{DESCRIPTION}

{Title of Invention}

BOIL-OFF GAS PROCESSING SYSTEM AND SHIP

{Technical Field}

{0001}

The present invention relates to a boil-off gas processing system and a ship.

{Background Art}

{0002}

In a ship that carries a liquefied gas such as a Liquefied Natural Gas (LNG) or a Liquefied Petroleum Gas (LPG), a liquefied gas evaporates in a tank storing the liquefied gas, and a boil-off gas is generated. When a boil-off gas is generated in the tank, the pressure in the tank increases and may exceed a predetermined pressure. Thus, a ship that carries a liquefied gas is provided with a re-liquefaction device that applies a re-liquefaction process to a boil-off gas taken from a tank. A boil-off gas to which a liquefaction process has been applied by the re-liquefaction device may be in a gas-liquid mixture state without being fully liquefied. Thus, a gas-liquid separation process may be applied to a boil-off gas in a gas-liquid mixture state to which a liquefaction process has been applied, and the boil-off gas may be separated into a gas phase and a liquid phase (for example, PTL 1 and PTL 2).

{0003}

PTL 1 discloses a device in which a boil-off gas (BOG) generated from an LNG tank is compressed by a BOG compressor and then cooled and re-liquefied by a heat exchanger. In this device, a BOG is cooled to a saturated state by a liquefier of the heat exchanger, and a non-condensed component is separated from the saturated liquid by a gas-liquid separation drum provided downstream of the liquefier. A nitrogen-rich gas obtained by the separation is then taken out and processed in a boiler as appropriate.

{0004}

PTL 2 discloses a device in which a BOG generated from an LNG storage tank is re-liquefied by a re-liquefaction device and the re-liquefied BOG is separated into a liquefied methane and a mixture gas by a nitrogen separator. In this device, only when the nitrogen gas content rate is out of a reference range, a mixture gas containing a nitrogen gas is discharged to outside of the system and combusted in a boiler tank.

{Citation List}

{Patent Literature}

{0005}

{PTL 1}

Japanese Patent No. 3908881

{PTL 2}

Japanese Patent Application Laid-Open No. 2000-338093

{Summary of Invention}

{Technical Problem}

{0006}

In the devices disclosed in PTL 1 and PTL 2, there is no consideration of utilizing the separated gas-phase boil-off gas in a propulsion machinery internal-combustion engine. In such devices, when a gas-phase boil-off gas separated by a separation device is utilized in a propulsion machinery internal-combustion engine, the whole amount of the separated gas-phase boil-off gas will be supplied to the propulsion machinery internal-combustion engine. However, for some components of a separated gas-phase boil-off gas or some operation states of the propulsion machinery internal-combustion engine, the separated gas-phase boil-off gas may not be suitably combusted in the propulsion machinery internal-combustion engine.

{0007}

The present invention has been made in view of such circumstances and intends to provide a boil-off gas processing system and a ship that can supply a gas-phase boil-off gas separated from a re-liquefied boil-off gas in a gas-liquid mixture state to a desired device, thereby suitably combusting the gas-phase boil-off gas.

{Solution to Problem}

{0008}

To solve the above problem, the boil-off gas processing system and the ship of the present invention employ the following solutions.

A boil-off gas processing system according to one aspect of the present invention includes: a boiler configured to combust a boil-off gas generated in a tank storing a liquefied gas and generate steam; a re-liquefaction device configured to perform a liquefaction process on the boil-off gas generated in the tank; a separator unit configured to separate, into a gas phase and a liquid phase, a boil-off gas in a gas-liquid mixture state on which the liquefaction process has been performed by the re-liquefaction device; a first pipe configured to guide a gas-phase boil-off gas separated by the separator unit to a propulsion machinery internal-combustion engine configured to combust a boil-off gas; a second pipe configured to guide the gas-phase boil-off gas separated by the separator unit to the boiler; and a switch unit configured to switch whether to guide the gas-phase boil-off gas separated by the separator unit to the propulsion machinery internal-combustion engine or to the boiler.

{0009}

The configuration described above includes the first pipe configured to guide a gas-phase boil-off gas separated by the separator unit (hereafter, referred to as "separated gas") to the propulsion machinery internal-combustion engine and the

second pipe configured to guide the separated gas to the boiler. This allows the separated gas to be guided to any of the propulsion machinery internal-combustion engine and the boiler. Therefore, the separated gas can be subjected to a combustion process and can be utilized as fuel in the propulsion machinery internal-combustion engine and/or the boiler. Therefore, the energy efficiency of the overall system can be improved compared to a configuration that does not utilize a separated gas.

{0010}

Further, the configuration described above includes a switch unit configured to switch whether to guide the separated gas to the propulsion machinery internal-combustion engine or to the boiler. This allows the separated gas to be guided to a desired device; that is, to either the propulsion machinery internal-combustion engine or the boiler. Therefore, for example, the separated gas can be guided to a supply destination in accordance with the operation state of the propulsion machinery internal-combustion engine and the boiler, the component of the separated gas, or the like. Therefore, the separated gas can be suitably combusted in the propulsion machinery internal-combustion engine and the boiler.

{0011}

Further, the boil-off gas processing system according to

one aspect of the present invention may include: a nitrogen content measurement unit configured to measure a nitrogen content of the gas-phase boil-off gas separated by the separator unit; a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the nitrogen content measured by the nitrogen content measurement unit; and a switch control unit configured to control the switch unit so that the gas-phase boil-off gas separated by the separator unit is supplied to the supply destination determined by the determination unit.

