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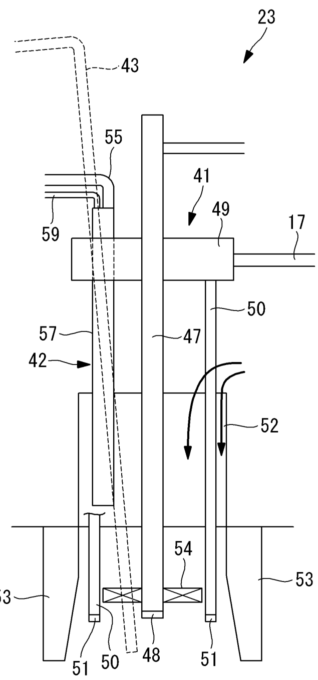
(54) **BOILER, BOILER SYSTEM, AND BOILER OPERATION METHOD**

(57) An object is to make it possible to handle boil-off gas and, at the same time, utilize the energy of the boil-off gas. A boiler is supplied with boil-off gas that has been generated in an LNG tank storing LNG and is provided with a burner (23) that burns the boil-off gas. The burner (23) has a continuous discharge igniter and an intermittent discharge igniter (43) which has a higher frequency of sparks during ignition than the continuous discharge igniter (56). The intermittent discharge igniter (43) is used to process the boil-off gas in the boiler.

FIG. 2A



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Description

[Technical Field]

[0001] The present invention relates to a boiler, a boiler system, and a method of operating a boiler.

[Background Art]

[0002] LNG carriers transport liquefied natural gas (LNG) with an LNG tank filled with LNG. Since LNG with which the LNG tank is filled has a low vaporization temperature, a large amount of boil-off gas is generated due to evaporation of LNG during the voyage of the LNG carrier under the influence of the outside air temperature and the like. The pressure of the LNG tank rises when the boil-off gas is generated inside the LNG tank. The pressure inside the LNG tank is appropriately maintained typically by consumption of the boil-off gas by a main machine engine or the like of the LNG carrier. When the main machine or the like of the LNG carrier cannot handle all of the boil-off gas, the boil-off gas is burned by a gas combustion unit (GCU) or the like so as to prevent the rise in the pressure inside the LNG tank. An LNG carrier described in PTL 1 is the one that is equipped with such a device.

[0003] PTL 1 discloses an LNG carrier equipped with a gas burner provided downstream of an LNG storage tank. In the LNG carrier described in PTL 1, when the operation of an evaporative gas re-liquefaction device is stopped, the pressure of the LNG storage tank rises due to the evaporative gas (boil-off gas) generated inside the LNG storage tank and, when the pressure exceeds the set safety pressure, the evaporative gas (boil-off gas) is sent to a gas burner (GCU) to be burned and incinerated.

[0004] There is also an LNG carrier having a boiler that burns boil-off gas generated inside the LNG tank. PTL 2 discloses a conventional boiler for burning boil-off gas.

[Citation List]

[Patent Literature]

[0005]

[PTL 1] the Publication of Japanese Patent No. 4563420

[PTL 2] Japanese Unexamined Patent Application, Publication No. H04-046892

[Summary of Invention]

[Technical Problem]

[0006] Meanwhile, according to the configuration of PTL 1, the energy of the boil-off gas cannot be effectively utilized because the boil-off gas is simply burned and incinerated in the GCU.

[0007] The conventional boiler which burns boil-off gas as in PTL 2 includes only one type of ignition device that performs ignition of a burner provided in the boiler. In order to burn the boil-off gas in the boiler, it is necessary to selectively use multiple devices associated with the ignition of the burner according to the conditions in the boiler and the LNG tank. However, since the conventional boiler includes only one type of ignition device, redundancy of the ignition device has been low and multiple ignition devices have not been able to be selectively used according to the conditions in the boiler and the LNG tank.

[0008] The present invention has been made in view of such circumstances and an object of the present invention is to provide a boiler, a boiler system, and a method of operating a boiler that are capable of handling boil-off gas and simultaneously utilizing energy of the boil-off gas.

[Solution to Problem]

[0009] In order to solve the above-described problem, a boiler, a boiler system, and a method of operating a boiler according to the present invention adopt the following solutions.

[0010] The boiler according to an aspect of the present invention is a boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel, the boiler including a burner that burns the boil-off gas, the burner including a first ignition device and a second ignition device having a higher frequency of sparks during ignition than the first ignition device.

[0011] According to the above-described configuration, the boil-off gas generated in the fuel tank is supplied to the boiler. By virtue of this, the boil-off gas generated in the fuel tank can be burned by the boiler. Accordingly, the boil-off gas can be processed without providing a dedicated device (GCU or the like) for combustion of the boil-off gas and, at the same time, steam can be generated by the energy of the boil-off gas.

[0012] According to the above-described configuration, the burner has the first ignition device and the second ignition device which has a higher frequency of sparks during ignition than the first ignition device. Since the second ignition device has a higher frequency of sparks during ignition than the first ignition device, the second ignition device has to bear a larger load at the time of the ignition and more susceptible to wear than the first ignition device. That is, the opposite of this fact applies to the first ignition device, for the first ignition device has a lower frequency of sparks during ignition than the second ignition device, so that the first ignition device is less susceptible to wear than the second ignition device. In this manner, the burner includes ignition devices differing from each other in their characteristics. Accordingly, the boil-off gas can be properly burned and steam can be generated by selectively using one of the multiple ignition devices having different characteristics depending on the conditions in the boiler and the fuel tank, and the product life of the ignition device can be extended.

[0013] In the boiler according to an aspect of the present invention, the second ignition device may be used to start combustion by the boil-off gas in the burner.

[0014] When the boil-off gas is generated in the fuel tank and the pressure inside the fuel tank increases, it is possible that the fuel tank is damaged. As a result, in a case where the boil-off gas is burned and processed to lower the pressure inside the fuel tank, it is necessary to burn the boil-off gas quickly when the pressure inside the fuel tank becomes equal to the threshold pressure smaller by a predetermined value than the pressure at which the fuel tank may be damaged. Hence, when the boil-off gas is to be burned and processed, the time needed for ignition of the burner is preferably shorter. According to the above-described configuration, the second ignition device is used when the boil-off gas is burned. Since the second ignition device can perform ignition in a shorter time than the first ignition device, the boil-off gas can be burned quickly. Accordingly, in the boiler, the boil-off gas can be burned and processed and the pressure inside the fuel tank can be appropriately maintained at a level equal to or lower than the predetermined value.

[0015] The boiler according to an aspect of the present invention may further include a steam drum that contains steam inside, and the first ignition device may be used to start boosting of a steam pressure in the steam drum by the combustion of the burner.

[0016] In a case where the boil-off gas is burned in the boiler in a state where the steam pressure inside the steam drum is low, it is possible that the boiler becomes overloaded. Also, due to the boiler being overloaded, the amount of the boil-off gas burned and processed in the boiler may be restricted, which makes it difficult to burn and process a predetermined amount of boil-off gas. Hence, when the boil-off gas is burned in the boiler, it is necessary to perform boosting of the steam pressure inside the steam drum if the steam pressure inside the steam drum is not sufficient. According to the above-described configuration, the first ignition device is used when the boosting of the pressure inside the steam drum is performed. As a result, the second ignition device which is more susceptible to damage than the first ignition device does not need to be used to perform boosting of the steam pressure inside the steam drum. Accordingly, the frequency of use of the second ignition device can be reduced, and the product life of the second ignition device can be extended.

[0017] The boiler system according to an aspect of the present invention is a boiler system that includes the above-described boiler, and further includes a drum pressure sensing means that senses a steam pressure in the steam drum; a tank pressure sensing means that senses a pressure in the fuel tank; a time-to-reach-target-pressure computation unit that computes a time for the steam pressure in the steam drum to reach a target steam pressure on the basis of the steam pressure in the steam drum sensed by the drum pressure sensing means and a target pressure in the steam drum, the target pressure being a steam pressure at which the boil-off gas is burned; a time-to-reach-predetermined-pressure computation unit that computes a time for the pressure in the fuel tank to reach a predetermined pressure on the basis of the pressure in the fuel tank sensed by the tank pressure sensing means and a predetermined pressure in the fuel tank, the predetermined pressure being a pressure at which the boil-off gas is supplied to the fuel tank; an ignition timing computation unit that computes an ignition timing such that the steam pressure in the steam drum is equal to the target steam pressure when the pressure in the fuel tank reaches the predetermined pressure, the ignition timing being computed on the basis of the time to reach the target pressure computed by the time-to-reach-target-pressure computation unit and the time to reach the predetermined pressure computed by the time-to-reach-predetermined-pressure computation unit; and an ignition control means that causes the first ignition device to light the burner at the ignition timing computed by the ignition timing computation unit and starts the boosting of the steam pressure in the steam drum.

