility of Figure 4A. In this view, arrows again depict the process of regasification for the light hydrocarbons.

[0026] Figure 5A demonstrates an LNG transportation vessel as a barge vessel. The barge vessel is being towed by a tug boat.

[0027] Figure 5B demonstrates the LNG transportation vessel as a trailer vessel. The trailer vessel is being pulled by an over-the-road rig.

DETAILED DESCRIPTION

[0028] The following words and phrases are specifically defined for purposes of the descriptions and claims herein. To the extent that a term has not been defined, it should be given its broadest definition that persons in the pertinent art have given that term as reflected in printed publications, dictionaries and/or issued patents.

[0029] “Natural gas” means a light hydrocarbon gas or a mixture including two or more light hydrocarbon gases that includes greater than 25 molar percent methane on a hydrocarbon species basis. For example, natural gas may contain methane along with other hydrocarbon components such as, but not limited to, ethane, propane, butane, or isomers thereof. Natural gas may also include non-hydrocarbon contaminant species such as, for example, carbon dioxide, hydrogen sulfide, water, carbonyl sulfide, mercaptans and nitrogen.

[0030] “LNG” or "liquefied natural gas" means natural gas or a portion thereof that has been liquefied. The term collectively includes any light hydrocarbon or mixture of two or more light hydrocarbons in substantially liquid form that includes greater than 25 molar percent methane on a hydrocarbon species molar basis. LNG includes, for example, natural gas induced into a liquid form through cooling at about atmospheric pressure and by both cooling and application of increased pressure over ambient pressure such as “PLNG.”

[0031] “Vessel” means any fluid transportation structure. Non-limiting examples of a vessel include a marine vessel, a barge vessel, or a trailer vessel.

[0032] “Marine vessel” means a vessel configured to transport volumes of fluids such as LNG over an ocean or other large water body.

[0033] “Barge vessel” means a vessel configured to transport volumes of fluids such as LNG over a river or within a marine inlet or bay.

[0034] “Trailer vessel” means a vessel configured to transport volumes of fluids such as LNG on a trailer. The trailer is pulled by a truck, a rig, or other mechanized vehicle over-the-road.

[0035] The terms “on-loading” and “off-loading” refer to the movement of fluids onto and off of a vessel, respectively. The terms are not limited as to the manner in which fluid movement is accomplished.

[0036] "Gas transfer system" means a system for on-loading or off-loading of fluids in at least a partially gaseous phase. Non-limiting examples of features for a gas transfer system include compressors, valves, conduits and pumps.

[0037] "Ambient temperature" refers to the temperature prevailing at any particular location.

[0038] "Expander" means any device capable of reducing pressure in a fluid line, including but not limited to an expansion valve or turboexpander.

[0039] Some embodiments of the invention include apparatus and methods for liquefying natural gas. In some embodiments natural gas includes a light hydrocarbon gas or a mixture including two or more light hydrocarbon gases that includes greater than 25 molar percent methane. Alternatively, natural gas may include greater than 40 molar percent methane or greater than 70 molar percent methane on a hydrocarbon species basis.

[0040] Some embodiments of the invention include apparatus and methods for liquefying natural gas to form LNG or regasifying LNG to reform natural gas. In some embodiments LNG includes natural gas or a portion thereof that has been liquefied. LNG may include any light hydrocarbon or mixture of two or more light hydrocarbons in substantially liquid form that includes greater than 25 molar percent methane on a hydrocarbon species basis. Alternatively, LNG may include greater than 40 molar percent methane or greater than 70 molar percent methane on a hydrocarbon species basis.

[0041] The following provides a description of specific embodiments shown in the drawings:

[0042] **Figure 1A** presents a plan view of a fluid transportation vessel **100**. The illustrative fluid transportation vessel **100** is a marine vessel. The vessel **100** is specifically configured to carry liquefied natural gas, or "LNG," over an ocean or other large water body. In one aspect, the vessel **100** is nominally 300 meters in length. The vessel **100** includes a main deck **12**, visible in the plan view of **Figure 1A**.

[0043] **Figure 2** provides a side view of the vessel **100** of **Figure 1A**. A profile of the vessel **100** can be seen, defined by a hull **16**. The hull **16** is generally under the main deck **12**. The hull **16** provides for a "ship-shaped" vessel that is preferably self-propelled. However, it is understood that the scope of the present inventions is not limited to vessels that are ship-shaped or self-propelled.

[0044] The marine vessel **100** includes a bridge **20**. The bridge 20 is typically at either the fore or aft sections of the vessel. The bridge **20** is seen in both **FIGS. 1A** and **2** at the bow of the ship **100**. The bridge **20** is positioned on the deck **12**, and provides living quarters for the ship's officers and crew members. The bridge **20** also provides navigational and operational controls for the ship **100**. It is understood that the vessel will also have a navigation system that will include a steering or guidance mechanism, a rudder and instrumentation (all not shown).

[0045] The marine vessel **100** further includes a cargo storage area **30**, or "containment structure." The containment structure **30** is shown schematically in **Figures 1A** and **2**, and is intended to represent a single "insulated compartment." The illustrative containment structure **30** includes a plurality of containers **30A** configured to hold a cryogenic fluid such as LNG under pressure. The containment structure **30** is cut away in each of **Figures 1A** and **2** to expose a sampling of containers **30A**. It is understood that the containment structure **30** is not limited to a single "insulated compartment;" the containers 30A may be individually insulated.

[0046] Selected sets of bottles **30A** are in fluid communication with one another to form a "tank." The bottles **30A** have appropriate valving **32** for moving LNG into and out of the bottles **30A**. In one aspect, four-inch piping connections are provided for moving cryogenic fluids into and out of the containers **30A**, though it is understood that other dimensions may be employed. The containers **30A** may be at ambient pressure or slightly higher, and contain natural gas chilled to a temperature of approximately -160° F (-106.7° C) or less to provide liquefaction. Alternately the natural gas may be chilled to a temperature of approximately -190° F (-123.3° C) or less. Alternatively, the containers may be at ambient pressure or slightly higher, and contain natural gas chilled to a temperature of between approximately -200° F to -270° F (-128.9° C to -167.8° C). The containers **30A** may alternatively be stored at a higher pressure above approximately 150 psi, and at temperature of approximately -193° F (-125° C) or more. Alternatively, the containers may be stored at a pressure in the range of approximately 250 - 450 psi, and at temperature between about -175° F and -130° F (-115° C to -90° C). Those of ordinary skill in the art will understand that the liquefaction temperature of a hydrocarbon will depend upon its pressure and composition.

[0047] The bottles **30A** are preferably cylindrical in shape, and are typically fabricated from a steel material. Where the containers **30A** serve as a pressure vessel, they are preferably fabricated from a steel material having walls of appropriate thickness. One or more bottles **30A** in fluid communication together form a single "tank."

[0048] Various other LNG containment structures are known for marine vessels. Examples are provided in **Figures 1B** and **1C**. **Figure 1B** presents a containment structure for an LNG transportation vessel **100B** as a plurality of Moss sphere tanks **30B**. The exemplary vessel **10** is again a marine vessel. The Moss sphere tanks **30B** are semispherical or elongated in shape, and may have a diameter of up to 40 or more meters. Typically, three to five Moss sphere tanks will be placed on a single marine vessel. LNG is stored in the Moss sphere tanks at ambient pressure.

[0049] **Figure 1C** presents a containment structure **30C** for an LNG transportation vessel **100C** as a membrane tank. The exemplary vessel **100C** is again a marine vessel. A membrane tank is typically a square or rectangular structure having steel lining (not shown) for providing a fluid-tight compartment. The lining is structurally supported by a frame that is insulated. The framing forms an insulated cargo hold. Each membrane tank **30C** may be 40 meters x 40 meters in footprint, for example.

[0050] Each illustrative marine vessel **100**, **100B**, **100C** also includes a gas processing facility. The gas processing facility is shown schematically at **40**, and is intended to represent any facility that can selectively cool or heat fluids such as natural gas. Preferably, the gas processing facility **40** will first cool the natural gas from an essentially ambient temperature where the natural gas is in a gaseous phase, to a lower temperature where the natural gas is in a substantially liquefied phase. This occurs in connection with a procedure for on-loading of natural gas onto the vessel, e.g., vessel **100**. In addition, the gas processing facility **40** will preferably also heat the natural gas from a temperature where the natural gas is in a substantially liquefied phase, to an essentially ambient temperature where the natural gas is converted back to its gaseous phase. This occurs in connection with a procedure for off-loading of natural gas from the vessel **100**, **100B** or **100C**.

[0051] **Figure 3** presents a more detailed view of the gas processing facility **40**, in one embodiment. In this view, the gas processing facility **40** is set up for the cooling of fluids, or "liquefaction." Arrows depict the flow of fluids for the process of cooling the natural gas. More specifically, arrow **G** shows the movement of gas through the gas processing facility **40** located on the vessel **100**, while arrow **C** demonstrates the pumping of a coolant to cryogenically refrigerate the gas.

[0052] **Figures 4A** and **4B** present other schematic views of the gas processing facility **40** of **Figures 1**, **1B** and **1C**. In these views, the gas processing facility **40** is set up for the heating of fluids, or "regasification." Arrows depict the flow of fluids for a process of regasification of light hydrocarbons. Arrow **G** shows the movement of gas through the gas processing facility 40 located on the vessel **100**, while arrow **H** demonstrates the pumping of a heat exchanger fluid to warm the gas. **Figures 4A** and **4B** provide alternate gas processing systems for regasification.

[0053] The gas processing facility of **Figure 3** is an intermediate facility between the reception of natural gas from the field, and the storage of LNG in the containment structure **30** for transport. Similarly, the gas processing facilities of **Figures 4A** and **4B** each provide an intermediate facility between the offloading of natural gas from the containment structure **30** to an import terminal. To accommodate the movement of hydrocarbons onto and off of the vessel, a gas transfer system is provided. The gas transfer system is represented schematically by line **50** in **Figures 3, 4A** and **4B**. In practice, the gas transfer system **50** will comprise a line that provides fluid communication between the gas processing facility **40** and a line (not shown) external to the vessel **100**. For example, where the fluid transportation vessel is a marine vessel (such as the vessel **100** of **Figure 1A**) or a barge vessel (seen in **Figure 5A**), the line will connect to a marine jumper. The marine jumper will preferably be buoyed with either integral or attached buoys. Where the fluid transportation vessel is a trailer vessel (seen in **Figure 5B**), the line will connect to a land hose.

