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Fuel cell ship

Abstract

A fuel cell ship includes a propulsion device that generates propulsive force on a hull by electric power, an electric power supply unit that supplies the electric power to the propulsion device, and a degradation rate control unit that adjusts a degradation rate. The electric power supply unit includes a plurality of fuel cells that generate electric power by an electrochemical reaction of fuel and at least one storage battery.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
8123577	12/2011	Riggs	440/6	H01M 12/06
8683937	12/2013	Sancoff	114/61.15	B63G 8/36
10364009	12/2018	Sako	N/A	H01M 8/04089
2006/0009092	12/2005	Krietzman	440/6	B63H 21/17
2006/0012248	12/2005	Matsushita et al.	N/A	N/A
2007/0122667	12/2006	Kelley	429/513	C01B 3/382
2010/0041285	12/2009	Riggs	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2908372	12/2017	EP	N/A
H07-050172	12/1994	JP	N/A
2015196411	12/2014	JP	N/A
2017-174565	12/2016	JP	N/A
2018-014291	12/2017	JP	N/A
2018-092815	12/2017	JP	N/A
2019-149267	12/2018	JP	N/A

OTHER PUBLICATIONS

European Search Report issued dated May 30, 2023 issued in EP Application No. 22175790.9. cited by applicant

Japanese Office Action dated Dec. 10, 2024 issued in JP Application No. 2021-092702. cited by applicant

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application is claims priority under 35 U.S.C. § 119 to JP Application No. 2021-092702 filed Jun. 2, 2021, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

(2) The present invention relates to a fuel cell ship.

BACKGROUND ART

(3) In the related art, a fuel cell ship in which a fuel gas (for example, hydrogen gas) is supplied from a fuel tank to a fuel cell and a propulsion device is driven by electric power generated by the fuel cell has been proposed (see, for example, Patent Document 1).

PRIOR ART DOCUMENT

Patent Document

(4) Patent Document 1: Japanese Unexamined Patent Application Publication No. 2018-92815

SUMMARY OF INVENTION

Technical Problem

(5) In the configuration of Patent Document 1, the fuel cell ship is equipped with one fuel cell, and thus if the fuel cell fails while the fuel cell ship is sailing, or if the fuel cell reaches the end of its equipment life, there is a risk that the fuel cell ship will not be able to continue sailing and will stop at sea.

(6) The present invention has been made to solve the above-mentioned problems, with an object of the present invention being to provide a fuel cell ship capable of avoiding a situation in which the fuel cell ship stops at sea when a fuel cell fails during sailing or when a fuel cell reaches the end of its equipment life during sailing.

Solution to Problem

(7) The fuel cell ship according to one aspect of the present invention includes a propulsion device that generates propulsive force on a hull by electric power, and an electric power supply unit that supplies the electric power to the propulsion device, and the electric power supply unit includes a plurality of fuel cells that generate electric power by an electrochemical reaction of fuel and at least one storage battery.

Advantageous Effects of Invention

(8) With the configuration described above, it is possible to avoid situations in which a fuel cell ship stops at sea while sailing even if fuel cells fail, or equipment life of the fuel cells is reached while the fuel cell ship is sailing.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. 1 is an explanatory diagram illustrating a schematic configuration of a fuel cell ship according to an embodiment of the present invention.

(2) FIG. 2 is a block diagram schematically illustrating a configuration of main units of the fuel cell ship.

(3) FIG. 3 is a block diagram schematically illustrating another configuration of the fuel cell ship.

(4) FIG. 4 is a time chart schematically illustrating a replacement plan for each fuel cell as an operation plan for the fuel cell ship.

- (5) FIG. 5 is a graph showing the relationship between the operating time and the cell voltage of the fuel cell for the case of low load operation in which degradation is suppressed and the case of high load operation in which degradation is promoted.
- (6) FIG. 6 is a graph showing the relationship between electric power generation output per fuel cell and the degradation progress rate.
- (7) FIG. 7 is a flowchart illustrating a flow of adjusting the degradation rate of the fuel cell.
- (8) FIG. 8 is a graph showing an example of a transition of the electric power load of the fuel cell ship with respect to the passage of time.
- (9) FIG. 9 is a graph schematically showing a change in the degradation rate with respect to the operating time of the fuel cell.
- (10) FIG. 10 is flowchart illustrating another flow of adjusting the degradation rate of the fuel cell.
- (11) FIG. 11 is an explanatory diagram schematically illustrating an internal structure of the fuel cell ship.