[0018] According to the above-described configuration, the burner is lit such that the steam pressure inside the steam drum becomes equal to the target pressure when the pressure in the fuel tank becomes equal to the predetermined pressure at which the boil-off gas is supplied to the boiler. Accordingly, when the boil-off gas is burned in the boiler, the steam pressure inside the steam drum can be made to be the steam pressure sufficient for combustion of the boil-off gas, and the boiler can be prevented from being overloaded because of the boiler steam pressure failing to reach the target steam pressure, so that the boil-off gas can be burned appropriately. In addition, as the amount of generation of the boil-off gas generated inside the fuel tank, i.e., the tendency of pressure rise in the fuel tank, may vary depending on the conditions such as maritime environment, it may not be possible to be in time for the start of combustion of the boil-off gas if the boosting of the pressure of the boiler is started only based on the predetermined pressure inside the fuel tank. According to the above-described configuration, on the basis of the pressure in the fuel tank that has been sensed, the ignition timing is computed such that the steam pressure inside the steam drum becomes equal to the target steam pressure when the pressure in the fuel tank becomes equal to the predetermined pressure. Accordingly, when the pressure in the fuel tank reaches the predetermined pressure, boosting of the steam pressure inside the steam drum to the target pressure will have already been completed, so that the boil-off gas can be quickly supplied to the boiler to be burned and the pressure inside the fuel tank can be reduced. The predetermined pressure is, for example, a threshold pressure smaller by a predetermined value than the pressure at which the fuel tank may be damaged.

[0019] According to the above-described configuration, the time for the pressure in the fuel tank to reach the predetermined pressure is computed and the burner inside the steam drum is lit in advance to boost the steam pressure inside the steam drum, and the state of the target pressure is entered so as to be in agreement with the time at which the pressure in the fuel tank reaches the predetermined pressure. In this manner, the boosting of the steam pressure inside the steam drum is performed in accordance with the speed of the pressure rise in the fuel tank, and it is not necessary to maintain the steam pressure inside the steam drum always in the high-pressure state in order to burn the boil-off gas. Accordingly, the period of time in which the boiler operates at a high pressure is shortened and the amount of consumption of fuel (marine gas oil (MGO) or the like) at the boiler can be reduced as compared with a boiler system which always maintains the high-pressure state such that the boil-off gas can be processed.

[0020] A method of operating a boiler according to an aspect of the present invention is a method of operating a boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel, the method including a boosting step of lighting a burner provided in the boiler by a first ignition device and boosting a steam pressure in a steam drum by combustion by the burner; and a combustion step, after the boosting step, of lighting the burner by a second ignition device having a higher frequency of sparks during ignition than the first ignition device, and performing combustion by the boil-off gas in the burner.

[Advantageous Effects of Invention]

[0021] According to the present invention, the boil-off gas can be processed by the boiler and, at the same time, the energy of the boil-off gas can be utilized.

[Brief Description of Drawings]

[0022]

[Fig. 1] Fig. 1 is an overall configuration diagram of a system incorporated in a vessel according to an embodiment of the present invention.

[Fig. 2A] Fig. 2A is a longitudinal cross-sectional view illustrating a burner according to an embodiment of the present invention.

[Fig. 2B] Fig. 2B is a longitudinal cross-sectional view illustrating the burner according to the embodiment of the present invention, the burner being illustrated in a state where intermittent discharge igniter is elevated.

[Fig. 3] Fig. 3 is a bottom view illustrating the burner of Fig. 2A.

[Fig. 4] Fig. 4 is a longitudinal cross-sectional view illustrating the main part of the burner of Fig. 2A.

[Fig. 5] Fig. 5 is a graph showing a rise in pressure inside the steam drum of Fig. 1.

[Fig. 6] Fig. 6 is a graph showing a rise in pressure in the LNG tank of Fig. 1.

[Description of Embodiments]

[0023] An embodiment of a boiler, a boiler system, and a method of operating a boiler according to the present invention will be described hereinbelow with reference to the drawings.

[0024] As illustrated in Fig. 1, the boiler system according to the embodiment is implemented, for example, in an LNG carrier 2 that includes a gas-driven main machine engine 10. The LNG carrier 2 incorporates an LNG tank (fuel tank) 3 that stores liquefied natural gas (LNG), a boiler 4 that burns boil-off gas generated inside the LNG tank 3 and generates steam, an economizer 5 which collects heat of flue gas generated by the main machine engine 10 and generates steam, and a control system 6 that controls the boiler 4.

[0025] The boil-off gas generated inside the LNG tank 3 is supplied to the main machine engine 10, a power generation mixed-fuel combustion engine (not shown), a re-liquefaction device 15, etc. by a first supply compressor 13 provided in a boil-off gas supply pipe 12. The main machine engine 10 and the power generation mixed-fuel combustion engine burns the supplied boil-off gas to obtain driving force. The re-liquefaction device 15 compresses and cools the boil-off gas and thereby re-liquefies the boil-off gas so as to send the re-liquefied boil-off gas back to the LNG tank 3 via a return pipe 16.

[0026] Part of the boil-off gas generated inside the LNG tank 3 is supplied to the boiler 4 via a boil-off gas supply pipe 17 which connects the LNG tank 3 to the boiler 4. The boil-off gas supply pipe 17 includes a second supply compressor 18 for use in supplying the boil-off gas to the boiler 4 and a vent pipe 19 that releases the boil-off gas to the atmosphere. The LNG tank 3 includes a tank pressure gauge (tank pressure sensing means) 20 that senses the pressure in the LNG tank 3. The tank pressure gauge 20 transmits the acquired pressure in the LNG tank 3 to a cargo tank control system 40.

[0027] The boiler 4 includes a furnace (not shown), a steam drum 21 provided at an upper installation location, and a water drum 22 provided at a lower installation location. The furnace includes a burner 23 (see Fig. 2A), and combustion takes place in the furnace. The burner 23 is lit in the furnace and, when the water that has been supplied is heated inside the boiler 4, then the water rises from the water drum 22 at the lower installation location to the steam drum 21 at the upper installation location, and steam and water are separated at the steam drum 21. The steam drum 21 includes a drum pressure gauge (drum pressure sensing means) 24 that measures the steam pressure in the steam drum 21. The drum pressure gauge 24 transmits the steam pressure in the steam drum 21 that has been acquired to the control system 6. The steam drum 21 connects to a boiler steam supply pipe 28 for supplying the steam separated at the steam drum

21 to a power generation turbine 26, a condenser 27, steam-using devices, etc. A generator 29 is coupled to the rotation shaft of the power generation turbine 26 and the generator 29 generates power by the rotation force of the power generation turbine 26. The steam discharged from the power generation turbine 26 is supplied to the condenser 27 via a steam discharge pipe 30.

[0028] Two economizers 5 are provided, each of which causes heat exchange between the combustion flue gas discharged from the main machine engine 10 and the water so as to generate steam. The economizer 5 and the steam drum 21 are interconnected by an economizer steam supply pipe 32. The economizer steam supply pipe 32 supplies the steam and liquid generated in the economizer 5 to the steam drum 21. In the steam drum 21, the separated steam is supplied via the boiler steam supply pipe 28 to the individual devices such as the power generation turbine 26. The water drum 22 and the economizer 5 are interconnected by a water supply pipe 33. The water supply pipe 33 supplies the water in the water drum 22 to the economizer 5 by a pump 34 provided at a midstream location. It should be noted that a steam separator 35 may be independently provided to separate steam and liquid generated in the economizer 5 from each other at the steam separator 35. In this case, as illustrated by the broken lines in Fig. 1, the economizer 5 and the steam separator 35 are interconnected by the economizer steam supply pipe 36 and the water supply pipe 37. The steam generated at the economizer 5 is supplied to the steam separator 35 by the economizer steam supply pipe 36. The water supply pipe 37 supplies the water inside the steam separator 35 to the economizer 5 by a pump 38 provided at a midstream location. Although two economizers 5 are provided in this embodiment, one single economizer 5 may be provided or three or more economizers 5 may be provided.

[0029] In this embodiment, the boiler 4, the control system 6, the tank pressure gauge 20, the drum pressure gauge 24, etc. constitute the boiler system.

[0030] Next, the burner 23 provided in the furnace of the boiler 4 will now be described in detail with reference to Figs. 2A to 4.

[0031] As illustrated in Figs. 2A and 2B, the burner 23 includes a main burner 41 that forms flame inside the furnace, a pilot burner 42 that performs ignition of the main burner 41, and an intermittent discharge igniter (second ignition device) 43.

[0032] The main burner 41 includes an oil supply unit that supplies oil, a gas supply unit that supplies the boil-off gas, and an air passage that supplies combustion air.