{0012}

In the configuration described above, the nitrogen content of the separated gas is measured, and the supply destination is determined based on the measured nitrogen content. Accordingly, the supply destination of the separated gas can be a suitable supply destination in terms of nitrogen content. For example, when the separated gas is not suitably combusted in the propulsion machinery internal-combustion engine in view of nitrogen content, the separated gas is guided to the boiler to perform a combustion process on the separated gas and utilize energy generated with the combustion process for steam generation. Therefore, the energy efficiency of the overall system can be improved compared to a configuration that does not utilize energy generated with the

combustion process. As discussed above, in the configuration described above, the separated gas can be guided to a supply destination in accordance with the nitrogen content, and energy efficiency can be improved.

{0013}

To perform a combustion process on a separated gas that is not suitably combusted by the propulsion machinery internal-combustion engine, it may be considered to provide a dedicated combustion device used for processing a separated gas (hereafter, referred to as "combustion processing device"). In the configuration provided with such a combustion processing device, it is required to provide both a combustion processing device and a boiler when steam needs to be generated. On the other hand, in the configuration described above, a separated gas that is not suitably combusted in the propulsion machinery internal-combustion engine can be combusted in the boiler, and steam can be generated. In this configuration, it is not required to provide a combustion processing device. Therefore, the configuration can be simplified compared to a case where a combustion processing device is provided.

{0014}

Note that the determination made by the determination unit based on the nitrogen content may be performed in accordance with whether or not the nitrogen content exceeds a

predetermined threshold. Specifically, if the nitrogen content measured by the nitrogen content measurement unit exceeds a predetermined threshold, the determination unit may determine that the supply destination of the separated gas (gas-phase boil-off gas separated by the separator unit) is the boiler. With such a configuration, the supply destination of the separated gas can be a more suitable supply destination in terms of nitrogen content. As such, when the separated gas is not suitably combusted in the propulsion machinery internal-combustion engine because of a high nitrogen content of the separated gas, it is possible not to guide the separated gas to the propulsion machinery internal-combustion engine. The predetermined threshold may be, for example, an upper limit value of the nitrogen content in fuel that can be suitably combusted by the propulsion machinery internal-combustion engine.

{0015}

Further, the boil-off gas processing system according to one aspect of the present invention may include: a heat quantity measurement unit configured to measure a quantity of heat of the gas-phase boil-off gas separated by the separator unit; a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the quantity of heat measured by the heat quantity measurement unit; and a switch control unit

configured to control the switch unit so that the gas-phase boil-off gas separated by the separator unit is supplied to the supply destination determined by the determination unit.

{0016}

In the configuration described above, the quantity of heat of the separated gas is measured, and the supply destination is determined based on the measured quantity of heat. Accordingly, the supply destination of the separated gas can be a suitable supply destination in terms of quantity of heat. For example, when the separated gas is not suitably combusted in the propulsion machinery internal-combustion engine in view of quantity of heat, the separated gas is guided to the boiler to perform a combustion process on the separated gas and utilize energy generated with the combustion process for steam generation. Therefore, the energy efficiency of the overall system can be improved compared to a configuration that does not utilize energy generated with the combustion process. As discussed above, in the configuration described above, the separated gas can be guided to a supply destination in accordance with the quantity of heat, and energy efficiency can be improved.

{0017}

It may be considered to provide a combustion processing device for performing the combustion process on a separated gas that is not suitably combusted by the propulsion machinery

internal-combustion engine. In a configuration provided with such a combustion processing device, it is required to provide both a combustion processing device and a boiler steam needs to be generated. On the other hand, in the configuration described above, the separated gas that is not suitably combusted in the propulsion machinery internal-combustion engine can be combusted in the boiler, and steam can be generated. In this configuration, it is not required to provide a combustion processing device. Therefore, the configuration can be simplified compared to the case where a combustion processing device is provided.

{0018}

Specifically, if the quantity of heat measured by the heat quantity measurement unit exceeds a predetermined threshold, the determination unit may determine that the supply destination of the separated gas (gas-phase boil-off gas separated by the separator unit) is the propulsion machinery internal-combustion engine. With such a configuration, the supply destination of the separated gas can be a more suitable supply destination in terms of quantity of heat. When the separated gas has a high quantity of heat and can be suitably combusted by the propulsion machinery internal-combustion engine, the boil-off gas can be guided to the propulsion machinery internal-combustion engine. The predetermined threshold may be, for example, a lower limit

value of the quantity of heat of fuel that can be suitably combusted by the propulsion machinery internal-combustion engine.

{0019}

Further, the boil-off gas processing system according to one aspect of the present invention includes: a pressure measurement unit configured to measure a pressure of the boiler; a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the pressure measured by the pressure measurement unit when flame is formed in the boiler; and a switch control unit configured to control the switch unit so that a boil-off gas is supplied to the supply destination determined by the determination unit. When the pressure measured by the pressure measurement unit is lower than a predetermined threshold, the determination unit may determine that a supply destination of the gas-phase boil-off gas separated by the separator unit is the boiler.

{0020}

In the configuration described above, if the pressure in the boiler is lower than a predetermined threshold, the supply destination of the separated gas is determined to be the boiler. Accordingly, when steam is not suitably generated in the boiler, the separated gas can be guided to the boiler. Therefore, steam can be generated suitably and stably in the

boiler.