[0054] **Figure 5A** demonstrates an LNG transportation vessel as a barge vessel **500A**. The barge vessel **500A** is being towed by a tug boat **510A**. The vessel **500A** includes a gas transfer system **502A**, a gas processing facility **504A**, and a fluid containment structure **506A**. The gas transfer system **502A** will typically define a hose configured to connect to a marine jumper line (not shown). The barge vessel **500A** is preferably pulled by a tug **510A**. The vessel **500A** may be integral to the tug **510A**, but is preferably a separate floating apparatus that can be hitched and unhitched. **Figure 5A** shows a hitching line **501A**. The tug **510A**, of course, includes an engine and propeller (not shown). The engine is typically diesel or gasoline powered, and operates to drive the propeller in the water **W**. The barge **510A** may also include a battery (not shown) for powering electrical equipment such as lights. Preferably, the gas processing facility **504A** is powered by either the engine or the battery of the tug **510A**.

[0055] **Figure 5B** demonstrates the LNG transportation vessel as a trailer vessel **500B**. The vessel **500B** includes a gas transfer system **502B**, a gas processing facility **504B**, and a fluid containment structure **506B**. The gas transfer system **502B** will typically define a valve and, perhaps, a hose configured to connect to a supply line (not shown). The trailer vessel **500B** is being pulled by an over-the-road rig **510B**. The trailer vessel **500B** is disposed on a multi-axle trailer **520B** for land-based transport.

[0056] The trailer vessel **500B** is propelled by being pulled behind the rig **510B**, or "truck." The vessel **500B** may be integral to the truck **510B**, but is preferably on a separate trailer **520B** that can be hitched and unhitched. The truck **510B**, of course, includes an engine and shaft (not shown). The engine is typically diesel or gasoline powered, and operates to drive a shaft that transmits rotational motion to a transmission. The truck **510B** also includes a battery (not shown) for powering electrical equipment. Preferably, the gas processing facility **504B** is powered by the engine of the truck **510B**, reducing equipment requirements. The engine may drive an electrical generator for creating electrical power for the gas processing facility **504B**.

[0057] In practice, a volume of fluid such as natural gas is brought from the field to a gathering center. The gathering center may be on land, near shore, or offshore. The natural gas is stored at an essentially ambient temperature. In the case of a marine vessel such as vessels **100**, **100B**, and **100C**, the vessel is offshore and receives natural gas pumped from the gathering facility (not shown) onto the vessel through the gas transfer system **50**. The natural gas is not stored directly in the containment structure **30** of the vessel **100**; rather, it is pumped through the gas processing facility **40** for liquefaction in accordance with **Figure 3**.

[0058] Referring again to **Figure 3**, a gas process facility **40** is again shown. The gas process facility **40** is used for the purpose of condensing a fluid, such as natural gas. Arrow **G** depicts the flow of gas during liquefaction, as described above.

[0059] The gas process facility **40** includes a first heat exchanger **42**. The first heat exchanger **42** acts to cool the natural gas by thermal contact between the natural gas and a heat exchanger fluid. The first heat exchanger **42** provides suitable adjacent fluid channels (not shown) for directing hydrocarbons and a heat exchanger fluid, respectively, so that the two channels are in thermal contact with one another. In this sequence, the heat exchanger fluid acts as a refrigerant flowing through lines "**C**."

[0060] The gas process facility **40** also includes a compressor **44**. The compressor **44** receives the heat exchanger fluid, or refrigerant, as it cycles from the first heat exchanger **42**, and compresses the refrigerant. The process of compressing the refrigerant also acts to temporarily warm the refrigerant as it moves through the compressor **44**. In one arrangement, the refrigerant is approximately 35° F (1.7° C) upon exiting the first heat exchanger **42**, and is 300° F (148.9° C) upon exiting the compressor **44**.

[0061] The gas process facility **40** also includes a second heat exchanger **46**. The compressed refrigerant is cooled in the second heat exchanger **46**. The second heat exchanger **46** provides adjacent fluid channels (not shown) through which the refrigerant and a coolant fluid flow. The coolant fluid acts to chill the refrigerant through thermal contact. In the context of a marine vessel such as the vessel **100** of **Figure 1A**, the coolant may be the abundantly available sea water or air. In the context of a barge vessel (such as vessel **500A** seen in **Figure 5A**), the coolant may be fresh water or air. In the context of a trailer vessel (such as vessel **500B** seen in **Figure 5B**), the coolant is most typically air.

[0062] The gas process facility **40** also includes an expander **48**. The expander **48** acts to expand the compressed refrigerant. The expander **48** may be an expansion valve, a turboexpander, or any other device for expanding fluid. The process of expanding the compressed refrigerant acts not only to decompress the refrigerant, but also to further chill it. In one arrangement, the refrigerant is at a temperature of approximately 65° F upon exiting the second heat exchanger **46**, but is -170° F upon exiting the expander **48**. The significantly chilled refrigerant is then cycled back through the first heat exchanger **42** where it again acts to refrigerate the natural gas. Ultimately, the natural gas is condensed into a substantially liquid phase. Thus, the gas process facility **40** of **Figure 3** acts as a liquefaction facility.

[0063] Referring now to **Figure 4A**, the gas process facility **40** is again shown. However, in this arrangement the gas process facility **40** is used for the purpose of heating a fluid, such as natural gas. Arrow **G** depicts the process of regasification for the light hydrocarbons as described above. The arrows are generally directed in opposite directions from the arrows of **Figure 3**.

[0064] The gas process facility **40** again includes a first heat exchanger **42**. In this instance, however, the first heat exchanger **42** acts to warm the natural gas by thermal contact between the natural gas and the heat exchanger fluid. In this sequence, the heat exchanger fluid acts as a heating fluid flowing through lines "**H**." The first heat exchanger **42** provides suitable fluid channels (not shown) for directing natural gas in its liquid phase, and a heat exchanger fluid, so that the two channels are in thermal contact with one another. In this sequence, the heat exchanger fluid acts as a heating fluid.

[0065] After cycling through the first heat exchanger **42**, the heat exchanger fluid moves to the second heat exchanger **46**. The heat exchanger fluid bypasses the expander **48**. It can be seen in **Figure 4A** that the arrows do not indicate the flow of fluids through the expander **48**.

[0066] In the regasification process shown in **Figure 4A**, the second heat exchanger **46** now acts to warm the heat exchanger fluid. In this respect, the process of cycling the heat exchanger fluid through the first heat exchanger **42** has produced a cooling of the heat exchanger fluid. The heat exchanger fluid is now very cold upon exiting the exchanger **42**. Thus, the heat exchanger fluid is warmed in the second heat exchanger **46**. The second heat exchanger **46** provides adjacent fluid channels (not shown) through which the heat exchanger fluid and a warming fluid flow. The warming fluid acts to warm the heat exchanger fluid through thermal contact. In the context of a marine vessel such as the vessel **100** of **Figure 1A**, the warming fluid may be sea water. Alternatively, the warming fluid is fresh water maintained on the vessel at ambient temperature by a combustion or other warming process not shown. Alternatively, the second heat exchanger **46** may be a tank which receives and heats fresh water directly, such as through combustion. In the context of a barge vessel (such as vessel **500A** seen in **Figure 5A**), or in the context of a trailer vessel (such as vessel **500B** seen in **Figure 5B**), the warming fluid may be either air or water.

[0067] From the second heat exchanger **46**, the heat exchanger fluid moves through the compressor **44**. The compressor **44** compresses the heating fluid, and delivers it to the first heat exchanger **42** in a further warmed state. As noted above, the process of compressing the fluid also acts to warm the fluid as it moves through the compressor **44**. In one arrangement, the heat exchanger fluid is approximately 55° F upon exiting the second heat exchanger **46**, but is approximately 300° F upon exiting the compressor **44**. The significantly warmed heat exchanger fluid is then cycled back through the first heat exchanger **42** where it again acts to warm the natural gas. Ultimately, the natural gas is vaporized into a substantially gaseous phase for offloading. Thus, the gas process facility **40** of **Figure 4** acts as a regasification facility.

[0068] Specific temperatures have been provided in connection with certain components of the gas process facility **40**. However, it is understood that the scope of the present inventions is not limited to any particular temperatures, so long as the temperature of the heat exchanger fluid as it enters the first heat exchanger is sufficiently low to liquefy the natural gas (or other fluid) in the liquefaction process, and sufficiently high to vaporize the natural gas (or other fluid) in the gasification process. It is noted, however, that the gas processing facility **40** operates more efficiently where water is available in the second heat exchanger **46** that is warm, i.e., five degrees Fahrenheit or more above freezing. In an environment that lacks a suitable ambient temperature warming medium, integration of the liquefaction and vaporization heat exchangers is difficult. In this scenario, the gas processing facility **40** would preferably employ a vaporization means heated through combustion of a portion of the natural gas product. The fired vaporization facilities would benefit from the integration of utilities like water supply and fuel gas systems with the liquefaction process.

[0069] As noted above, **Figure 4B** presents an alternate arrangement for the gas processing facility of **Figure 4A**. In this view, arrows again depict the process of regasification for the light hydrocarbons. The system is now shown at **40'**. In the arrangement of **Figure 4B**, the heat exchanger fluid is again cycled through the first heat exchanger **42** in order to warm ("regasify") the LNG. The regasified hydrocarbons exit the gas processing facility **40'** through line **50**. Ultimately, the natural gas is vaporized into a substantially gaseous phase for offloading. Thus, the gas process facility **40'** of **Figure 4B** also acts as a regasification facility.

[0070] The process of cycling the heat exchanger fluid through the first heat exchanger **42** has produced a cooling of the heat exchanger fluid, substantially liquefying it. To reheat the heat exchanger fluid, the heat exchanger fluid is first moved through a pump **49**. The pump **49** serves as an alternate fluid movement device vis-à-vis the compressor **44**. It can again be seen that the heat exchanger fluid again bypasses the expander **48**. The pump **49** is provided after the first **42** heat exchanger in order to energize and warm the heat exchanger fluid. The pump **49** also transfers the liquid heat exchanger fluid, e.g., sea water, towards the second heat exchanger **46**.

[0071] As with facility **40** of **FIG. 4A**, the second heat exchanger **46** acts to further warm the heat exchanger fluid. The second heat exchanger **46** provides adjacent fluid channels (not shown) through which the heat exchanger fluid and a warming fluid flow. The warming fluid acts to warm the heat exchanger fluid through thermal contact. In the context of a marine vessel such as the vessel **100** of **Figure 1A**, the warming fluid may again be seawater or fresh water that has been warmed through a direct combustion process. In the context of a barge vessel (such as vessel **500A** seen in **Figure 5A**), or in the context of a trailer vessel (such as vessel **500B** seen in **Figure 5B**), the warming fluid may be either air or water.