[0033] The oil supply unit includes an oil supply pipe 47 in which the oil supplied from the oil supply device (not shown) via the oil supply channel 11 flows (see Fig. 1). The oil supply pipe 47 is formed of a cylindrical member extending in an up-and-down direction substantially at the center of the burner 23, in which the oil flows downward from above. The oil supply pipe 47 is arranged such that its lower end is positioned inside the furnace. A tip 48 is provided at the lower end of the oil supply pipe 47, and the oil that passed through the tip 48 is sprayed inside the furnace. The oil to be supplied may include, for example, light oil and heavy oil.

[0034] The gas supply unit has a gas supply chamber 49 connected to the boil-off gas supply pipe 17 in which the boil-off gas from the LNG tank 3 flows and five gas distribution pipes 50 extending downward from the gas supply chamber 49. The five gas distribution pipes 50 are, as illustrated in Fig. 3, arranged at equal intervals such that the oil supply pipe 47 is surrounded by the gas distribution pipes 50. As illustrated in Figs. 2A and 2B, the gas distribution pipes 50 are arranged such that their lower ends are positioned inside the furnace. A nozzle 51 is provided at the lower end of the gas distribution pipe 50 and the boil-off gas is squirted by the nozzle 51 into the furnace.

[0035] The air passage is provided such that it covers and encloses the oil supply pipe 47 and the gas distribution pipes 50. The air passage includes a cylindrical air passage unit 52 extending in the up-and-down direction, a cylindrical burner tile 53 extending downward from the lower end of the air passage unit 52, and a plurality of swirlers 54 provided inside the burner tile 53. The air passage unit 52 causes the combustion air supplied from an air supply device (not shown) to flow in the inside as indicated by the arrows in Figs. 2A and 2B. A cylindrical burner tile 53 is attached to the lower portion of the air passage unit 52, the upper portion of the inner circumferential surface of the burner tile 53 extends substantially in the vertical direction, and the lower portion of the inner circumferential surface is formed such that the diameter increases as it becomes closer to the center of the furnace. That is, the lower portion of the burner tile 53 defines a hollow section in the shape of a circular truncated cone. The multiple swirlers 54 are provided between the gas distribution pipes 50 and the outer circumferential surface of the oil supply pipe 47, and are arranged at equal intervals in the circumferential direction of the oil supply pipe 47.

[0036] The pilot burner 42 is arranged, as illustrated in Figs. 2A and 2B, near the main burner 41 such that the pilot burner 42 is in parallel with the oil supply pipe 47 of the main burner 41 and its lower end resides above the lower ends of the oil supply pipe 47 and the gas distribution pipes 50. The pilot burner 42 includes, as illustrated in Fig. 4, an oil supply pipe 55 extending in the up-and-down direction with oil flowing inside the oil supply pipe 55, a continuous discharge igniter 56 (first ignition device) extending substantially in parallel with the oil supply pipe 55, and a pilot burner main body 57 provided so as to cover the oil supply pipe 55 and the continuous discharge igniter 56. The oil supply pipe 55 causes the oil supplied from the oil supply pump (not shown) to flow inside the oil supply pipe 55. A tip 58 is provided at the lower end of the oil supply pipe 55, and the oil that has passed through the tip 58 is sprayed. The continuous discharge igniter 56 is coupled to the igniter cable 59 and discharges continuously by electricity from the igniter cable 59. The lower end section of the continuous discharge igniter 56 is bent so as to be disposed vertically below the lower end of the oil supply pipe 55. That is, the ignition of the pilot burner 42 is performed by discharging from the lower end section of the continuous discharge igniter 56 to the oil sprayed from the oil supply pipe 55. A flame is formed downward from the pilot burner 42. The flame is formed such that the lower end of the flame resides below the lower ends of the oil supply pipe 47 and the gas distribution pipes 50. That is, the oil or gas discharged from the oil supply pipe 47 or the gas distribution pipe 50 is ignited using the formed flame.

[0037] The intermittent discharge igniter 43 extends, as illustrated in Figs. 2A and 2B, near the main burner 41 in the up-and-down direction and is obliquely arranged such that its lower end is closer to the main burner 41. The lower end section of the intermittent discharge igniter 43 discharges intermittently. The intermittent discharge igniter 43 is supported such that it is movable by a predetermined distance upward and downward. At the time of the ignition, the lower end section of the intermittent discharge igniter 43 is arranged, as illustrated in Fig. 2A, such that it is positioned below the lower ends of the oil supply pipe 47 and the gas distribution pipe 50. Then, the lower end section of the intermittent discharge igniter 43 discharges to the oil or gas sprayed from the oil supply pipe 47 or the gas distribution pipes 50, so that ignition is performed. After the ignition, as illustrated in Fig. 2B, the lower end is elevated upward such that it is positioned above the lower ends of the oil supply pipe 47 and the gas distribution pipes 50. By being elevated after the ignition, the lower end of the intermittent discharge igniter 43 is prevented from being damaged by the flame of the main burner 41.

[0038] The intermittent discharge igniter 43 has more sparks during ignition than the continuous discharge igniter 56 which performs ignition of the pilot burner 42. More specifically, the intermittent discharge igniter 43 discharges at a voltage in the order of 1500 volts, creates sparks intermittently until completion of the ignition of the main burner 41, and creates continuously twenty sparks per second until the completion of the ignition. The continuous discharge igniter 56 discharges at a voltage in the order of 10,000 volts and maintains the ignition state until completion of the ignition of the pilot burner 42. That is, the continuous discharge igniter 56 has only one spark.

[0039] The ignition of the main burner 41 by the intermittent discharge igniter 43 is directly performed on the oil sprayed from the oil supply pipe 47 of the main burner 41 or the gas sprayed from the gas distribution pipes 50 using the spark discharged from the intermittent discharge igniter 43. Meanwhile, the ignition of the main burner 41 by the pilot burner 42 is performed using the flame of the pilot burner 42 lit by the discharge of the continuous discharge igniter 56. That is, the continuous discharge igniter 56 indirectly performs the ignition of the main burner 41 by way of the flame of the pilot burner 42. Specifically, the ignition of the main burner 41 by the continuous discharge igniter 56 requires many steps such as driving the oil supply device that feeds oil to the oil supply pipe 55, causing the oil to flow inside the oil supply pipe 55 and then lighting the pilot burner 42 by the continuous discharge igniter 56, and confirming the ignition of the pilot burner 42 and then lighting the main burner 41. As a result, the indirect ignition of the main burner 41 by the continuous discharge igniter 56 needs a longer time than the direct ignition of the main burner 41 by the intermittent discharge igniter 43.

[0040] The control system 6 has a time-to-reach-target-pressure computation unit that computes the time for the steam pressure inside the steam drum 21 to reach the target steam pressure Pb2; a time-to-reach-predetermined-pressure computation unit that computes the time for the pressure inside the LNG tank 3 to reach a predetermined pressure Pset; an ignition timing computation unit that computes the ignition timing Ts for the main burner 41 so as to ensure that the steam pressure inside the steam drum 21 becomes equal to the target steam pressure Pb2 when the pressure inside the LNG tank 3 becomes equal to the predetermined pressure Pset; and an ignition control means that lights the main burner 41 at the ignition timing Ts computed by the ignition timing computation unit and starts the boosting of the steam pressure in the steam drum 21.

[0041] The control system 6 is constituted, for example, by a central processing unit (CPU), a random access memory (RAM), a read-only memory (ROM), a computer-readable storage medium, etc. In addition, the series of processes to realize the various functions are stored, for example, in a storage medium or the like in the form of a program or programs, and the various functions are realized by reading the program(s) by the CPU onto the RAM or the like and executing information processing and calculation. It should be noted that configurations according to which the programs are installed in advance in the ROM or any other storage media, provided in a state where they are stored in a computer-readable storage media, or distributed by wired or wireless communications units, or any other relevant configurations may be adopted. The computer-readable storage medium may include a magnetic disc, a magneto-optical disc, a CD-ROM disc, a DVD-ROM disc, a semiconductor memory device, etc.

[0042] The time-to-reach-target-pressure computation unit computes a time to reach the target pressure Tr which is the time for the steam pressure Pb1 inside the steam drum to reach a target steam pressure Pb2 on the basis of the steam pressure Pb1 in the steam drum 21 acquired by the drum pressure gauge 24 and the target steam pressure Pb2 in the steam drum 21 which is the steam pressure at which combustion of the boil-off gas in the boiler 4 can take place.

[0043] More specifically, first, a graph (see Fig. 5) is read which indicates the time for the steam pressure inside the steam drum 21 stored in the control system 6 to be a predetermined steam pressure from the state of 0 bar. Next, this graph is used to acquire the time Tb2 to reach the target steam pressure Pb2 and the time Tb1 to reach the steam pressure Pb1 inside the steam drum 21 acquired by the drum pressure gauge 24. In addition, the time Tb1 to reach the steam pressure Pb1 inside the steam drum 21 acquired by the drum pressure gauge 24 is subtracted from the time Tb2 to reach the target steam pressure Pb2 to compute the time to reach the target pressure Tr.