{0021}

Further, the boil-off gas processing system according to one aspect of the present invention includes: a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit; and a switch control unit configured to control the switch unit so that a boil-off gas is supplied to the supply destination determined by the determination unit. When flame is formed in the boiler, the determination unit may determine that a supply destination of the gas-phase boil-off gas separated by the separator unit is the boiler.

{0022}

In the configuration described above, when flame is formed in the boiler, the supply destination of the separated gas is determined to be the boiler. Accordingly, when flame is formed in the boiler, the separated gas can be preferentially used as fuel. This can reduce the amount of another fuel used for forming flame.

{0023}

A ship according to one aspect of the present invention includes a boil-off gas processing system described in any of the above.

{Advantageous Effects of Invention}

{0024}

According to the present invention, a gas-phase boil-off gas separated from a re-liquefied boil-off gas in a gas-liquid mixture state can be guided to a desired device and thus can be suitably combusted.

{Brief Description of Drawings}

{0025}

{Fig. 1}

Fig. 1 is a configuration diagram illustrating an overview of a ship according to an embodiment of the present invention.

{Fig. 2}

Fig. 2 is a block diagram illustrating a boil-off gas processing system provided in the ship of Fig. 1.

{Description of Embodiments}

{0026}

One embodiment of a boil-off gas processing system and a ship according to the present invention will be described below with reference to the drawings.

A boil-off gas processing system 4 according to the present embodiment is applied to a ship 1 that carries a Liquefied Natural Gas (LNG). Note that what is carried by the ship 1 is not limited to the LNG and may be other liquefied gasses such as a Liquefied Petroleum Gas (LPG), for example.

{0027}

The ship 1 has a propulsion machinery engine (propulsion

machinery internal-combustion engine) 2, tanks 3 that store an LNG (liquefied gas), a boil-off gas processing system 4 that processes a boil-off gas generated in the tanks 3, a power generating diesel engine 5 that generates power used in the ship, and an economizer 6 that generates steam by utilizing heat of an exhaust gas discharged from the power generating diesel engine 5.

{0028}

The propulsion machinery engine 2 is a two-stroke engine that can combust both a fuel oil and a fuel gas as fuel. The propulsion machinery engine 2 drives a drive unit (not illustrated) by combusting a combustion oil (for example, a heavy oil or the like) or a combustion gas (for example, an LNG or the like). The drive unit drives and rotates a propeller (for example, a screw or the like) (not illustrated) that gives the ship 1 propulsion power by using driving force from the propulsion machinery engine 2.

{0029}

A plurality of tanks 3 are provided (four tanks are provided in the present embodiment, as an example). Each tank 3 is made of aluminum, for example, and is configured to store an LNG therein. A discharge pipe 3a used for discharging a boil-off gas to the outside is provided in the top of each tank 3.

{0030}

The boil-off gas processing system 4 has a supply pipe 11 used for supplying a boil-off gas discharged from the tanks 3 to the propulsion machinery engine 2, a compressor unit 12 that compresses a boil-off gas flowing through the supply pipe 11, a re-liquefaction device 13 that applies a liquefaction process to a boil-off gas, a gas-liquid separator (separator unit) 14 that separates, into a gas and a liquid, a boil-off gas in a gas-liquid mixture state to which the liquefaction process has been applied, and a boiler 15 that generates steam.

{0031}

A supply pipe 11 supplies, to the propulsion machinery engine 2, a boil-off gas that has flowed therein via the discharge pipes 3a provided in respective tanks 3. Thus, the supply pipe 11 connects the tanks 3 to the propulsion machinery engine 2. The supply pipe 11 is provided with a compressor unit 12 that compresses a boil-off gas flowing in the supply pipe 11, as described above.

{0032}

From the supply pipe 11, a generating engine supply pipe 16 is branched downstream of the compressor unit 12. The generating engine supply pipe 16 is used to supply a part of the boil-off gas flowing through the supply pipe 11 to the power generating diesel engine 5. Further, from the supply pipe 11, a circulation pipe 17 is branched downstream of the

branch position of the generating engine supply pipe 16. The circulation pipe 17 is provided with a circulation pipe valve 17a. The circulation pipe valve 17a can adjust the flow rate of the boil-off gas flowing in the circulation pipe 17 by adjustment of the opening. Note that the circulation pipe valve 17a can also be fully closed and fully opened.

{0033}

From the supply pipe 11, a boiler supply pipe 19 is branched upstream of the compressor unit 12. The boiler supply pipe 19 is connected to a burner (not illustrated) whose downstream end is provided in the boiler 15. The boiler supply pipe 19 is configured to supply a part of the boil-off gas flowing through the supply pipe 11 to the boiler 15 (in details, a burner). The boiler supply pipe 19 is provided with a first valve 19a. The first valve 19a can adjust the flow rate of the boil-off gas flowing in the boiler supply pipe 19 by adjustment of the opening. Note that the first valve 19a can also be fully closed and fully opened.

{0034}

The compressor unit 12 has a plurality of high pressure compressors 12a (five high pressure compressors in the present embodiment, as an example) that compress the boil-off gas flowing through the supply pipe 11. The five high pressure compressors 12a are arranged in series. Thus, multi-step compression is performed in the compressor unit 12, which

increases the pressure of the boil-off gas up to 300 kg/cm^2.