[0072] From the second heat exchanger **46**, the heat exchanger fluid returns directly to the first heat exchanger **42** where it again acts to warm the natural gas. It can be seen that the compressor **44** has been bypassed in **FIG 4B**. The compressor **44** is optionally not used when a pump **49** is employed. The process of pumping the fluid through pump **44** provides the pressure needed to cycle the heat exchanger fluid through the system **40'**.

[0073] It can be seen from the arrangements of **Figures 3, 4A** and **4B** that substantially the same physical equipment and heat exchange fluids for both the liquefaction operation and the regasification operation may be employed. By modifying the refrigeration system operation as shown in **Figure 3**, it is possible to use the same heat exchangers and heat transfer fluids for vaporization of the gas via systems **40, 40'** of **Figures 4A** and **4B**. This results in equipment savings on the vessel. Where the vessel is a marine vessel, if the water temperature at the import location is warm, i.e., approximately five degrees Fahrenheit or more above freezing, or if ambient heating medium of any type is available from a source near the import location, it is possible to install the liquefaction and regasification equipment **40** on the vessel, e.g., vessel **100**, in a more cost-effective manner.

[0074] In the gas process facility **40** shown in **Figures 3** and **4A**, the heat exchanger fluid is moved through the system **40** by compression. Compression may be accomplished by using the compressor **44** as the fluid movement device. In the gas process facility **40'** shown in **Figure 4B**, the heat exchanger fluid is moved through the system by pumping. Pumping may be accomplished in connection with pump **49** as the fluid movement device. Power is provided to either the compressor **44** or the pump **49** (and other mechanical parts of the gas process facilities **40** and **40'**) by a power generator. A power generator is shown schematically at **41** in **Figures 3, 4A** and **4B**.

[0075] The power generator **41** is preferably an engine. The engine may be gas-powered, with the gas being provided from either naturally-occurring boil-off of natural gas from the LNG stored in the containment structure **30**, or from an independent fuel supply (not shown). Alternatively, the engine may be diesel powered. In this instance, a diesel supply (not shown) would be provided on the ship. In the arrangement of **Figures 3** and **4A**, it can be seen that the power generator **41** drives a motor **43m**. Arrow "**e**" indicates an electric line providing power to the motor **43m**. The motor **43m** in turn, provides mechanical power to run the vessel's propulsion system, shown schematically at **43**. Arrow "**s**" is indicative of a mechanical shaft going to the propulsion system **43**.

[0076] It is preferred that the ship's propulsion system **43** be integrated with the power system for powering the gas processing facility **40** or **40'**. Thus, when the ship is not in transit, the power generator may be used to drive separate motors **44m** and **49m** (**49m** not shown). The motors **44m** and **49m**, in turn, provide mechanical power to either the compressor **44** (in the arrangement of **FIGS. 3** and **4A** and **B**) or the pump **49** (in the arrangement of **FIG. 4B**), respectively.

[0077] In order for the gas processing facility **40** to share a power generator **41** with the ship's propulsion system **43**, the power requirements should be generally comparable. With propulsion and gas processing power requirements being comparable, a single, integrated power generation plant and electric or hydrocarbon motor drive may be installed to provide the power needed for both operations. In this arrangement, the gas compression **44** and ship propulsion **43** are preferably not used at the same time so as to minimize the overall power generation needs for the ship. In one embodiment, the power generator **41** is a power generation plant that feeds a single variable frequency drive (VFD). The VFD is used to alternately control the ship's propulsion **43** and to power refrigeration motors **44m** and **49m**. It is understood that the present inventions are not limited to the way in which power is shared or transferred between the propulsion system **43** and the gas processing facility **40**. Other power arrangements may be used, such as the modification of motor windings, or the use of a gear box system that employs mechanical shafts.

[0078] In another embodiment, the ship's power generator **41** may be used for initial liquefaction of the natural gas, as described above in connection with **Figure 3**. However, a smaller separate compressor **45** may optionally be provided to provide power to the gas processing facility **40** during the transport stage. In this respect, natural gas that vaporizes during transport due to an increase in temperature within the containment structure **30** would be captured in the first heat exchanger **42**. The compressor **45** would be activated by an ancillary smaller motor **45m** to temporarily operate the condensing process in order to re-cool the natural gas without interrupting the ship's propulsion power **43**. The ancillary motor **45m** draws a smaller amount of power from the power generator **41**. An electric line "**e**" is shown between the power generator **41** and the smaller generator **45m**. Further, a mechanical shaft "**s**" is shown going into the compressor **45**. Finally, a bypass loop "**b**" is provided to circulate heat exchanger fluid through the smaller compressor **45** rather than the primary compressor **44**.

[0079] The use of a smaller, ancillary compressor **45** has many advantages. First, this arrangement allows reliquefaction of hydrocarbons during transit. This, in turn, accommodates a much higher boil-off gas rate from the containment structure 30.

This also reduces the insulation requirements for the cryogenic storage. Further, the use of a smaller, ancillary compressor **45** keeps the heat exchanger fluid and system equipment cold during transit, allowing the vessel to be prepared more quickly to receive natural gas more quickly upon docking at an export terminal for liquefaction.

[0080] In yet another embodiment, two independent power generation systems are provided. One system operates to power the ship's propulsion system **43**, while the other system operates the gas processing facility **40** along with the miscellaneous process equipment associated with liquefaction and vaporization. Such process equipment may include firefighting equipment, gas processing controls, fluid pumps, and drain valves.

[0081] A method for transporting liquefied natural gas on a vessel is also provided. The vessel may be a marine vessel such as vessel **100** of **Figure 1A**, a barge vessel such as vessel **500A** of **Figure 5A**, or a trailer vessel such as vessel **500B** of **Figure 5B**. A gas transfer system, such as system **50** of **Figure 3**, is provided on the vessel. Further, a containment structure is provided on the vessel for containing the liquefied natural gas. The containment structure may be, by example, one of the structures shown in **Figures 1A**, **1B**, **1C**, **5A** or **5B**. In addition, a gas processing facility is provided on the vessel. The gas processing facility may be such as facility **40** of **Figures 3** and **4A** or facility **40'** of **Figure 4B**, and may selectively cool and heat the natural gas.

[0082] As part of the method, the natural gas is on-loaded onto the outfitted vessel at an export terminal. The natural gas is on-loaded through a gas transfer system at essentially ambient temperature and in a gaseous phase. The transport vessel may optionally be integrated with the natural gas production system. The transport vehicle would receive raw fluids from the well, and provide the facilities to process the fluids into gas, ambient hydrocarbon liquid, and produced water. The production facilities would receive utility and operating benefits through integration with the liquefaction and vaporization facilities. The transport vehicle would also have the storage capacity to transport and deliver any ambient liquid hydrocarbon products created in the production system.

[0083] The natural gas flows through the first heat exchanger **42** of the gas processing facility **40** so as to cool the natural gas from its ambient temperature. The natural gas is brought to a lower temperature where it is in a substantially liquefied phase. Thus, the natural gas is "liquefied." The liquefied natural gas is then stored in the containment structure **30**, and is ready for transport on the vessel to an import terminal.

[0084] During the on-loading process, the ship's propulsion system **43** is preferably shut down. The ship's power generator **41** diverts power to the liquefaction process facilities **40**. Once the ship cargo is full, the gas processing system **40** is shut down, and the ship propulsion system **43** is started. The vessel **100** then transports the cryogenic cargo to the import location.

[0085] Upon arrival at an import terminal, the gas is off-loaded. In order to off-load the gas, the gas is pumped through the gas processing facility **40** so as to heat the natural gas from a temperature where the natural gas is in its substantially liquefied phase, to a temperature where the natural gas is converted back to its gaseous phase. The natural gas is then off-loaded through the gas transfer system **50**. While on station at the import location, the ship's propulsion system **43** is again shut down, and the cryogenic cargo is regasified as it is unloaded from the vessel **100**. This allows for optionally an integrated power generator for both the ship's propulsion system **43** and the gas processing facility **40**.

[0086] In one embodiment of the method invention, partially regasified fluids are pumped into a gas storage device on land. An example is a salt dome cavern facility. The gas storage device is integrated with the vessel to store pressurized gas off-loaded at the gas receiving terminal. The facility can be sized to supply continuous gas at the average delivery rate between deliveries. Pressurized gas storage is ideal because the cryogenic fluid can be inexpensively pumped to storage pressures before vaporization rather than having expensive gas compression with the storage facility.

[0087] It can thus be seen that an LNG transportation vessel is provided, and that a method for transporting LNG or other hydrocarbon fluids is also provided. The method of transporting, in one aspect, combines liquefaction, transportation and regasification processes. In addition, it can be seen that an integrated system is provided for transporting natural gas.

[0088] Conventional gas transportation means require large transfer rates over a period of 25-30 years to be economically attractive. As a result, many resources containing under approximately 5 TSCF (trillion standard cubic feet) of gas currently go undeveloped. The disclosed technology may allow an investor to monetize these smaller hydrocarbon reserves. The three functions of liquefaction, transport and regasification may be integrated into a single re-deployable unit for cost-effective transport of natural gas to consumer markets from remote locations. Stated another way, the integration of liquefaction, vaporization and transport means enables recovery of otherwise stranded hydrocarbon resources, and also decreases the overall manpower required for operations and maintenance, thus reducing operating expenses and crew requirements. The vessel allows monetization of small gas resources, and enables development of a series of small resources as it is re-deployable.

Claims:

We claim:

1. A method for transporting liquefied natural gas, comprising:

on-loading natural gas in a substantially gaseous phase onto a vessel at a first location;

cooling the natural gas on the vessel so as to convert it substantially into liquefied natural gas;

storing the liquefied gas in an insulated container;

transporting the liquefied natural gas on the vessel from the first location to a second location;

heating the liquefied natural gas on the vessel so as to reconvert it back into a substantially gaseous phase; and

off-loading the natural gas from the vessel at the second location.

2. The method of claim 1, wherein the steps of cooling the natural gas and heating the liquefied natural gas are each accomplished by using a gas processing facility.

3. The method of claim 2, wherein the same gas processing facility is used for both cooling the natural gas and heating the liquefied natural gas.