[0044] Specifically, in this embodiment, the target steam pressure Pb2 is set to 16 bar. Accordingly, the time Tb2 to reach the target steam pressure Pb2 will be 2.5 h. At this point, if the steam pressure Pb1 inside the steam drum 21 acquired by the drum pressure gauge 24 is 3 bar, then the time Tb1 to reach the steam pressure Pb1 is 1.8 h, so that the time to reach the target pressure Tr will be computed as 0.7 h according to the calculation of 2.5(Tb2) - 1.8(Tb1).

[0045] It should be noted that the control is merely an example and the method of computing the time to reach the target pressure Tr should be based on the steam pressure Pb1 acquired by the drum pressure gauge 24 and the target steam pressure Pb2 but is not limited to this method. For example, another graph may be used instead of the graph indicative of the time for the steam pressure inside the steam drum to be the predetermined steam pressure from the 0 bar state.

[0046] The time-to-reach-predetermined-pressure computation unit computes, as illustrated in Fig. 6, the time to reach the predetermined pressure Tpset, which is the time for the pressure inside the LNG tank 3 to reach the predetermined pressure Pset, on the basis of the pressure inside the LNG tank 3 sensed by the tank pressure gauge 20 and the predetermined pressure Pset inside the LNG tank 3 which is the pressure at which the boil-off gas is supplied to the LNG tank 3. The predetermined pressure Pset is, for example, a threshold pressure that is smaller by a predetermined value than the pressure at which the fuel tank may be damaged. In this embodiment, it is set to 10 kPa.

[0047] More specifically, first, when the pressure inside the LNG tank 3 starts to rise, information thereof is acquired from the tank pressure gauge 20. Next, after one hour, the pressure P1 inside the LNG tank 3 is acquired again from the tank pressure gauge 20. P1 is defined as the rate of pressure rise Pt inside the LNG tank 3 per hour. Next, the predetermined pressure Pset is divided by the rate of pressure rise Pt to compute the time to reach the predetermined pressure Tpset.

[0048] Specifically, if the rise in the pressure inside the LNG tank 3 is moderate and Pt is 0.5 (Pt1 illustrated in Fig. 6), then the predetermined pressure Pset is divided by 0.5, so that the time to reach the predetermined pressure Tpset is computed as 20 h (T1 illustrated in Fig. 6). Also, if the pressure rise is rapid and Pt is 0.75 (Pt2 illustrated in Fig. 6), then the predetermined pressure Pset is divided by 0.75, so that the time to reach the predetermined pressure Tpset is computed as 15 h (T2 illustrated in Fig. 6).

[0049] It should be noted that the mode of control is merely an example and the method of computing the time to reach the predetermined pressure Tpset should be based on the steam pressure Pb1 inside the steam drum 21 and the target steam pressure Pb2 inside the steam drum 21 but is not limited to this method. For example, the intervals at which the pressure inside the LNG tank 3 is acquired may be shorter than one hour or longer than one hour.

[0050] The ignition timing computation unit computes the ignition timing Ts to ensure that the steam pressure inside the steam drum 21 becomes equal to the target steam pressure Pb2 when the pressure inside the LNG tank 3 becomes equal to the predetermined pressure Pset, the ignition timing Ts being computed on the basis of the time to reach the target pressure Tr inside the steam drum 21 computed by the time-to-reach-target-pressure computation unit and the time to reach the predetermined pressure Tpset inside the LNG tank 3 computed by the time-to-reach-predetermined-pressure computation unit. The ignition timing Ts is the time from the current time point to the start of the boosting of the pressure of the steam drum 21 of the boiler 4. That is, it indicates that the boosting is started in Ts h from the current time point.

[0051] More specifically, the ignition timing Ts is computed by subtracting the time to reach the target pressure Tr inside the steam drum 21 from the time to reach the predetermined pressure Tpset inside the LNG tank 3. For example, if the time to reach the predetermined pressure Tpset is 15 h and the time to reach the target pressure Tr is 0.7 h, then the ignition timing Ts will be 14.3 h.

[0052] The ignition control unit compares the time T from the current time point to the time to reach the predetermined pressure Tpset with the ignition timing Ts, transmits a signal to the continuous discharge igniter 56, etc. when Ts reaches T, and performs ignition of the main burner 41 by the pilot burner 42. Then, the ignition control unit starts the boosting of the steam pressure of the steam drum 21.

[0053] Next, the operation of this embodiment will be described with reference to Figs. 1, 2A, and 2B.

[0054] First, a case where the boil-off gas is burned and processed (boil-off gas processing mode) will be described. When steam is not being generated, the boiler 4 causes steam to flow in the heating coil 61 of the water drum 22 such that the pressure inside the steam drum 21 is maintained at about 3 bar and performs warm-up operation. When the rise in the pressure inside the LNG tank is detected by the tank pressure gauge 20, a signal is transmitted from the tank pressure gauge 20 to the cargo tank control system 40. When the cargo tank control system 40 has received the signal from the tank pressure gauge 20, then the cargo tank control system 40 sends a signal to start the boil-off gas processing mode to the control system 6. When the control system 6 has received the signal from the cargo tank control system 40, then the control system 6 starts the boil-off gas processing mode. When the boil-off gas processing mode is started, the control system 6 performs the above-described control and computes the ignition timing Ts. The time T from the current time point to the time to reach the predetermined pressure Tpset is compared with the ignition timing Ts, and the ignition control means sends a signal to the pilot burner 42 at the time point at which Ts has become larger than T.

[0055] The pilot burner 42 that has received the signal drives the oil supply device which supplies oil to the oil supply pipe 55, causes the oil to be squirted from the oil supply pipe 55, and drives the continuous discharge igniter 56 to start discharge. In this manner, the pilot burner 42 is lit to form a flame. When the control unit has confirmed the formation of the flame at the pilot burner 42, the main burner 41 drives the oil supply device that supplies oil to the oil supply pipe 47 and causes the oil to be squirted from the oil supply pipe 47. The squirted oil is ignited by the flame of the pilot burner 42, as a result of which the main burner 41 forms the flame. When the fact that the main burner 41 is lit has been confirmed, then the supply of the oil to the pilot burner 42 is stopped and the pilot burner 42 is extinguished. In this manner, boosting of the pressure of the boiler 4 is started and the pressure inside the boiler 4 is raised (boosting step). It should be noted that, when the flame is formed at the main burner 41, the boil-off gas instead of the oil can be used as the fuel. In this case, instead of causing the oil to be squirted from the oil supply pipe 47, the boil-off gas is squirted from the gas distribution pipe 50 and the ignition is performed by the flame of the pilot burner 42.

[0056] When the pressure of the boiler 4 is raised to 16 bar which is the target steam pressure Pb2, then the supply of the oil to the main burner 41 is stopped, and the main burner 41 is temporarily extinguished and the boiler 4 is placed in the wait state where the boil-off gas is burned and processed. After the signal of the amount of the boil-off gas to be processed (e.g., 1200 kg/h) has been sent from the cargo tank control system 40 to the control system 6, the boil-off gas flows from the LNG tank 3 into the gas supply chamber 49 via the boil-off gas supply pipe 17. The boil-off gas that has flown into the gas supply chamber 49 is distributed by the five gas distribution pipes 50 and squirted from the lower ends of the individual gas distribution pipes 50. At this point, substantially at the same time, the intermittent discharge igniter 43 is moved such that its lower end is positioned below the lower end of the gas distribution pipe 50 (see Fig. 2A). When the movement is completed, the intermittent discharge igniter 43 discharges intermittently and ignites the boil-off gas squirted by the gas distribution pipe 50. As a result, the main burner 41 forms the flame. When the fact that the main burner 41 was lit has been confirmed, then the intermittent discharge igniter 43 stops discharge and moves such that its lower end is positioned above the lower end of the gas distribution pipe 50 (see Fig. 2B). Steam is generated by the combustion gas generated with the flame of the main burner 41. In this manner, in the boiler 4, the boil-off gas is burned and processed, and steam is generated (combustion step).

[0057] Next, when steam is to be generated by the boiler 4 in a mode other than the boil-off gas processing mode (normal mode), then the main burner 41 is lit with the pilot burner 42 and steam is generated inside the boiler 4. During stoppage of the boiler 4, steam is made to flow in the heating coil 61 inside the water drum 22 and the warm-up operation is performed.

[0058] According to this embodiment, the following effects can be obtained.

[0059] In this embodiment, the boil-off gas generated in the LNG tank 3 is supplied to the boiler 4. As a result, the boil-off gas generated in the LNG tank 3 can be burned in the boiler 4. Accordingly, the boil-off gas can be processed without providing a dedicated device for combustion of the boil-off gas (e.g., a gas combustion unit (GCU) or the like) and, at the same time, steam can be generated with the energy of the boil-off gas. Since the generated steam is utilized for power generation by the power generation turbine 26 or for use in a steam-using device or the like, the energy efficiency of the LNG carrier 2 as a whole can be improved.