{0035}

An extraction pipe 20 is branched from the pipe that connects the high pressure compressors 12a to each other. In details, the extraction pipe 20 is branched from a pipe that connects high pressure compressors 12a located second and third from the upstream. The extraction pipe 20 extracts a part of the boil-off gas flowing in the pipe that connects the high pressure compressors 12a to each other and supplies the extracted boil-off gas to the re-liquefaction device 13. The extraction pipe 20 is provided with an extraction pipe valve 20a. The extraction pipe valve 20a can adjust the flow rate of the boil-off gas flowing in the extraction pipe 20 by adjustment of the opening. Note that the extraction pipe valve 20a can also be fully closed and fully opened.

{0036}

The re-liquefaction device 13 has a plurality of liquefying compressors 21 (three liquefying compressors in the present embodiment, as an example) to which the boil-off gas is supplied from the extraction pipe 20, a heat exchanger 22 that cools the boil-off gas compressed by the liquefying compressors 21, an expansion turbine 23 that expands a part of the boil-off gas cooled by the heat exchanger 22, and a motor 24 that drives the liquefying compressors 21 and the expansion turbine 23.

{0037}

The liquefying compressors 21 are connected to each other via pipes 21a. Further, the three liquefying compressors 21 are arranged in series. Thus, the three liquefying compressors 21 perform multi-step compression to increase the pressure of the boil-off gas. Further, the three liquefying compressors 21 are connected by a single drive shaft 25. The drive shaft 25 is connected to the expansion turbine 23 and the motor 24 and driven and rotated by the driving force of the motor 24. The boil-off gas discharged from the most downstream liquefying compressor 21 is supplied to the heat exchanger 22 via a first re-liquefaction pipe 26.

{0038}

The heat exchanger 22 exchanges heat of the boil-off gas compressed by the liquefying compressors 21 with heat of the boil-off gas expanded by the expansion turbine 23 and the gas-phase boil-off gas separated by the gas-liquid separator 14. The boil-off gas compressed by the liquefying compressors 21 is cooled by the heat exchange and partially condensed (liquefied) into a gas-liquid mixture state. The boil-off gas in the gas-liquid mixture state discharged from the heat exchanger 22 (in details, a fluid in which a boil-off gas and a re-liquefied LNG are mixed) is supplied to the gas-liquid separator 14 via a second re-liquefaction pipe 27. The second re-liquefaction pipe 27 is provided with a re-liquefaction

pipe valve 27a. The re-liquefaction pipe valve 27a can adjust the flow rate of the boil-off gas flowing in the second re-liquefaction pipe 27 by adjustment of the opening. Note that the re-liquefaction pipe valve 27a can also be fully closed and fully opened.

{0039}

In the heat exchanger 22, an extraction pipe 28 is branched from a pipe through which the compressed boil-off gas flows. The extraction pipe 28 extracts a part of the boil-off gas whose heat has been exchanged and cooled to some degrees and supplies the extracted part of the boil-off gas to the expansion turbine 23.

{0040}

The expansion turbine 23 is connected to the drive shaft 25 and rotated by the driving force of the motor 24 transmitted via the drive shaft 25. Further, the expansion turbine 23 adiabatically expands the supplied boil-off gas to reduce the temperature thereof. The boil-off gas expanded by the expansion turbine 23 (hereafter, referred to as “cooling source gas”) is supplied to the heat exchanger 22 via a first cooling source gas pipe 29. The cooling source gas supplied to the heat exchanger 22 exchanges heat with the boil-off gas compressed by the liquefying compressors 21 to cool the compressed boil-off gas. The cooling source gas discharged from the heat exchanger 22 flows into the extraction pipe 20

via a second cooling source gas pipe 30. Thus, the downstream end of the second cooling source gas pipe 30 is connected to an intermediate position of the extraction pipe 20. In details, the downstream end of the second cooling source gas pipe 30 is connected between the extraction pipe valve 20a and the re-liquefaction device 13 in the extraction pipe 20.

{0041}

The gas-liquid separator 14 is formed in a drum shape and separates the supplied boil-off gas in the gas-liquid mixture state into a gas phase and a liquid phase (re-liquefied LNG).

{0042}

An LNG pipe 31 is connected to the bottom of the gas-liquid separator 14. The LNG pipe 31 is connected to each tank 3 and supplies the LNG separated by the gas-liquid separator 14 to each tank 3. Further, the LNG pipe 31 is provided with a pump 31a in an intermediate position, and an LNG flows therethrough by the driving force of the pump 31a. Further, the LNG pipe 31 is provided with a re-circulation pipe 32 so as to bypass the pump 31a. In the re-circulation pipe 32, a part of the LNG discharged from the pump 31a is circulated to the LNG pipe 31 upstream of the pump 31a so that the flow rate of the LNG within the pump 31a does not decrease below a certain flow rate. The re-circulation pipe 32 is provided with a re-circulation pipe valve 32a. The re-circulation pipe valve 32a can adjust the flow rate of the LNG

flowing in the re-circulation pipe 32 by adjustment of the opening. Note that the re-circulation pipe valve 32a can also be fully closed and fully opened.