4. The method of claim 1, wherein the vessel is a marine vessel.

5. The method of claim 1, wherein the vessel is a barge vessel.

6. The method of claim 1, wherein the vessel is an over-the-road trailer vessel.

7. The method of claim 1, wherein the step of cooling the natural gas is accomplished by using a gas processing facility which comprises:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a compressor wherein the heat exchanger fluid is compressed and temporarily warmed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed heat exchanger fluid is cooled; and

an expander wherein the compressed heat exchanger fluid is further cooled, and decompressed before returning through the first heat exchanger.

8. The method of claim 1, wherein the step of heating the natural gas is accomplished by using a gas processing facility which comprises:

a first heat exchanger for warming the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

a heat exchanger fluid movement device.

9. The method of claim 8, wherein the heat exchanger fluid movement device comprises:

a compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger.

10. The method of claim 8, wherein the fluid movement device comprises:

a pump disposed in line between the first and second heat exchangers for pressurizing the liquefied heat exchanger fluid.

11. The method of claim 8, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and sea water at ambient ocean temperature.

12. The method of claim 8, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and air.

13. The method of claim 8, wherein the heat exchanger fluid is heated by thermal contact with an intermediate fluid that itself is heated by a combustion source outside of the second heat exchanger.

14. The method of claim 8, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and a combustion source.

15. The method of claim 7, wherein the heat exchanger fluid comprises a light hydrocarbon.

16. The method of claim 8, wherein the heat exchanger fluid comprises a light hydrocarbon.

17. The method of claim 1, wherein the steps of cooling the natural gas and heating the liquefied natural gas are each accomplished by using a single gas processing facility that:

(a) cools the natural gas by providing:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid, the heat exchanger fluid acting as a refrigerant;

a compressor wherein the refrigerant is compressed and temporarily warmed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed refrigerant is cooled; and

an expander wherein the compressed refrigerant is further cooled, and decompressed before returning through the first heat exchanger; and

(b) heats the natural gas by providing:

the first heat exchanger for warming the natural gas by thermal contact between the natural gas and the heat exchanger fluid;

the second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

a fluid movement device.

18. The method of claim 17, wherein the fluid movement device comprises:
the compressor, wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger.

19. The method of claim 17, wherein the fluid movement device comprises:
a pump disposed in line between the first and second heat exchangers for pressurizing the liquefied heat exchanger fluid.

20. The method of claim 17, wherein the heat exchanger fluid that cools the natural gas and the heat exchanger fluid that heats the natural gas are at least partially different.

21. A method for transporting liquefied natural gas on a vessel, comprising:

providing a gas transfer system for the vessel;

providing a gas processing facility on the vessel, the gas processing facility selectively cooling and heating the natural gas;

on-loading the natural gas onto the vessel through the gas transfer system, the natural gas being in essentially a gaseous phase; and

flowing the natural gas through the gas processing facility so as to cool the natural gas to a lower temperature where the natural gas is in a substantially liquefied phase; and

providing a containment structure on the vessel for containing the liquefied natural gas during transport.

22. The method of claim 21, further comprising the step of:

pumping the natural gas through the gas processing facility so as to heat the natural gas from a temperature where the natural gas is in its substantially liquefied phase, to a temperature where the natural gas is at least partially converted back to its gaseous phase; and

off-loading the natural gas from the vessel through the gas transfer system.

23. The method of claim 21, wherein the vessel is a marine vessel.

24. The method of claim 21, wherein the vessel is a barge vessel.

25. The method of claim 21, wherein the vessel is an over-the-road trailer vessel.

26. The method of claim 21, wherein the gas transfer system comprises:

a connection for receiving a buoyed line, thereby placing the gas processing facility in fluid communication with a marine jumper line.

27. The method of claim 21, wherein the gas transfer system comprises:

a connection for receiving a line for placing the gas processing facility in fluid communication with a hose.

28. The method of claim 21, wherein the containment structure is a plurality of pressure vessels for maintaining the liquefied natural gas under pressure.

29. The method of claim 21, wherein:

the containment structure is one or more Moss sphere tanks.

30. The method of claim 21, wherein the containment structure is a membrane tank.

31. The method of claim 21, wherein the gas processing facility comprises:

at least one heat exchanger through which the natural gas thermally contacts a heat exchanger fluid; and

at least one compressor for compressing the heat exchanger fluid.

32. The method of claim 21, wherein the gas processing facility cools the natural gas by providing:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a compressor wherein the heat exchanger fluid is compressed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed heat exchanger fluid is cooled; and

an expander wherein the compressed heat exchanger fluid is decompressed, and further cooled before returning through the first heat exchanger.

33. The method of claim 21, wherein the gas processing facility heats the natural gas by providing:

a first heat exchanger for warming the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

a fluid movement device.

34. The method of claim 33, wherein the fluid movement device comprises:

a compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger.

35. The method of claim 33, wherein the fluid movement device comprises:

a pump disposed in line between the first and second heat exchangers for pressurizing the liquefied heat exchanger fluid.

36. The method of claim 33, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and sea water at ambient ocean temperature.

37. The method of claim 33, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and air.

38. The method of claim 33, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and a combustion source.

39. The method of claim 33, wherein the heat exchanger fluid is heated by thermal contact with an intermediate fluid that itself is heated by a combustion source outside of the second heat exchanger.

40. The method of claim 21, wherein the gas processing facility:

(a) cools the natural gas by providing:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid, the heat exchanger fluid acting as a refrigerant;

a compressor wherein the refrigerant is compressed and temporarily warmed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed refrigerant is cooled; and

an expander wherein the compressed refrigerant is further decompressed and cooled before returning through the first heat exchanger; and

(b) heats the natural gas by providing:

the first heat exchanger for warming the natural gas by thermal contact between the natural gas and the heat exchanger fluid;

the second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

the compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger.

41. The method of claim 40, wherein the heat exchanger fluid that cools the natural gas and the heat exchanger fluid that heats the natural gas are at least partially different.

42. A vessel for transporting liquefied natural gas, comprising:

a gas transfer system for on-loading and off-loading natural gas to and from the vessel in its essentially gaseous phase;

a gas processing facility for selectively

(i) cooling the natural gas from a temperature where the natural gas is in a gaseous phase, to a lower temperature where the natural gas is in a substantially liquefied phase; and

(ii) heating the natural gas from a temperature where the natural gas is in a substantially liquefied phase, to a temperature where the natural gas is converted back to its gaseous phase;

a power generator for providing power to the gas processing facility; and

a containment structure for containing the liquefied natural gas during transport.

43. The vessel of claim 42, wherein the vessel is a marine vessel.

44. The vessel of claim 42, wherein the vessel is a barge vessel.

45. The vessel of claim 42, wherein the vessel is an over-the-road trailer vessel.

46. The vessel of claim 42, wherein the gas transfer system comprises:

a buoyed line for placing the gas processing facility in fluid communication with a marine jumper line.

47. The vessel of claim 42, wherein the gas transfer system comprises:

a line for placing the gas processing facility in fluid communication with a hose.

48. The vessel of claim 42, wherein the containment structure is a plurality of pressure vessels for maintaining the liquefied natural gas under pressure.

49. The vessel of claim 42, wherein:

the containment structure is one or more Moss sphere tanks.

50. The vessel of claim 42, wherein the containment structure is a membrane tank.

51. The vessel of claim 42, wherein the gas processing facility comprises:

at least one heat exchanger through which the natural gas thermally contacts a heat exchanger fluid; and

a fluid movement device for moving the heat exchanger fluid.

52. The vessel of claim 42, wherein the gas processing facility cools the natural gas by providing:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a compressor wherein the heat exchanger fluid is compressed and temporarily warmed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed heat exchanger fluid is cooled; and

an expander wherein the compressed heat exchanger fluid is decompressed and further cooled before returning through the first heat exchanger.

53. The vessel of claim 42, wherein the gas processing facility heats the natural gas by providing:

a first heat exchanger for warming the natural gas by thermal contact between the natural gas and a heat exchanger fluid;

a second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

a fluid movement device.

54. The vessel of claim 53, wherein the fluid movement device comprises:

a compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger

55. The vessel of claim 53, wherein the fluid movement device comprises:

a pump disposed in line between the first and second heat exchangers for pressurizing the liquefied heat exchanger fluid.

56. The vessel of claim 53, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and sea water at ambient ocean temperature.

57. The vessel of claim 53, wherein the second heat exchanger heats the heat exchanger fluid by providing thermal contact between the heat exchanger fluid and a combustion source.

58. The method of claim 53, wherein the heat exchanger fluid is heated by thermal contact with an intermediate fluid that itself is heated by a combustion source outside of the second heat exchanger.

59. The vessel of claim 42, wherein the gas processing facility:

(a) cools the natural gas by providing:

a first heat exchanger for cooling the natural gas by thermal contact between the natural gas and a heat exchanger fluid, the heat exchanger fluid acting as a refrigerant;

a compressor wherein the refrigerant is compressed and temporarily warmed after flowing through the first heat exchanger;

a second heat exchanger wherein the compressed refrigerant is cooled; and

an expander wherein the compressed refrigerant is decompressed and further cooled before returning through the first heat exchanger; and

(b) heats the natural gas by providing:

the first heat exchanger for warming the natural gas by thermal contact between the natural gas and the heat exchanger fluid;

the second heat exchanger wherein the heat exchanger fluid is warmed after flowing through the first heat exchanger; and

the compressor wherein the heat exchanger fluid is compressed and further warmed after flowing through the second heat exchanger and before returning through the first heat exchanger.

60. The vessel of claim 42, wherein the power generator selectively:

provides power to propel the vessel when the natural gas is stored in the containment structure; and

provides power to the gas processing facility when the natural gas is being cooled or heated.

61. The vessel of claim 60, further comprising:

an ancillary compressor for circulating and cooling the heat exchanger fluid while the vessel is transporting the LNG in order to recondense any natural gas that becomes vaporized during transport or maintain cold temperatures in the gas processing facility.

62. The method of claim 59, wherein the heat exchanger fluid that cools the natural gas and the heat exchanger fluid that heats the natural gas are at least partially different.

63. A method for transporting liquefied natural gas on a marine vessel, comprising:

providing a gas transfer system for the vessel, the gas transfer system receiving substantially raw fluids from an offshore natural gas production system;

providing a fluid processing system for separating produced gas from any other produced fluids;

on-loading the fluids produced from the natural gas production system;

providing a gas processing facility on the vessel for converting the produced gas into liquefied natural gas;

flowing the natural gas through the gas processing facility so as to cool the natural gas from its ambient temperature, to a lower temperature where the natural gas is in a substantially liquefied phase;

providing a containment structure on the vessel for containing the liquefied natural gas during transport; and

heating the liquefied natural gas on the vessel so as to reconvert it back into a substantially gaseous phase.