[0060] The burner 23 has the continuous discharge igniter 56 and the intermittent discharge igniter 43 having more frequent sparks during ignition than the continuous discharge igniter 56. Since the intermittent discharge igniter 43 performs the ignition directly for the main burner 41, the ignition can be performed in a shorter time than in a case where the ignition is performed indirectly for the main burner 41 by the pilot burner 42 that includes the continuous discharge igniter 56.

[0061] On the other hand, since the intermittent discharge igniter 43 has more frequent sparks at the time of the ignition than the continuous discharge igniter 56, the load at the time of the ignition is large and the intermittent discharge igniter 43 is more likely to be damaged than the continuous discharge igniter 56. Also, since the intermittent discharge igniter 43 has a larger number of times of sparks at one time of the ignition, the intermittent discharge igniter 43 is more likely to wear than the continuous discharge igniter 56 which performs the spark only once at one time of the ignition. Since the continuous discharge igniter 56 has smaller frequency of sparks at the time of the ignition than the intermittent discharge igniter 43, the continuous discharge igniter 56 is less likely to be damaged or worn than the intermittent discharge igniter 43. However, ignition of the main burner 41 using the continuous discharge igniter 56 is of an indirect nature necessitating many steps such as igniting the pilot burner 42 by the continuous discharge igniter 56, so that it takes a longer time for ignition than the direct ignition by the intermittent discharge igniter 43.

[0062] Thus, the burner 23 is equipped with ignition devices having different characteristics. Accordingly, the boil-off gas can be properly burned and steam can be generated by selectively using the ignition devices having differing characteristics depending on the situations in the boiler 4 and the LNG tank 3, and the product life can be extended and the redundancy of the ignition devices can be achieved.

[0063] When the boil-off gas is generated in the LNG tank 3 and the pressure inside the LNG tank 3 increases, then it is possible that the LNG tank 3 is damaged. Therefore, in a case where the boil-off gas is burned and processed to lower the pressure inside the LNG tank 3, it is necessary to burn the boil-off gas quickly when the pressure inside the LNG tank 3 becomes equal to the predetermined pressure Pset which is a threshold pressure smaller by a predetermined value than the pressure at which the LNG tank 3 may be damaged. Hence, when the boil-off gas is to be burned and processed, the time needed for ignition of the main burner 41 is preferably shorter. In this embodiment, the intermittent discharge igniter 43 is used when the boil-off gas is burned. Since the intermittent discharge igniter 43 can perform ignition in a shorter time than the pilot burner 42 which uses the continuous discharge igniter 56, the boil-off gas can be burned quickly. Accordingly, in the boiler 4, the boil-off gas can be burned and processed and the pressure inside the LNG tank 3 can be appropriately maintained at a level equal to or lower than the predetermined pressure Pset.

[0064] In a case where the boil-off gas is burned in the boiler 4 in a state where the steam pressure inside the steam drum 21 is low, it is possible that the boiler 4 becomes overloaded. Also, due to the boiler 4 being overloaded, the amount of the boil-off gas burned and processed in the boiler 4 may be restricted, which makes it difficult to burn and process a predetermined amount of boil-off gas. Hence, when the boil-off gas is burned in the boiler 4, it is necessary to perform boosting of the steam pressure inside the steam drum 21 if the steam pressure inside the steam drum 21 is not sufficient. In such a case, it is not in particular necessary to quickly perform the ignition of the main burner 41. In this embodiment, when the boosting of the pressure inside the steam drum 21 is performed, the pilot burner 42 that uses the continuous discharge igniter 56 is used. As a result, the intermittent discharge igniter 43 which is more susceptible to damage than the continuous discharge igniter 56 does not need to be used to perform boosting of the steam pressure inside the steam drum 21. Accordingly, the frequency of use of the intermittent discharge igniter 43 can be reduced, and the product life of the intermittent discharge igniter 43 can be extended. It should be noted that, as described above, in a case where boosting of the steam pressure inside the steam drum 21 is performed, it is not in particular necessary to quickly perform the ignition of the main burner 41, so that no problem arises because of performing the ignition by the pilot burner 42 which uses the continuous discharge igniter 56 with a longer time to complete the ignition than the intermittent discharge igniter 43.

[0065] The main burner 41 is lit such that the steam pressure inside the steam drum 21 becomes equal to the target steam pressure Pb2 when the pressure inside the LNG tank 3 becomes equal to the predetermined pressure Pset at which the boil-off gas is supplied to the boiler 4. Accordingly, when the boil-off gas is burned by the boiler 4, the steam pressure inside the steam drum 21 can be made to be the steam pressure sufficient for combustion of the boil-off gas, the boiler 4 can be prevented from being overloaded, and the boil-off gas can be burned appropriately. Also, since the steam pressure inside the steam drum 21 is equal to the target steam pressure Pb2 when the pressure inside the LNG tank 3 reaches the predetermined pressure Pset, the boil-off gas can be quickly supplied to the boiler 4 to be burned and the pressure inside the LNG tank 3 can be reduced.

[0066] Since the steam pressure inside the steam drum 21 is raised to be placed in the state of the target steam pressure Pb2 when the pressure inside the LNG tank 3 reaches a predetermined pressure, it is not necessary to maintain the steam pressure inside the steam drum 21 always in the high-pressure state in order to burn the boil-off gas. Accordingly, the consumption of energy of the boiler 4 can be reduced.

[0067] It should be noted that the present invention is not limited to the inventions according to the above-described embodiments, and modifications can be made thereto without the scope thereof is not deviated from. For example, while the example where the boil-off gas is ignited by the intermittent discharge igniter 43 has been described in the above-described embodiments, during failure or the like of the intermittent discharge igniter 43, the ignition may be performed with the pilot burner 42. During failure or the like of the pilot burner 42, ignition of the main burner may be performed by the intermittent discharge igniter 43 and the boosting of the pressure of the steam drum 21 of the boiler 4 may be performed. Redundancy can be achieved on the ignition device of the main burner 41 by such a configuration.

[0068] In a case where the generation of the steam at the economizer is not sufficient, the boiler 4 may be operated at a low load to compensate for the required steam of the LNG carrier 2. In this configuration, a low-load auxiliary boiler (donkey boiler, etc.), which is usually incorporated in the LNG carrier 2, does not need to be incorporated in the LNG carrier 2, so that the space in the LNG carrier 2 can be saved.

[Reference Signs List]

[0069]

3	LNG tank (fuel tank)
4	boiler
6	control system
17	boil-off gas supply pipe

20 tank pressure gauge (tank pressure sensing means)
21 steam drum
23 burner
24 drum pressure gauge (drum pressure sensing means)
41 main burner
42 pilot burner
43 intermittent discharge igniter (second ignition device)
47 oil supply pipe
50 gas distribution pipe
55 oil supply pipe
56 continuous discharge igniter (first ignition device)

Claims

1. A boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel, the boiler comprising a burner that burns the boil-off gas,
the burner including a first ignition device and a second ignition device having a higher frequency of sparks during ignition than the first ignition device.

2. The boiler according to claim 1, wherein the second ignition device is used to start combustion by the boil-off gas in the burner.

3. The boiler according to claim 2, further comprising a steam drum that contains steam inside, wherein the first ignition device is used to start boosting of a steam pressure in the steam drum by the combustion of the burner.

4. A boiler system comprising:

the boiler according to claim 3;
a drum pressure sensing means that senses a steam pressure in the steam drum;
a tank pressure sensing means that senses a pressure in the fuel tank;
a time-to-reach-target-pressure computation unit that computes a time for the steam pressure in the steam drum to reach a target steam pressure on the basis of the steam pressure in the steam drum sensed by the drum pressure sensing means and the target steam pressure in the steam drum, the target steam pressure being a steam pressure at which the combustion of the boil-off gas takes place;
a time-to-reach-predetermined-pressure computation unit that computes a time for the pressure in the fuel tank to reach a predetermined pressure on the basis of the pressure in the fuel tank sensed by the tank pressure sensing means and a predetermined pressure in the fuel tank, the predetermined pressure being a pressure at which the boil-off gas is supplied to the fuel tank;
an ignition timing computation unit that computes an ignition timing such that the steam pressure in the steam drum is equal to the target steam pressure when the pressure in the fuel tank reaches the predetermined pressure, the ignition timing being computed on the basis of the time to reach the target pressure computed by the time-to-reach-target-pressure computation unit and the time to reach the predetermined pressure computed by the time-to-reach-predetermined-pressure computation unit; and
an ignition control means that causes the first ignition device to light the burner at the ignition timing computed by the ignition timing computation unit and starts the boosting of the steam pressure in the steam drum.