{0043}

A separated gas pipe 33 is connected to the top of the gas-liquid separator 14. The gas-phase boil-off gas separated by the gas-liquid separator 14 (hereafter, referred to as "separated gas") flows in the separated gas pipe 33 for guiding the separated gas to the boiler 15 and the propulsion machinery engine 2. The separated gas pipe 33 connects the gas-liquid separator 14 and the boiler supply pipe 19 to each other. Thus, the downstream end of the separated gas pipe 33 is connected to an intermediate position of the boiler supply pipe 19. In details, the downstream end of the separated gas pipe 33 is connected between the first valve 19a and the boiler 15. Further, the heat exchanger 22 is provided in an intermediate position of the separated gas pipe 33. The separated gas supplied to the heat exchanger 22 exchanges heat with the boil-off gas compressed by the liquefying compressors 21 to cool the compressed boil-off gas. The separated gas pipe valve 34 is provided upstream of the heat exchanger 22 in the separated gas pipe 33. The separated gas pipe valve 34 can adjust the flow rate of the boil-off gas flowing in the separated gas pipe 33 by adjustment of the opening. Note that the separated gas pipe valve 34 can also be fully closed and

fully opened.

{0044}

Further, the separated gas pipe 33 is provided with a calorimeter 35 (heat quantity measurement unit) and a second valve 33a downstream of the heat exchanger 22. The calorimeter 35 is provided upstream of the second valve 33a. The calorimeter 35 measures the quantity of heat of the boil-off gas flowing in the separated gas pipe 33. The calorimeter 35 transmits the measured quantity of heat to a control device 50. The second valve 33a can adjust the flow rate of the boil-off gas flowing in the separated gas pipe 33 by adjustment of the opening. Note that the second valve 33a can also be fully closed and fully opened.

{0045}

Further, a branch pipe 36 is branched from an intermediate position of the separated gas pipe 33. In details, the branch pipe 36 is branched from a part between the calorimeter 35 and the second valve 33a in the separated gas pipe 33. The branched gas flows in the branch pipe 36, which connects the separated gas pipe 33 and the supply pipe 11. Thus, the downstream end of the branch pipe 36 is connected to the supply pipe 11. In details, the downstream end of the branch pipe 36 is connected upstream of the branch position of the boiler supply pipe 19 in the supply pipe 11. The branch pipe 36 is provided with a third valve 36a. The

third valve 36a can adjust the flow rate of the boil-off gas flowing in the branch pipe 36 by adjustment of the opening. Note that the third valve 36a can also be fully closed and fully opened.

{0046}

As described above, in the boil-off gas processing system 4 of the present embodiment, the separated gas can be guided to the boiler 15 by a part of the separated gas pipe 33 and the boiler supply pipe 19. Further, the separated gas can be guided to the propulsion machinery engine 2 by a part of the separated gas pipe 33 and a part of the branch pipe 36 and the supply pipe 11. Further, by controlling open/close of the second valve 33a provided in the separated gas pipe 33 and the third valve 36a provided in the branch pipe 36, it is possible to switch whether to guide the separated gas to the boiler 15 or to the propulsion machinery engine 2.

{0047}

The boiler 15 has a furnace 38, a burner (not illustrated) that forms flame in the furnace 38, a steam drum 39 arranged above, a water drum 40 arranged below, and a pipe (not illustrated) connecting the steam drum 39 and the water drum 40 to each other. The burner can combust both a fuel oil and a fuel gas. The boil-off gas or the separated gas is supplied to the burner via the boiler supply pipe 19. Further, a fuel oil is supplied to the burner via a fuel oil

pipe (not illustrated). The burner combusts a fuel oil or a combustion gas (boil-off gas or the like) or both of the fuel oil and the combustion gas to form flame in the furnace 38. When flame is formed in the furnace 38 by the burner, supply water in the boiler 15 is heated. Once the supply water is heated, the heated supply water rises from the water drum 40 arranged below to the steam drum 39 arranged above via a boiler pipe (not illustrated). In the steam drum 39, a gas and a liquid are separated. The separated steam is supplied via a boiler steam supply tube (not illustrated) to each device that requires steam. The steam drum 39 is provided with a pressure meter (pressure measurement unit) 41 that measures the steam pressure in the steam drum 39. The pressure meter 41 transmits the measured steam pressure in the steam drum 39 to the control device 50.

{0048}

The economizer 6 generates steam by exchanging heat between a combustion exhaust gas discharged from the power generating diesel engine 5 and water. The economizer 6 and the steam drum 39 are connected to each other via a steam pipe 42. The fluid in a gas-liquid mixture state generated by the economizer 6 is supplied to the steam drum 39 via the steam pipe 42 and separated into a gas and a liquid by the steam drum 39. In the steam drum 39, the separated steam is supplied to each device via a boiler steam supply tube (not

illustrated). Further, the water drum 40 and the economizer 6 are connected via a supply water pipe 43. A water supply tube is used to supply water in the water drum 40 to the economizer 6 by a pump 44 provided at an intermediate position.

{0049}

Further, the ship 1 is provided with the control device 50.

The control device 50 is formed of a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), a computer readable storage medium, and the like, for example. Further, as an example, a series of processes to implement respective functions is stored in a storage medium or the like in a form of a program. The CPU reads such a program into the RAM or the like and executes a process of edition and operation of information, so that various functions are implemented. Note that a program may be installed in advance in a ROM or other storage mediums, a program may be provided in a state of being stored in a computer readable storage medium, or a program may be delivered via a wired or wireless communication unit. The computer readable storage medium is a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like.