64. The method of claim 63, further comprising the step of:

providing a separate containment structure on the vessel for containing any produced liquid hydrocarbons during transport.

65. The method of claim 63, wherein the gas is offloaded at an export location into a gas storage device.

66. The method of claim 65, wherein the gas storage device is an underground salt dome gas storage cavern.

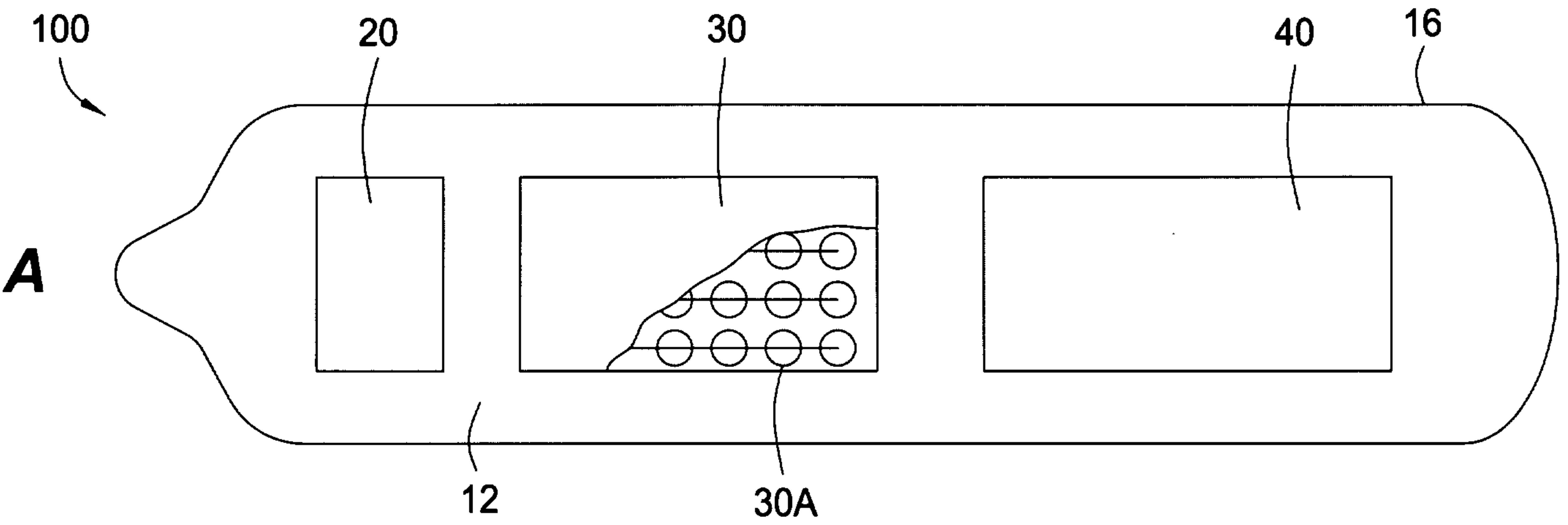


FIG. 1A

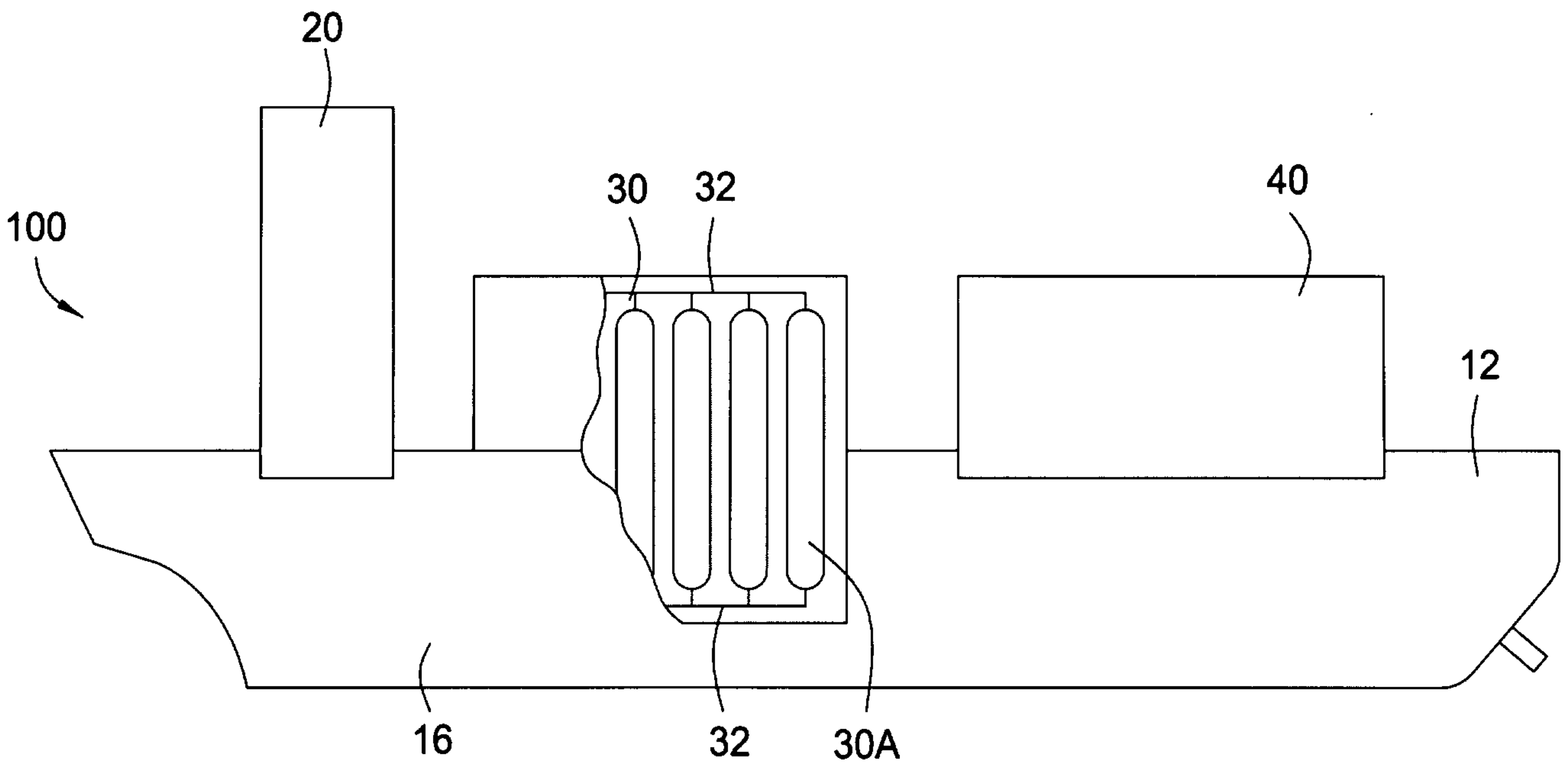


FIG. 2

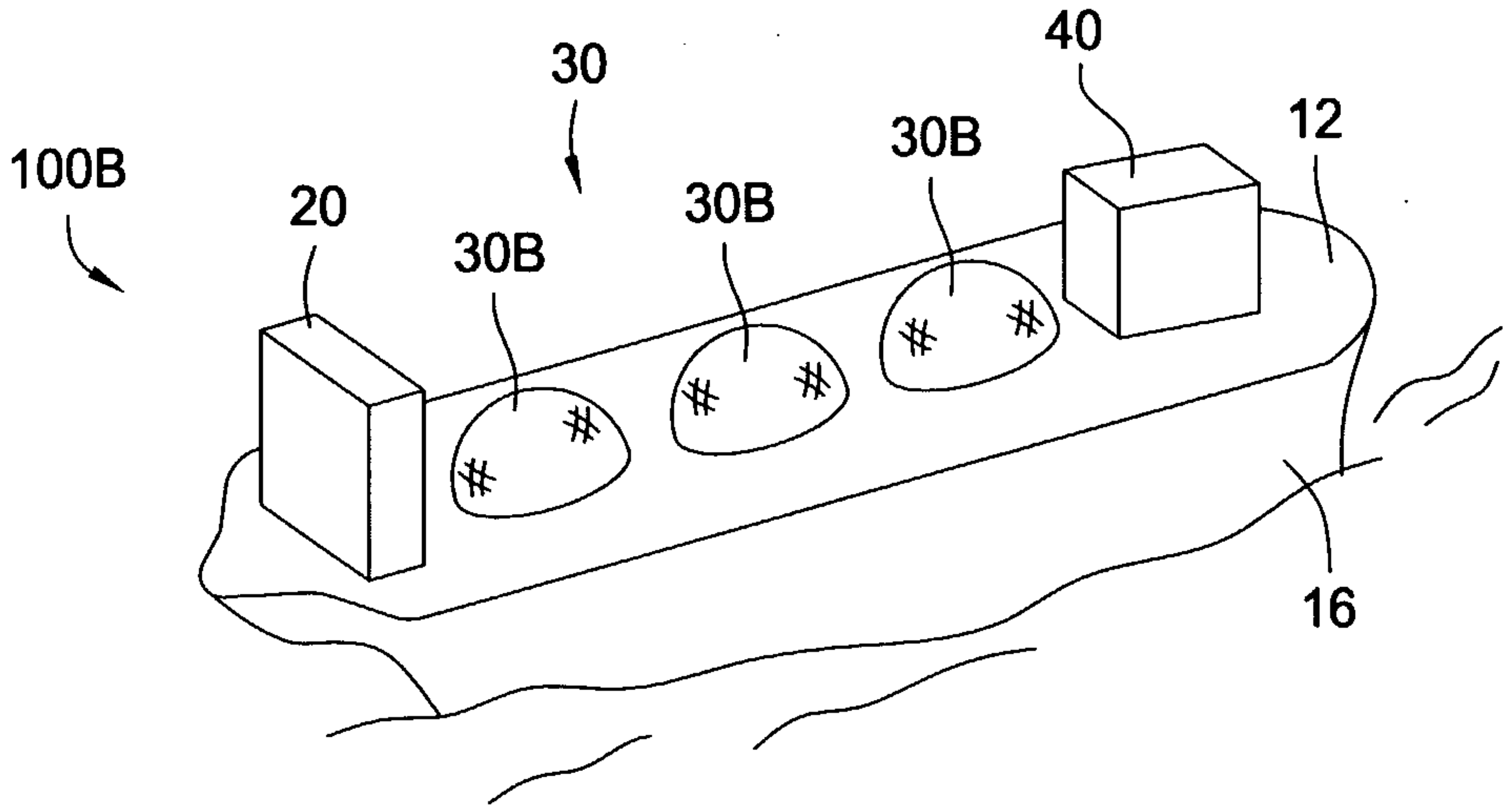


FIG. 1B

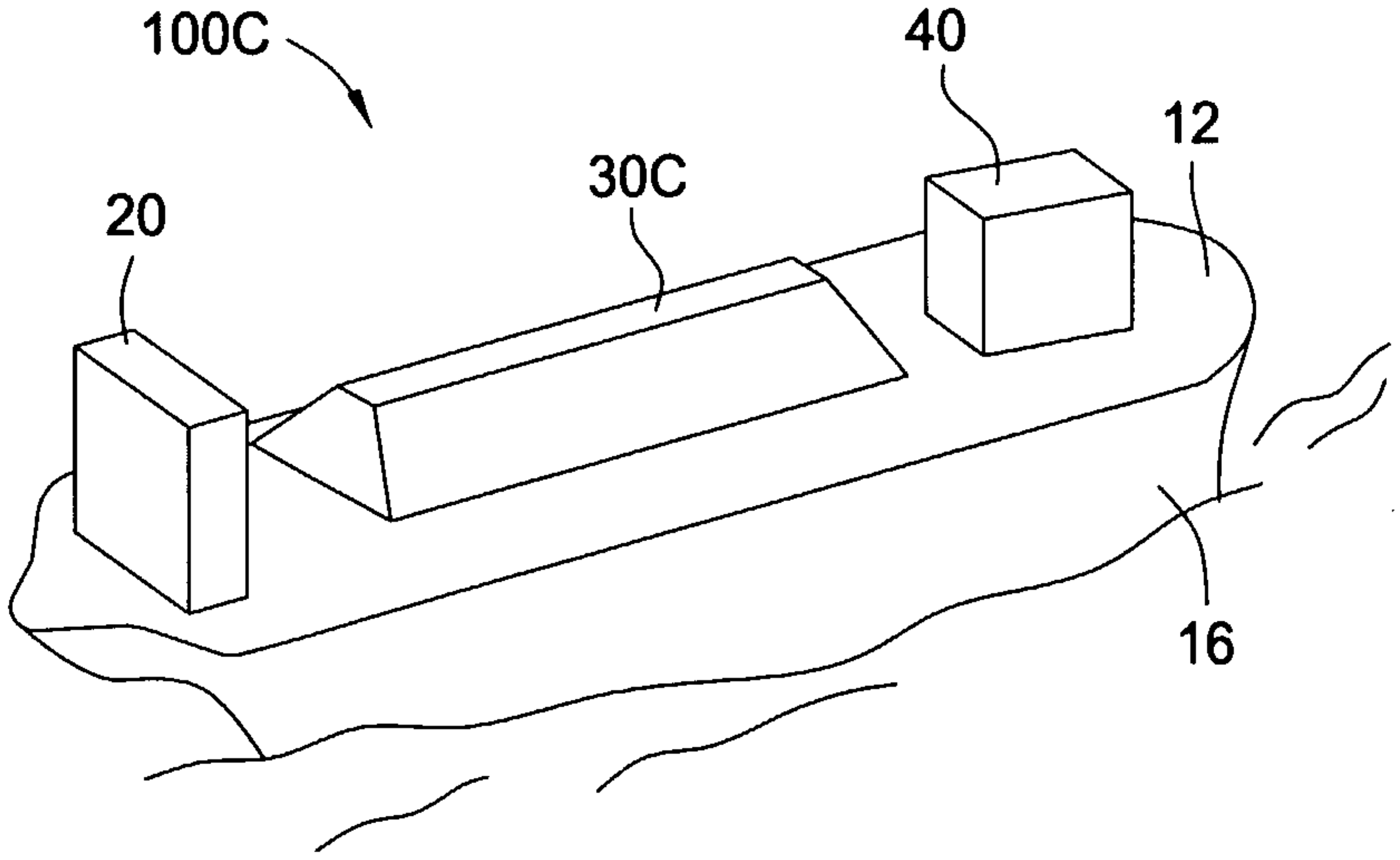


FIG. 1C

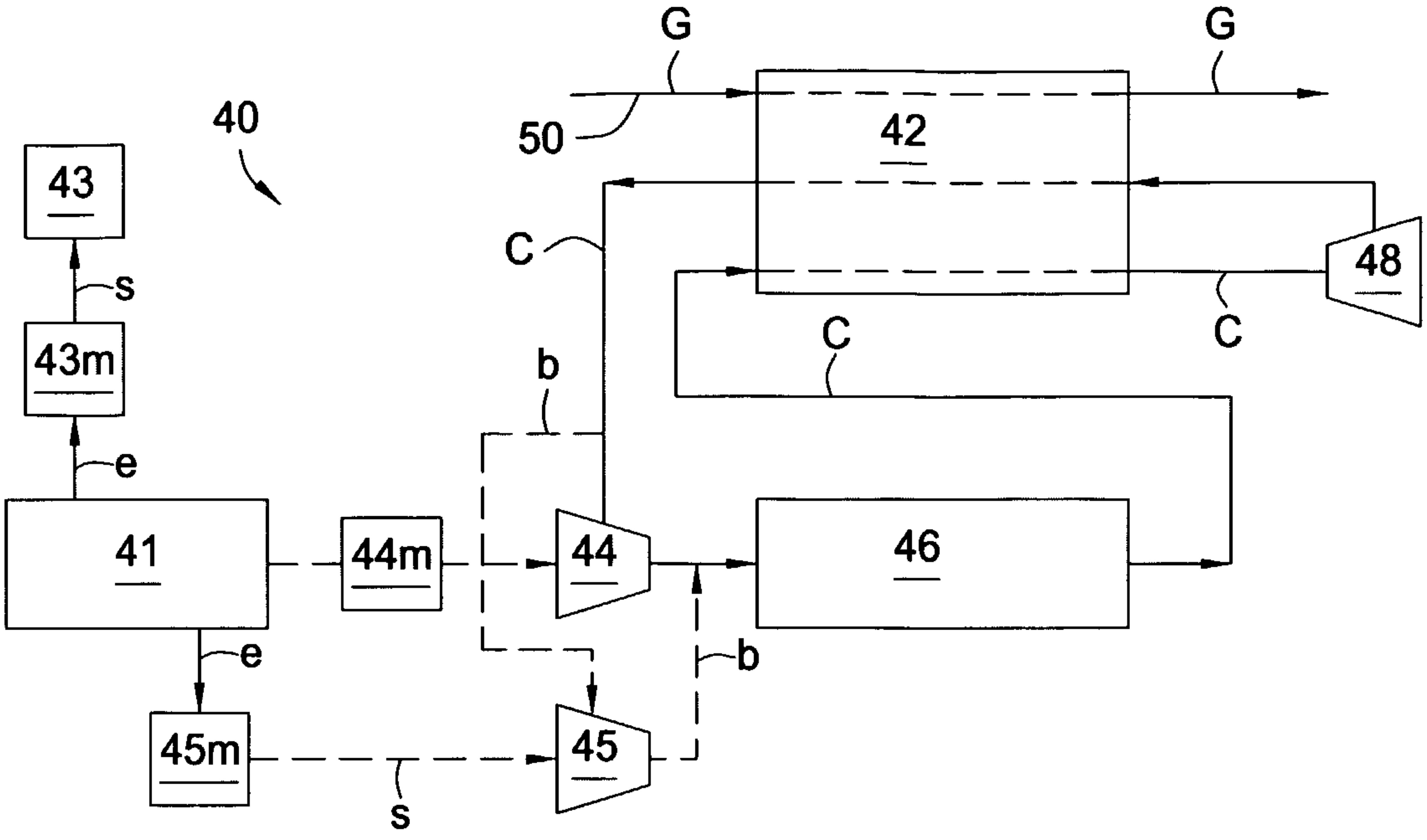

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FIG. 3

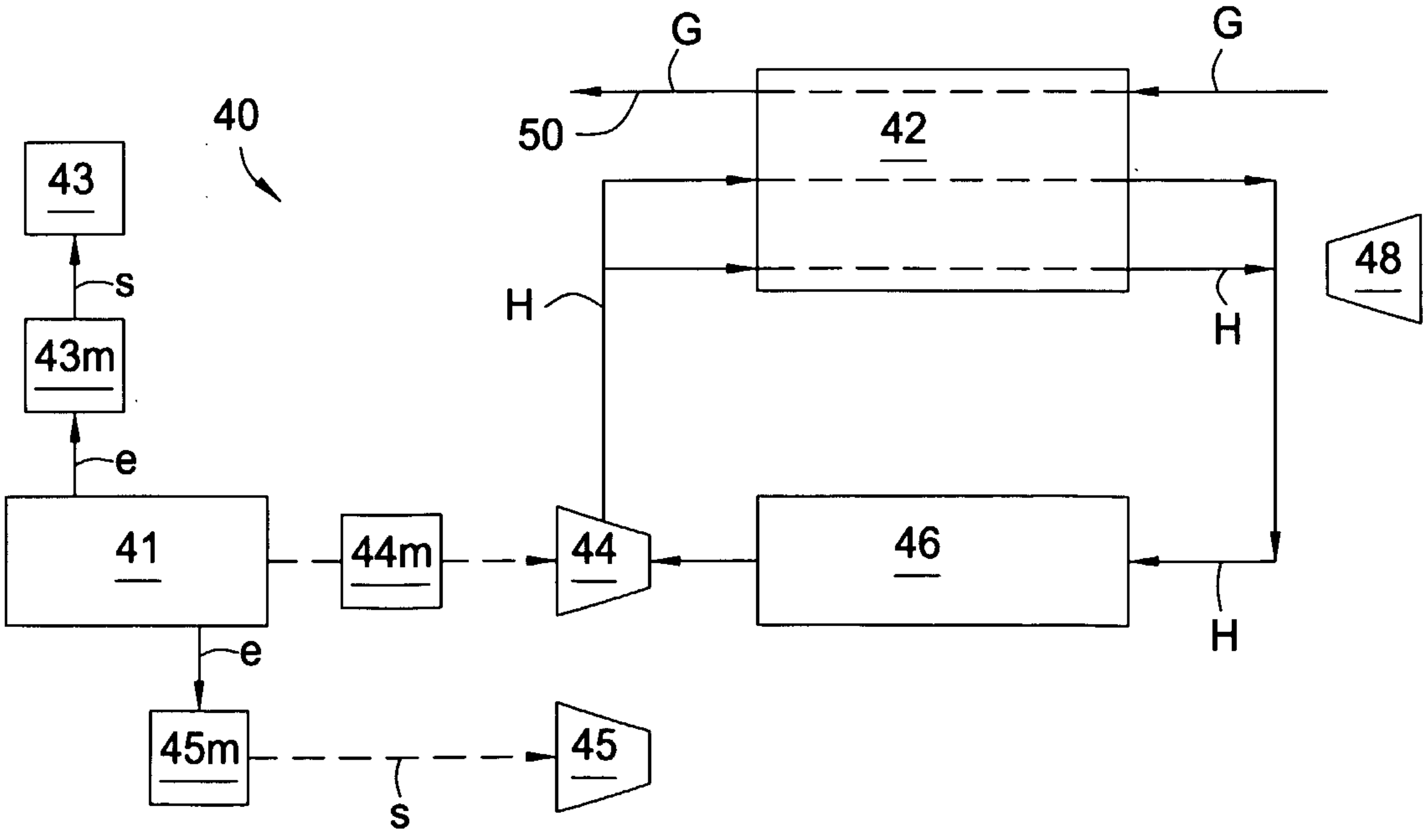
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FIG. 4A