5. A method of operating a boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel, the method comprising:

a boosting step of lighting a burner provided in the boiler by a first ignition device and boosting a steam pressure in a steam drum by combustion by the burner;
a combustion step, after the boosting step, of lighting the burner by a second ignition device having a higher frequency of sparks during ignition than the first ignition device, and performing combustion by the boil-off gas in the burner.

Amended claims under Art. 19.1 PCT

1. (amended) A boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel,
the boiler comprising a burner that burns the boil-off gas, and
a steam drum that contains steam inside, wherein the burner includes a first ignition device and a second ignition device having a higher frequency of sparks during ignition than the first ignition device,
the second ignition device is used to start combustion by the boil-off gas in the burner, and
the first ignition device is used to start boosting of a steam pressure in the steam drum by the combustion of the burner.

2. (deleted)

3. (deleted)

4. (amended) A boiler system comprising:

the boiler according to claim 1;
a drum pressure sensing means that senses a steam pressure in the steam drum;
a tank pressure sensing means that senses a pressure in the fuel tank;
a time-to-reach-target-pressure computation unit that computes a time for the steam pressure in the steam drum to reach a target steam pressure on the basis of the steam pressure in the steam drum sensed by the drum pressure sensing means and the target steam pressure in the steam drum, the target steam pressure being a steam pressure at which the combustion of the boil-off gas takes place;
a time-to-reach-predetermined-pressure computation unit that computes a time for the pressure in the fuel tank to reach a predetermined pressure on the basis of the pressure in the fuel tank sensed by the tank pressure sensing means and a predetermined pressure in the fuel tank, the predetermined pressure being a pressure at which the boil-off gas is supplied to the fuel tank;
an ignition timing computation unit that computes an ignition timing such that the steam pressure in the steam drum is equal to the target steam pressure when the pressure in the fuel tank reaches the predetermined pressure, the ignition timing being computed on the basis of the time to reach the target pressure computed by the time-to-reach-target-pressure computation unit and the time to reach the predetermined pressure computed by the time-to-reach-predetermined-pressure computation unit; and
an ignition control means that causes the first ignition device to light the burner at the ignition timing computed by the ignition timing computation unit and starts the boosting of the steam pressure in the steam drum.

5. A method of operating a boiler to which boil-off gas is supplied, the boil-off gas being generated in a fuel tank that stores fuel, the method comprising:

a boosting step of lighting a burner provided in the boiler by a first ignition device and boosting a steam pressure in a steam drum by combustion by the burner;
a combustion step, after the boosting step, of lighting the burner by a second ignition device having a higher frequency of sparks during ignition than the first ignition device, and performing combustion by the boil-off gas in the burner.

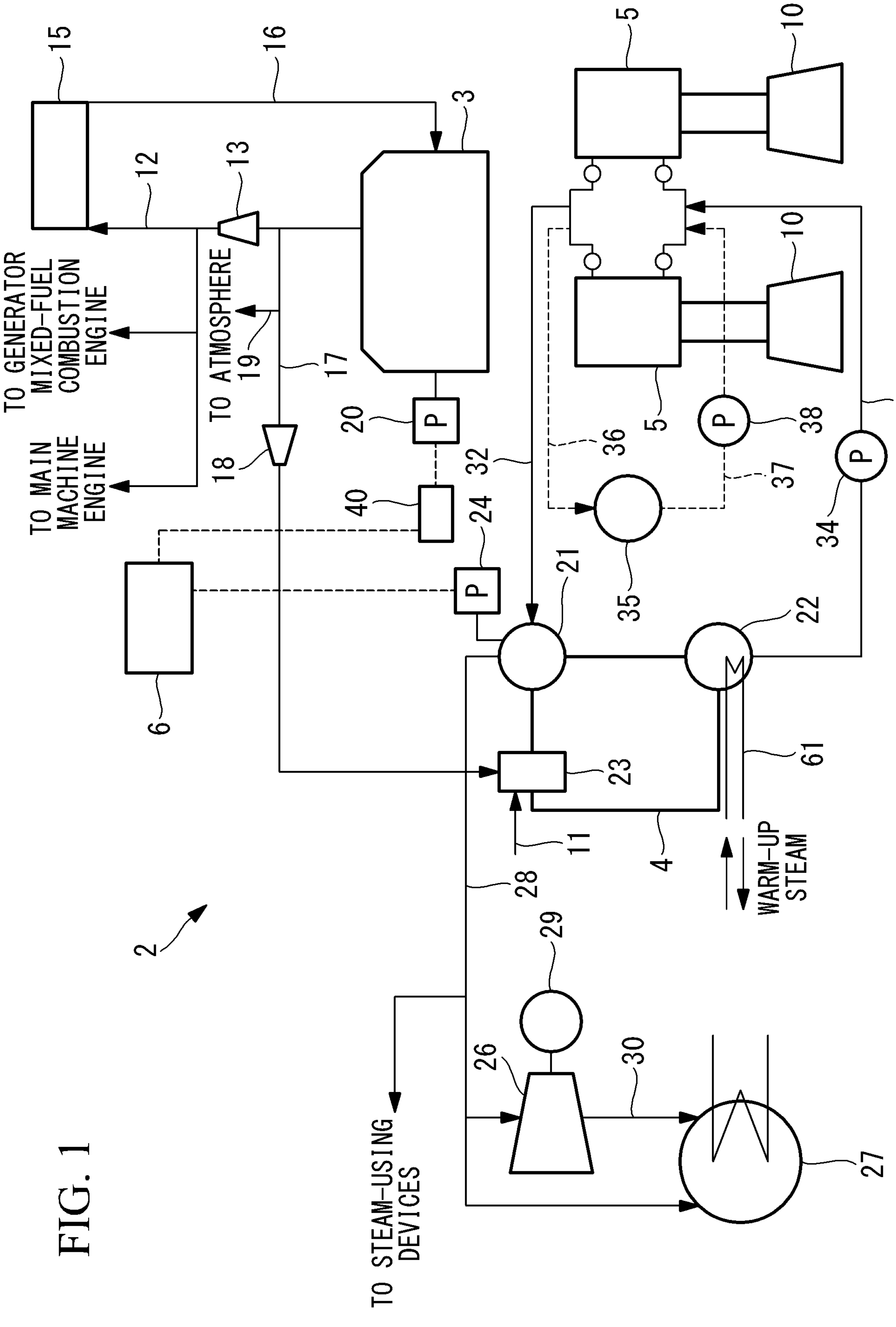
TO GENERATOR MIXED-FUEL COMBUSTION ENGINE
TO MAIN MACHINE ENGINE
TO ATMOSPHERE
TO STEAM-USING DEVICES
WARM-UP STEAM
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FIG. 1