{0050}

The control device 50 can control the opening of each

valve provided in the boil-off gas processing system 4 (including the first valve 19a to the third valve 36a) between 0% and 100% inclusive. As illustrated in Fig. 2, the control device 50 has a determination unit 51 that determines a supply destination of the separated gas based on a quantity of heat measured by the calorimeter 35, a switch control unit 52 that controls the second valve 33a and the third valve 36a so that the separated gas is supplied to the supply destination determined by the determination unit 51, and a storage unit 53 that stores a predetermined threshold. The predetermined threshold stored in the storage unit 53 may be, for example, a lower limit value of the quantity of heat of fuel that can be suitably combusted by the propulsion machinery engine 2.

The determination unit 51 determines that the supply destination of the separated gas is the propulsion machinery engine 2 if the quantity of heat of the separated gas (quantity of heat measured by the calorimeter 35) is greater than or equal to the predetermined threshold stored in the storage unit 53, and that the supply destination of the separated gas is the boiler 15 if the quantity of heat of the separated gas is less than the predetermined threshold.

{0051}

When the determination unit 51 determines that the supply destination of the separated gas is the propulsion machinery engine 2, the switch control unit 52 controls the second valve

33a provided in the separated gas pipe 33 to be fully closed (a state of the opening of 0%) and controls the third valve 36a provided in the branch pipe 36 to be fully opened (a state of the opening of 100%). Further, at this time, the first valve 19a provided in the boiler supply pipe 19 is fully closed.

When the determination unit 51 determines that the supply destination of the separated gas is the boiler 15, the switch control unit 52 controls the second valve 33a provided in the separated gas pipe 33 to be fully opened and controls the third valve 36a provided in the branch pipe 36 to be fully closed. Further, at this time, the first valve 19a provided in the boiler supply pipe 19 is fully closed.

{0052}

Next, a processing method of a boil-off gas and the flow of the boil-off gas according to the present embodiment will be described with reference to Fig. 1.

A boil-off gas generated in each tank 3 flows into the supply pipe 11 via the discharge pipe 3a when the pressure in each tank 3 exceeds a predetermined pressure. The boil-off gas that has flown into the supply pipe 11 flows in the supply pipe 11. At this time, if the first valve 19a of the boiler supply pipe 19 is opened, a part of the boil-off gas flows into the boiler supply pipe 19. The boil-off gas that has flown into the boiler supply pipe 19 is supplied to the boiler

15 and combusted as fuel.

{0053}

On the other hand, the boil-off gas that has not flown into the boiler supply pipe 19 flows in the supply pipe 11 and is compressed in the compressor unit 12. The boil-off gas compressed in the compressor unit 12 flows in the supply pipe 11, is supplied to the propulsion machinery engine 2, and is combusted as fuel. A part of the boil-off gas compressed in the compressor unit 12 flows into the generating engine supply pipe 16 and is supplied to the generating engine. Further, when the boil-off gas is not required by the propulsion machinery engine 2, the circulation pipe valve 17a provided in the circulation pipe 17 is opened to return the boil-off gas to the supply pipe 11 via the circulation pipe 17.

{0054}

When the boil-off gas is re-liquefied, the extraction pipe valve 20a provided in the extraction pipe 20 is opened. Accordingly, the boil-off gas compressed up to a predetermined pressure in the compressor unit 12 is supplied to the re-liquefaction device 13 via the extraction pipe 20. In the re-liquefaction device 13, the boil-off gas is compressed by the three liquefying compressors 21. The compressed boil-off gas is supplied to the heat exchanger 22 via the first re-liquefaction pipe 26. In the heat exchanger 22, heat of the boil-off gas and heat of the cooling source gas and separated

gas are exchanged. This causes the boil-off gas to be cooled and partially condensed (liquefied) into a gas-liquid mixture state. The boil-off gas in the gas-liquid mixture state discharged from the heat exchanger 22 (in details, a fluid in which the boil-off gas and the re-liquefied LNG are mixed) is supplied to the gas-liquid separator 14 via the second re-liquefaction pipe 27.

{0055}

In the gas-liquid separator 14, the boil-off gas in the gas-liquid mixture state is separated into a gas phase (separated gas) and a liquid phase (re-liquefied LNG). Note that nitrogen is contained in the boil-off gas. Since nitrogen is less liquefied than other components (such as methane), the gas phase (separated gas) resulted from gas-liquid separation is a gas with a high nitrogen content.

The re-liquefied LNG is guided to each tank 3 via the LNG pipe 31. In such a way, the boil-off gas is re-liquefied and returned to the tanks 3. On the other hand, the separated gas is supplied to the heat exchanger 22 via the separated gas pipe 33. The separated gas resulted from the heat exchange by the heat exchanger 22 flows in the separated gas pipe 33. If the supply destination is the boiler 15 (that is, if the second valve 33a is opened, and the third valve 36a is closed), the separated gas flowing in the separated gas pipe 33 is supplied to the boiler 15 via the boiler supply pipe 19

and combusted as fuel. When the supply destination is a propulsion machinery engine 2 (that is, when the second valve 33a is closed, and the third valve 36a is opened), the separated gas flows into the supply pipe 11 via the branch pipe 36. Once flowing into the supply pipe 11, the separated gas is guided to the propulsion machinery engine 2 via the compressor unit 12 or the like.

{0056}

According to the present embodiment, the following effects and advantages are achieved.