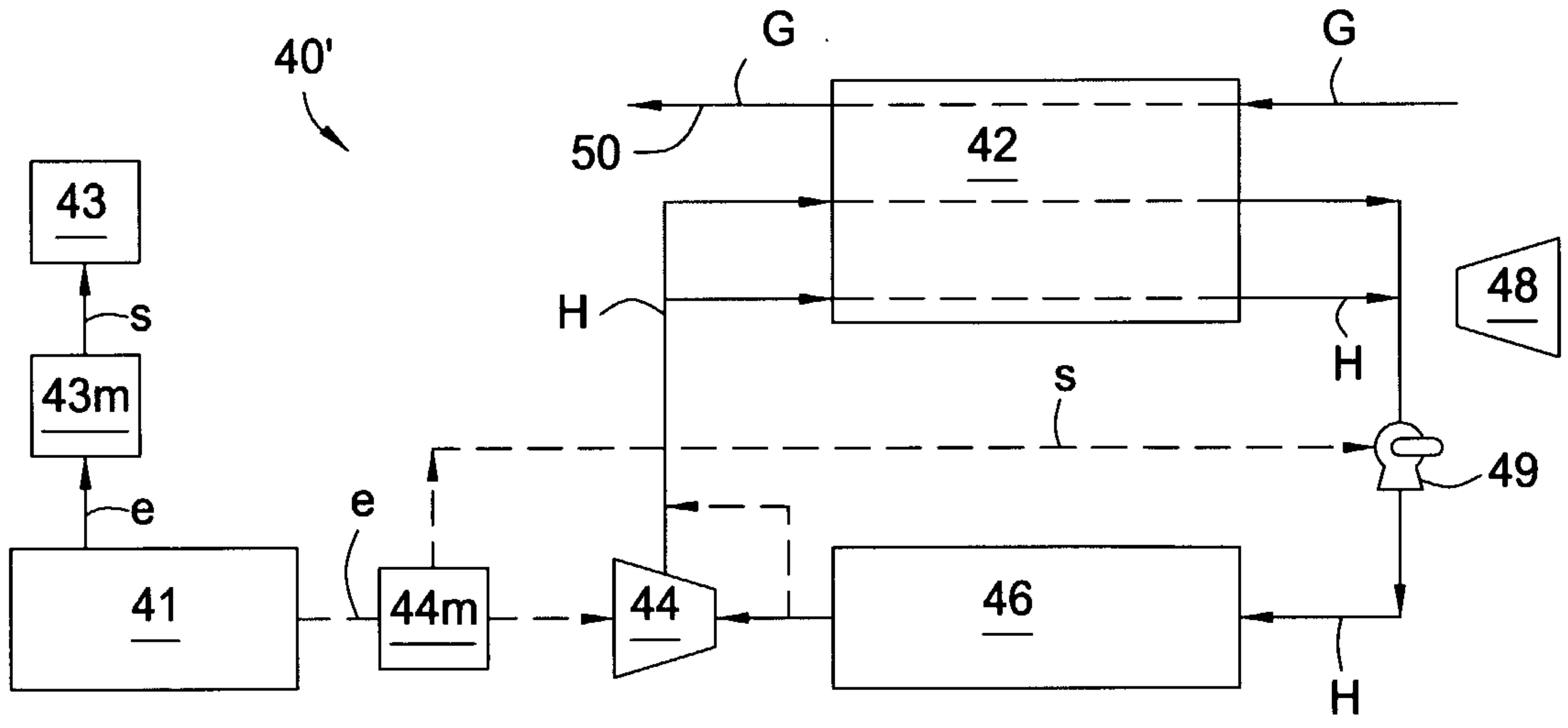


FIG. 4B

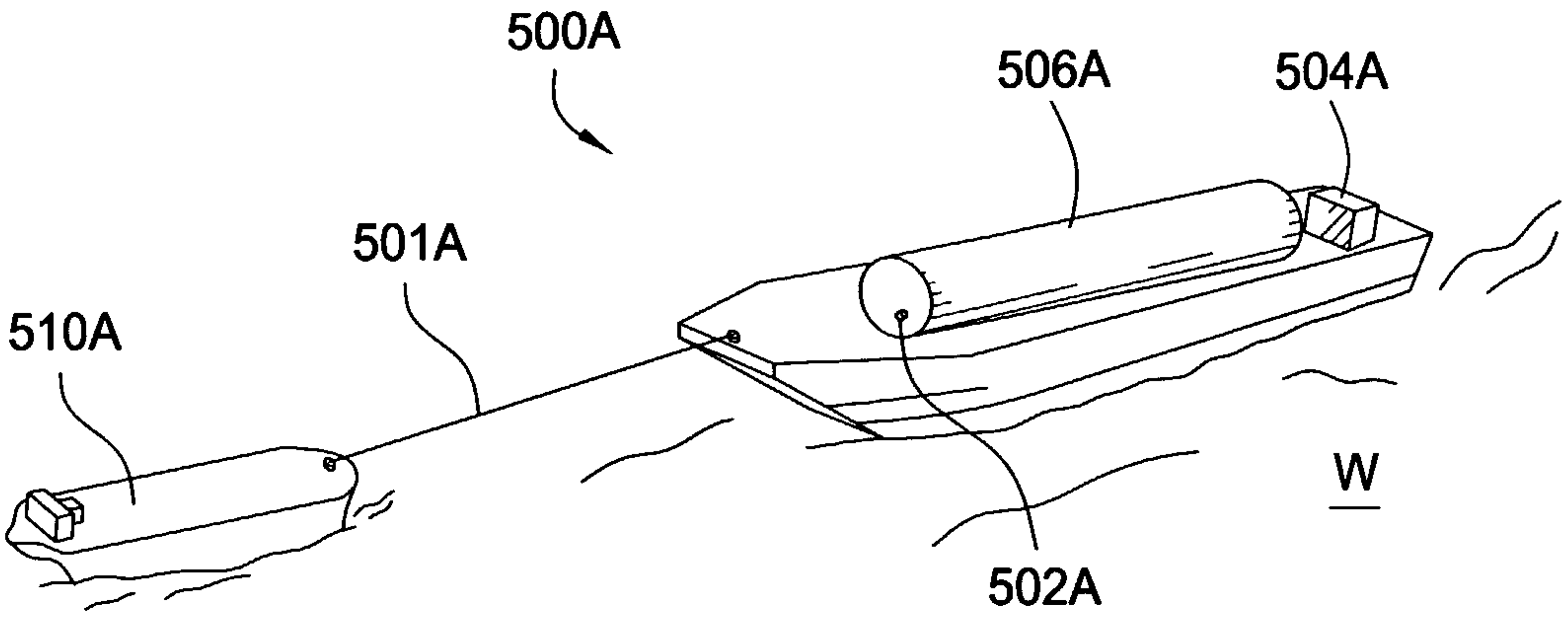


FIG. 5A

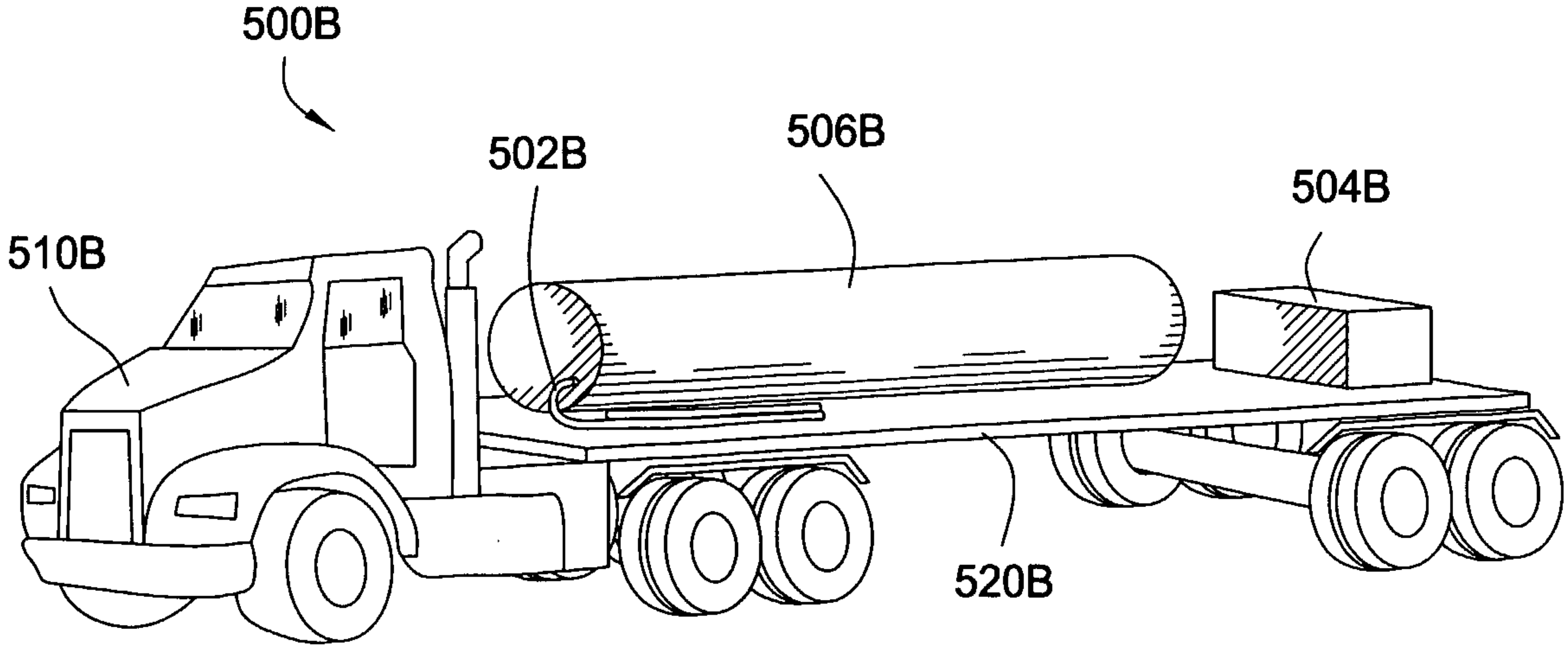
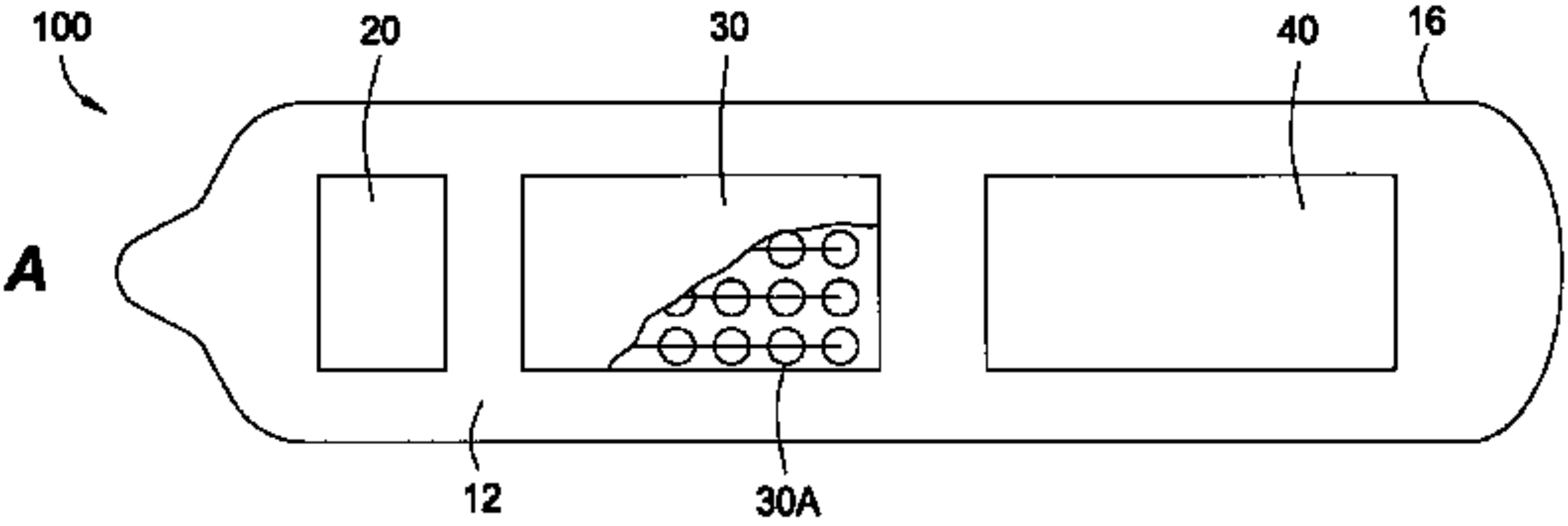


FIG. 5B