FIG. 2A

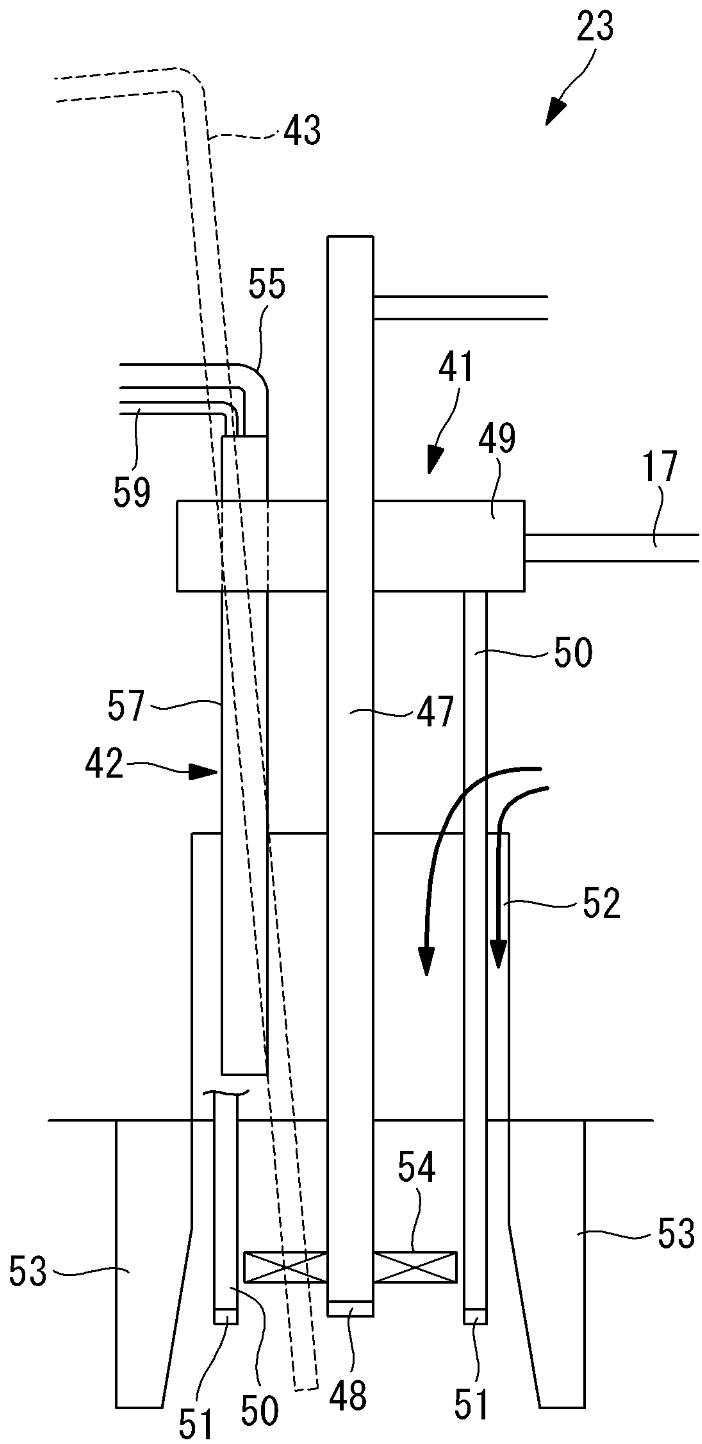


FIG. 2B

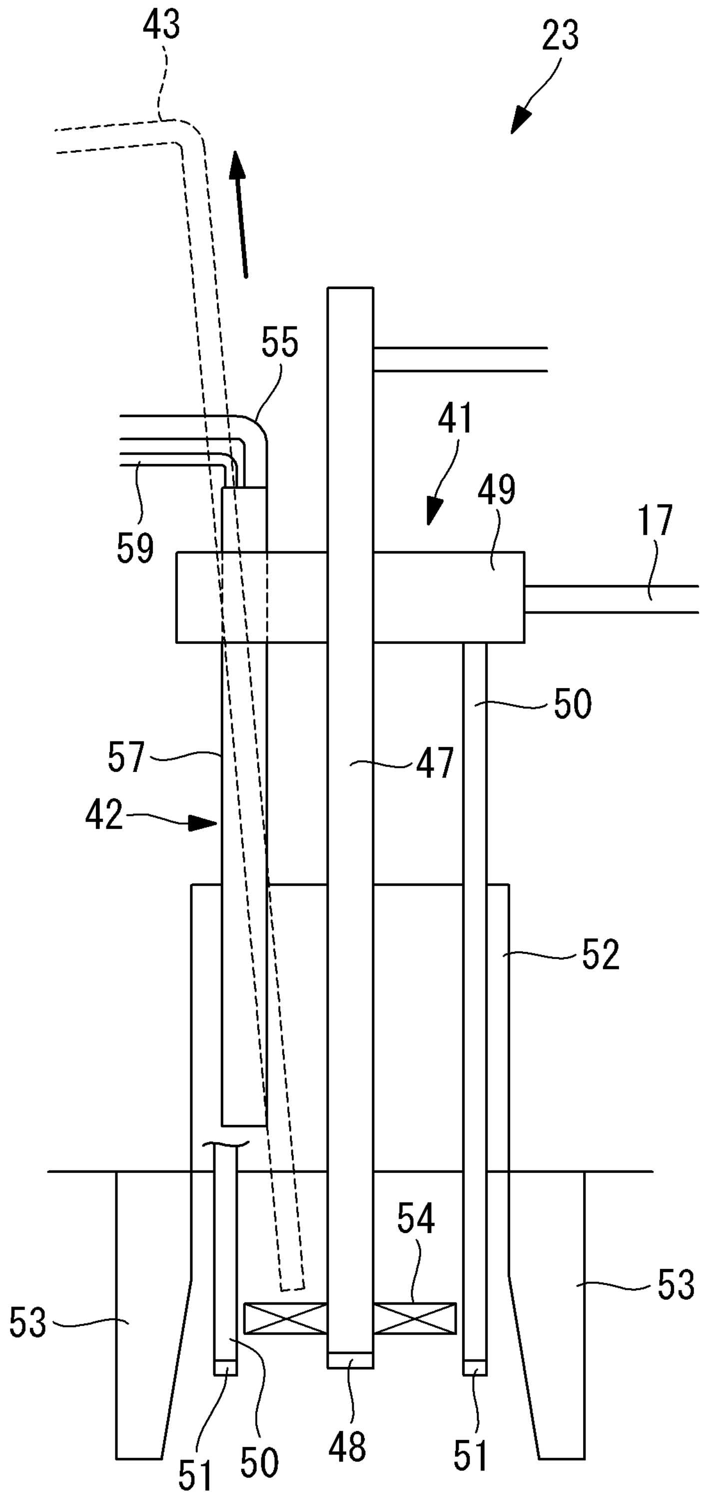


FIG. 3

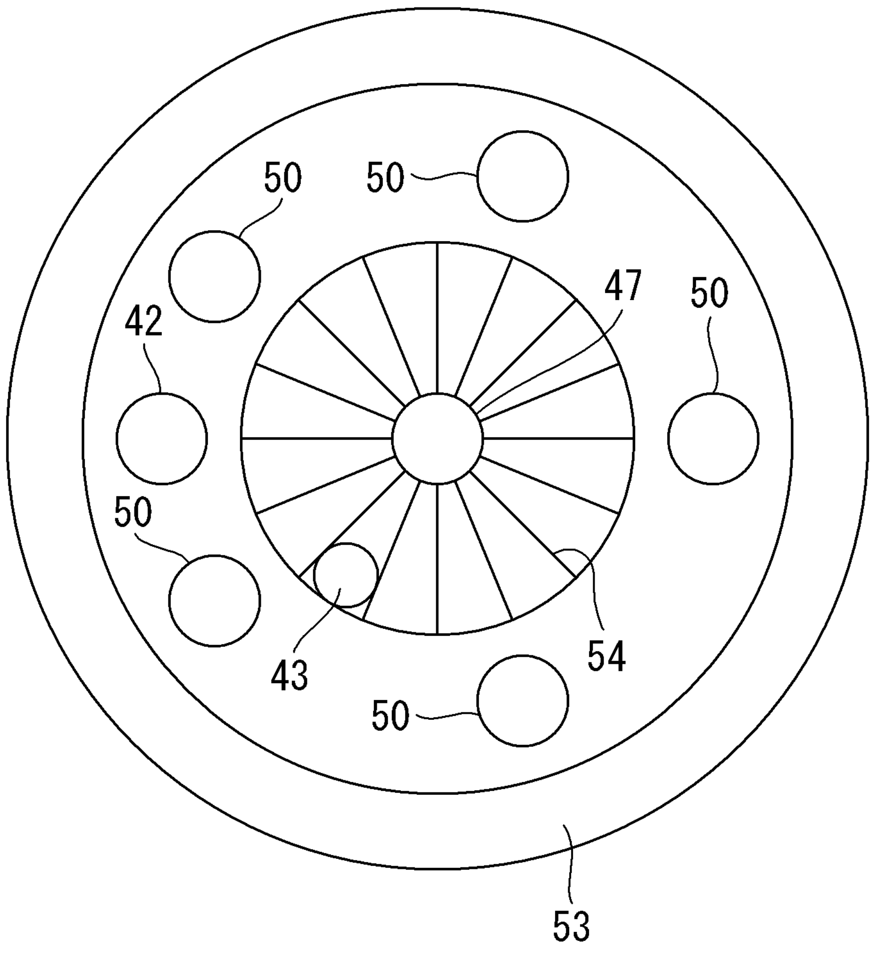


FIG. 4

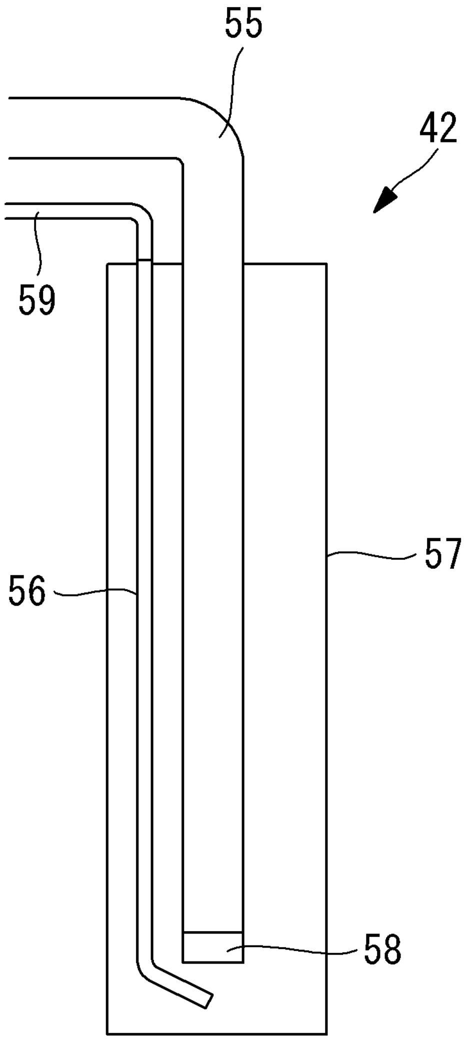


FIG. 5

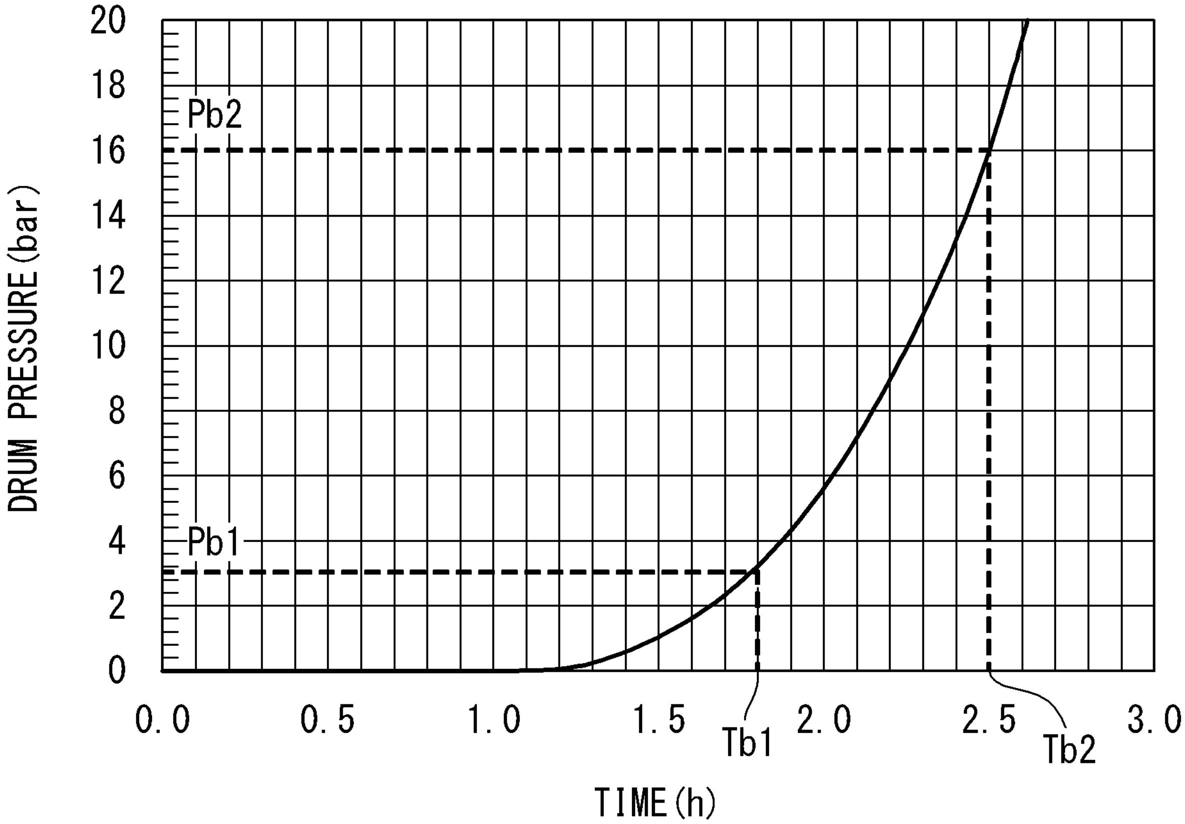
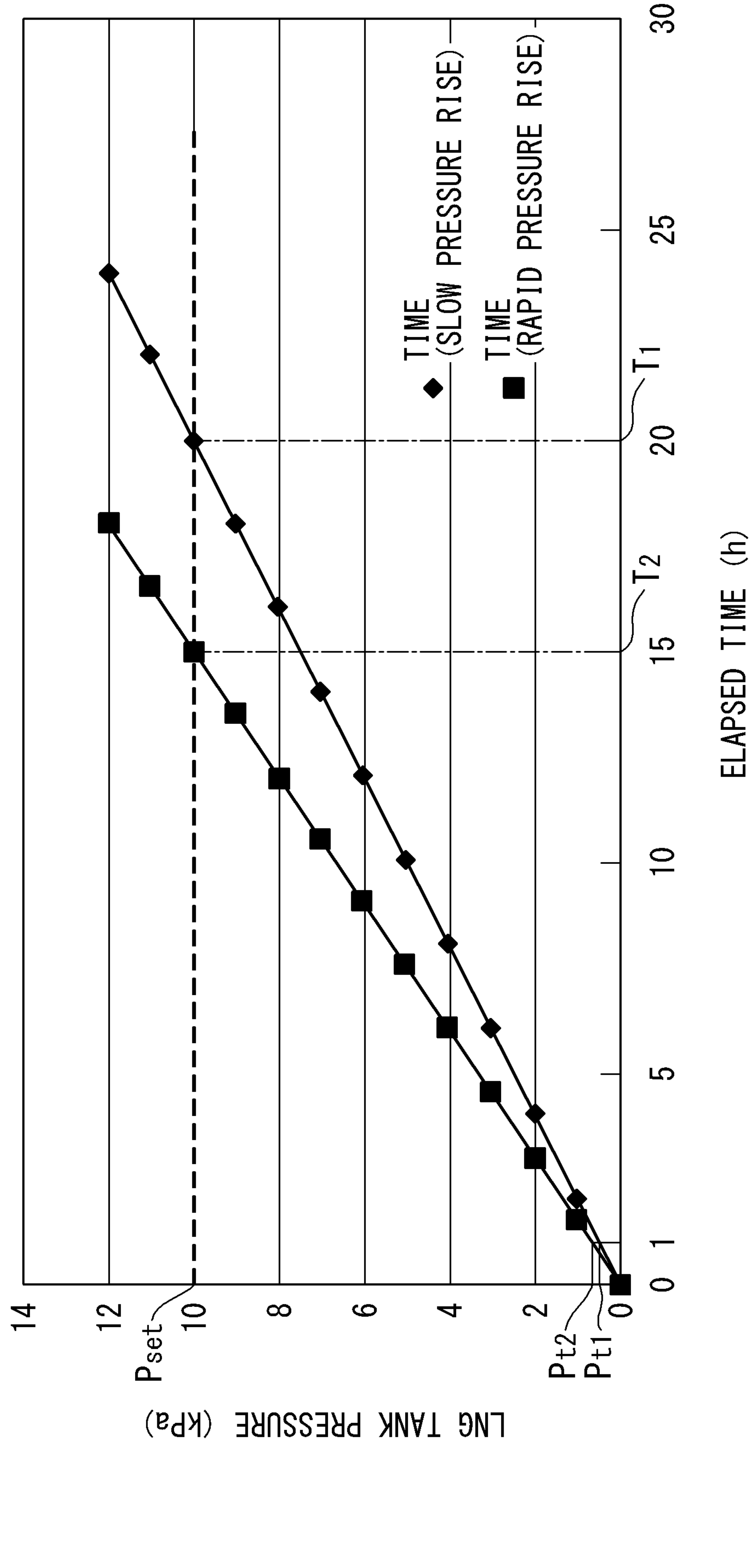

20
18
16
14
12
10
8
6
4
2
0
DRUM PRESSURE (bar)
Pb2
Pb1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Tb1
Tb2
TIME (h)

FIG. 6


LNG TANK PRESSURE (kPa)
ELAPSED TIME (h)
TIME (SLOW PRESSURE RISE)
TIME (RAPID PRESSURE RISE)
Pset
Pt2
Pt1
T1
T2
0
2
4
6
8
10
12
14
0
1
5
10
15
20
25
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/004249

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F23Q3/00(2006.01)i, F22B35/14(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F23Q3/00, F22B35/14, B63B25/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2012-117781 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 21 June 2012, paragraphs [0028]-[0045], fig. 1-3 (Family: none)	1-3 4-5
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 147820/1975 (Laid-open No. 061666/1977) (YOKOGAWA KOKU DENKI KK) 06 May 1977, specification, page 1, line 12 to page 5, line 4, lines 1-2 (Family: none)	1-3 4-5
Y	JP 51-140002 A (HITACHI, LTD.) 02 December 1976, page 1, lower left column, line 17 to page 2, upper left column, line 2, fig. 1 (Family: none)	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 April 2018 (13.04.2018)	24 April 2018 (24.04.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/004249

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 063640/1975 (Laid-open No. 143844/1976) (YOKOGAWA KOKU DENKI KK) 19 November 1976, specification, page 2, line 16 to page 4, line 13, drawings (Family: none)	1-5
A	WO 2008/030107 A1 (KENDAL, Stephen, Percy) 13 March 2008, page 5, line 21 to page 6, line 15, fig. 3 & NZ 549704 A & AU 2007293762 A1	1-5

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4563420 B **[0005]**
- JP H04046892 B **[0005]**