In the present embodiment, a separated gas separated by the gas-liquid separator 14 can be guided to any of the propulsion machinery engine 2 and the boiler 15. Therefore, the separated gas can be subjected to a combustion process and can be utilized as fuel in the propulsion machinery engine 2 and/or the boiler 15. Accordingly, the energy efficiency of the overall system can be improved compared to a configuration that does not utilize a separated gas (a configuration to perform a combustion process on the separated gas by a gas combustion unit (GCU) or the like).

{0057}

Further, whether the separated gas is guided to the propulsion machinery engine 2 or guided to the boiler 15 can be switched by the second valve 33a and the third valve 36a. This allows the separated gas to be guided to a desired

device; that is, to either the propulsion machinery engine 2or the boiler 15. Therefore, for example, the separated gas can be guided to a supply destination in accordance with the operation state of the propulsion machinery engine 2 and the boiler 15, the component of the separated gas, or the like. Accordingly, the separated gas can be suitably combusted in the propulsion machinery engine 2 and the boiler 15.

{0058}

As described above, since nitrogen is less likely to be liquefied, the separated gas tends to have a high nitrogen content. Therefore, a gas having a high nitrogen content may have a low quantity of heat and may not be suitably combusted in the propulsion machinery engine 2.

In the present embodiment, the quantity of heat of the separated gas is measured by the calorimeter 35, and a supply destination is determined based on the measured quantity of heat. Accordingly, the supply destination of the separated gas can be a suitable supply destination in terms of quantity of heat.

{0059}

In details, in the present embodiment, if the quantity of heat of the separated gas (the quantity of heat measured by the calorimeter 35) is greater than a predetermined threshold stored in the storage unit 53, the supply destination of the separated gas is determined to be the propulsion machinery

engine 2. Accordingly, when the quantity of heat of the separated gas is high and the separated gas can be suitably combusted in the propulsion machinery engine 2, the separated gas can be guided to the propulsion machinery engine 2 and suitably combusted.

On the other hand, when the quantity of heat of the separated gas is low and the separated gas cannot be suitably combusted in the propulsion machinery engine 2 (in other words, when the quantity of heat of the separated gas is less than a predetermined threshold stored in the storage unit 53), the separated gas is guided to the boiler 15, the separated gas can be subjected to a combustion process, and energy generated due to the combustion process can be utilized for generating steam.

As described above, in the present embodiment, the separated gas can be guided to a supply destination in accordance with the quantity of heat. Further, since energy generated by combustion can be utilized even when the separated gas is supplied to any of the supply destinations, the energy efficiency can be improved.

{0060}

It may be considered to provide a combustion processing device such as a gas combustion unit (GCU) used for only the combustion process of a separated gas that is not suitably combusted in the propulsion machinery engine 2. However, the

ship 1 may be provided with a boiler used for generating steam used in the ship when it is necessary to generate steam used in the ship. In such a case, for the configuration provided with a combustion processing device, it is required to provide both the combustion processing device and the boiler in the ship 1. On the other hand, in the present embodiment, the separated gas that is not suitably combusted in the propulsion machinery engine 2 can be combusted in the boiler 15, and steam can be generated. In this configuration, it is not required to provide a combustion processing device. Therefore, the configuration can be simplified compared to the configuration provided with a combustion processing device.

[Modified Example]

{0061}

Next, a modified example of the present embodiment will be described.

The present modified example differs from the embodiment described above in that, instead of the calorimeter 35, a nitrogen content measuring machine (nitrogen content measurement unit) that measures the nitrogen content of the separated gas is provided in the separated gas pipe 33, and in that an upper limit value of the nitrogen content of fuel that can be suitably combusted in the propulsion machinery engine 2 is stored in the storage unit 53 as a predetermined threshold. Further, the present modified example differs from the

embodiment described above in that the determination unit 51 determines that the supply destination of the separated gas is the propulsion machinery engine 2 if the nitrogen content of the separated gas is less than a predetermined threshold.

{0062}

According to the present modified example, the supply destination of the separated gas can be a suitable supply destination in terms of nitrogen content. In details, in the present modified example, if the nitrogen content of the separated gas is greater than a predetermined threshold stored in the storage unit 53, the supply destination of the separated gas is determined to be the boiler 15. Accordingly, when the nitrogen content of the separated gas is high and the separated gas is not suitably combusted in the propulsion machinery engine 2, the separated gas can be suitably combusted in the boiler 15. Further, the nitrogen content of the separated gas is lower than the predetermined threshold stored in the storage unit 53, the supply destination of the separated gas is determined to be the propulsion machinery engine 2. Accordingly, when the nitrogen content of the separated gas is low and the separated gas can be suitably combusted in the propulsion machinery engine 2, the separated gas can be suitably combusted in the propulsion machinery engine 2.

{0063}

As described above, since nitrogen is less likely to be liquefied and the separated gas tends to have a high nitrogen content, the supply destination is determined in terms of nitrogen content, and the separated gas can be supplied to a supply destination in accordance with the component of the separated gas in a more direct manner. Therefore, the supply destination of the separated gas can be a more suitable supply destination in terms of nitrogen content.

{0064}

Note that the present invention is not limited to the embodiment described above and can be modified as appropriate within the scope not departing from the spirit thereof.