A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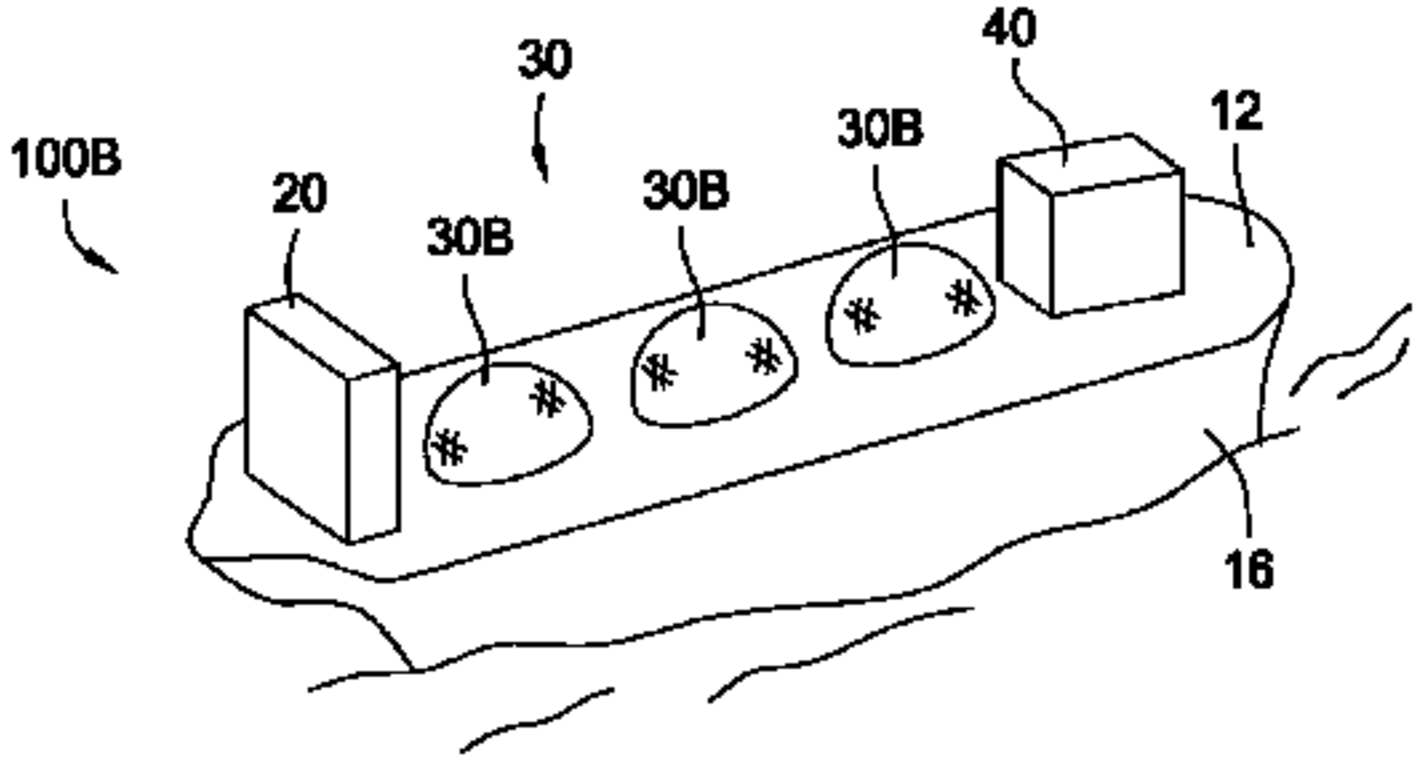
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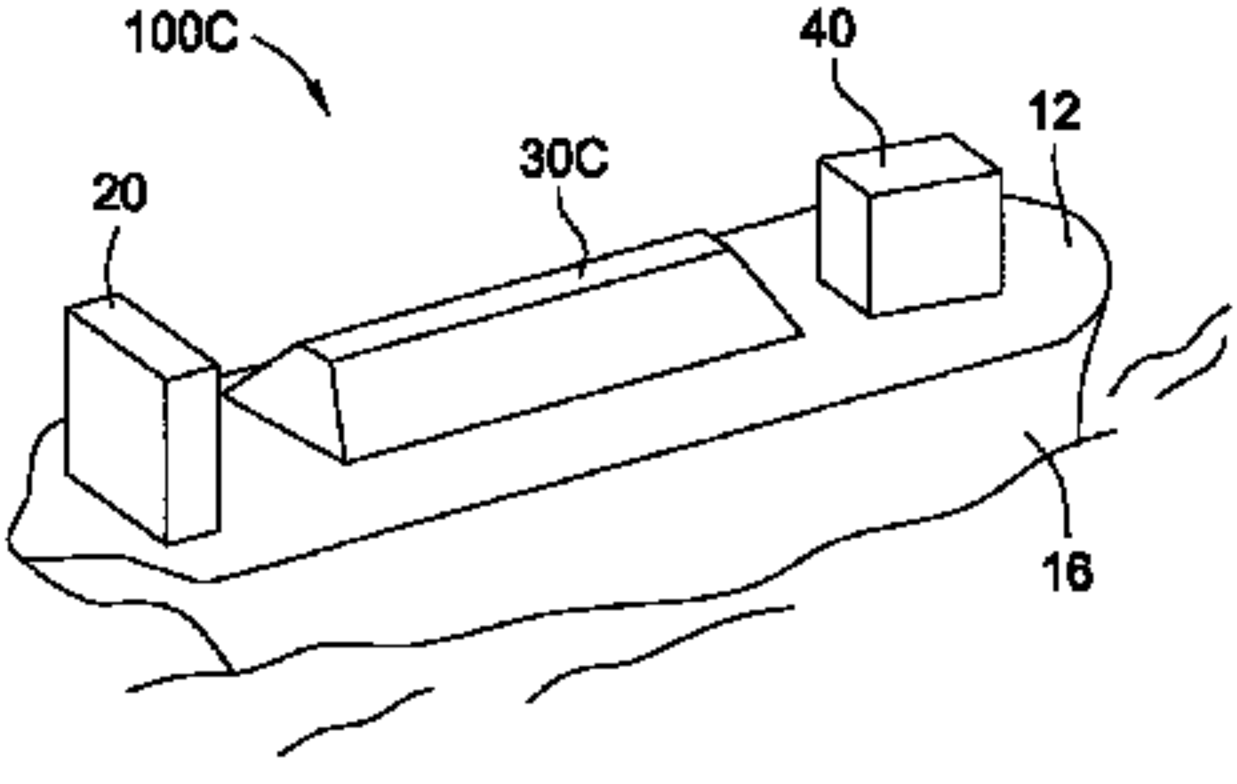
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C