{0065}

For example, when steam is generated not only in the economizer 6 but also in the boiler 15 by forming flame in the furnace 38 of the boiler 15 (that is, when reheating is performed in the boiler 15), the supply destination of the separated gas may be determined based on a measurement result from the pressure meter 41 that measures the steam pressure in the steam drum 39 of the boiler 15. In details, if the pressure measured by the pressure meter 41 is lower than a predetermined threshold, the determination unit 51 may determine that the supply destination of the separated gas is the boiler 15. The predetermined threshold may be, for example, a setting value at which a steam amount required in a

ship can be ensured. Further, instead of the predetermined threshold, the steam amount required in a ship may be acquired sequentially,. If the steam amount is less than a pressure in accordance with the required steam amount, the supply destination of the separated gas may be determined to be the boiler 15.

{0066}

With such a configuration, when steam is not suitably generated in the boiler 15, the separated gas can be guided to the boiler 15. Therefore, steam can be generated suitably and stably in the boiler 15.

{0067}

Further, when reheating is performed in the boiler 15, the supply destination of the separated gas may be determined to be the boiler 15. In other words, during reheating in the boiler 15, the separated gas may be used as fuel of the boiler 15 preferentially over the fuel oil supplied via a fuel oil pipe (not illustrated) and the boil-off gas supplied via the boiler supply pipe 19.

Such a configuration can reduce the amount of another fuel for forming flame (a fuel oil or the boil-off gas supplied via the boiler supply pipe 19).

{0068}

Further, although the example in which the first valve 19a to the third valve 36a are operated by the control device

50 has been described in the embodiment described above, the present invention is not limited thereto. For example, the first valve 19a to the third valve 36a may be opened or closed by operations performed by an operator.

{Reference Signs List}

{0069}

1 ship

2 propulsion machinery engine

3 tank

3a discharge pipe

4 boil-off gas processing system

5 power generating diesel engine

6 economizer

11 supply pipe

12 compressor unit

12a high pressure compressor

13 re-liquefaction device

14 gas-liquid separator

15 boiler

16 generating engine supply pipe

17 circulation pipe

17a circulation pipe valve

19 boiler supply pipe

19a first valve

20 extraction pipe

20a extraction pipe valve

21 liquefying compressor

21a pipe

22 heat exchanger

23 expansion turbine

24 motor

25 drive shaft

26 first re-liquefaction pipe

27 second re-liquefaction pipe

27a re-liquefaction pipe valve

28 extraction pipe

29 first cooling source gas pipe

30 second cooling source gas pipe

31 LNG pipe

31a pump

32 re-circulation pipe

32a re-circulation pipe valve

33 separated gas pipe

33a second valve

34 separated gas pipe valve

35 calorimeter

36 branch pipe

36a third valve

38 furnace

39 steam drum

40 water drum

41 pressure meter

42 steam pipe

43 supply water pipe

44 pump

50 control device

51 determination unit

52 switch control unit

{CLAIMS}

{Claim 1}

A boil-off gas processing system comprising:

a boiler configured to combust a boil-off gas generated in a tank storing a liquefied gas and generate steam;

a re-liquefaction device configured to perform a liquefaction process on the boil-off gas generated in the tank;

a separator unit configured to separate, into a gas phase and a liquid phase, a boil-off gas in a gas-liquid mixture state on which the liquefaction process has been performed by the re-liquefaction device;

a first pipe configured to guide a gas-phase boil-off gas separated by the separator unit to a propulsion machinery internal-combustion engine configured to combust a boil-off gas;

a second pipe configured to guide the gas-phase boil-off gas separated by the separator unit to the boiler; and

a switch unit configured to switch whether to guide the gas-phase boil-off gas separated by the separator unit to the propulsion machinery internal-combustion engine or to the boiler.

{Claim 2}

The boil-off gas processing system according to claim 1 further comprising:

a nitrogen content measurement unit configured to measure a nitrogen content of the gas-phase boil-off gas separated by the separator unit;

a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the nitrogen content measured by the nitrogen content measurement unit; and

a switch control unit configured to control the switch unit so that the gas-phase boil-off gas separated by the separator unit is supplied to the supply destination determined by the determination unit.

{Claim 3}

The boil-off gas processing system according to claim 1 further comprising:

a heat quantity measurement unit configured to measure a quantity of heat of the gas-phase boil-off gas separated by the separator unit;

a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the quantity of heat measured by the heat quantity measurement unit; and

a switch control unit configured to control the switch unit so that the gas-phase boil-off gas separated by the separator unit is supplied to the supply destination determined by the determination unit.

{Claim 4}

The boil-off gas processing system according to claim 1 further comprising:

a pressure measurement unit configured to measure a pressure of the boiler;

a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit based on the pressure measured by the pressure measurement unit when flame is formed in the boiler; and

a switch control unit configured to control the switch unit so that a boil-off gas is supplied to the supply destination determined by the determination unit,

wherein when the pressure measured by the pressure measurement unit is lower than a predetermined threshold, the determination unit determines that a supply destination of the gas-phase boil-off gas separated by the separator unit is the boiler.

{Claim 5}

The boil-off gas processing system according to claim 1 further comprising:

a determination unit configured to determine a supply destination of the gas-phase boil-off gas separated by the separator unit; and

a switch control unit configured to control the switch unit so that a boil-off gas is supplied to the supply

destination determined by the determination unit,

wherein when flame is formed in the boiler, the determination unit determines that a supply destination of the gas-phase boil-off gas separated by the separator unit is the boiler.

{Claim 6}

A ship comprising the boil-off gas processing system according to any one of claims 1 to 5.