DESCRIPTION OF EMBODIMENTS

(12) An embodiment of the present invention will be described below based on the drawings. In this description, direction is defined as follows. First, a direction from the stern to the bow of the fuel cell ship is “front”, and a direction from the bow to the stern is “rear”. A horizontal direction perpendicular to a front-rear direction is defined as a left-right direction. At this time, when the fuel cell ship is moving forward, the left side is defined as “left” and the right side is defined as “right” when viewed from the operator. The upstream side in the gravity direction perpendicular to the front-back direction and the left-right direction is referred to as “up”, and the downstream side is referred to as “down”.

(13) [1. Schematic Configuration of Fuel Cell Ship]

(14) First, a configuration that will be a premise for a fuel cell ship SH according to the present embodiment will be described with reference to FIG. 1. FIG. 1 is an explanatory diagram illustrating a schematic configuration of the fuel cell ship SH. The fuel cell ship SH includes a hull 1 and a cabin 2. The cabin 2 is arranged on an upper surface of the hull 1.

(15) The fuel cell ship SH further includes a fuel cell system 3, a fuel gas storage unit 4, a storage battery system 5, a propulsion device 6, a plurality of pieces of peripheral equipment 11, and a control device 12. In FIG. 1, a control signal or a high voltage power supply line is indicated by a solid line, and a control signal or a low voltage power supply line is indicated by a dashed line.

(16) The fuel cell system 3 functions as a main power supply. The fuel cell system 3 consumes a fuel gas to generate electric power (specifically, DC electric power). The fuel gas is a combustible gas. Typically, the fuel gas is hydrogen gas. The fuel cell system 3 supplies generated electric power to the propulsion device 6 and the peripheral equipment 11. The fuel cell system 3 can also supply electric power to the storage battery system 5 to charge the storage battery system 5.

(17) The fuel gas storage unit 4 is a fuel storage unit that stores the fuel gas to be supplied to the fuel cell system 3. The supply of the fuel gas from the fuel gas storage unit 4 to the fuel cell system 3 is performed via a fuel gas supply pipe 32 described later (see FIG. 11).

(18) The storage battery system 5 functions as an auxiliary power source for supplying the stored electric power (specifically, DC electric power) to the propulsion device 6 and the peripheral equipment 11. By the storage battery system 5 functioning as an auxiliary power source, it is possible to compensate for a shortage of electric power supplied from the fuel cell system 3 to the propulsion device 6 or the like. The storage battery system 5 may convert the voltage into an appropriate voltage to supply electric power to the control device 12.

(19) The propulsion device 6 is driven by electric power supplied from at least one of the fuel cell system 3 and the storage battery system 5, and generates a propulsive force on the hull 1. That is, the fuel cell ship SH includes the propulsion device 6 that generates propulsive force on the hull 1 by electric power.

(20) The propulsion device 6 includes an electric power conversion device 6a, a propulsion motor

6b, and a propeller **6c**. The electric power conversion device **6a** converts the electric power supplied from the fuel cell system **3** into electric power according to the specifications of the propulsion motor **6b**. For example, the electric power conversion device **6a** converts DC electric power into AC electric power. In this case, the electric power conversion device **6a** has, for example, an inverter. The propulsion motor **6b** is driven by electric power (for example, AC electric power) supplied from the electric power conversion device **6a**. When the propulsion motor **6b** is driven, the rotational force of the propulsion motor **6b** is transmitted to the propeller **6c**. As a result, the propeller **6c** rotates, and a propulsive force is generated on the hull **1**. A configuration is also possible in which a marine gear is provided between the propulsion motor **6b** and the propeller **6c**. (21) Examples of the peripheral equipment **11** include a compressor, a solenoid valve, and a pump. Examples of the peripheral equipment **11** also include electrical equipment such as lighting equipment and air conditioning equipment, but the types of peripheral equipment **11** are not particularly limited.

(22) The control device **12** controls the fuel cell system **3**, the fuel gas storage unit **4**, the storage battery system **5**, the propulsion device **6**, and the plurality of pieces of peripheral equipment **11**. The control device **12** is composed of, for example, one or two or more computers. The computer is, for example, a Programmable Logic Controller (PLC), but may also be an Electronic Control Unit (ECU). The control device **12** is supplied with electric power from a battery (for example, a lead battery) (not illustrated) or the storage battery system **5**, via a device that converts electric power into an appropriate voltage.

(23) The control device **12** has a control unit **12a** and a storage unit **12b**. The control unit **12a** includes a processor such as a Central Processing Unit (CPU). The storage unit **12b** includes a storage device and stores data and computer programs. Specifically, the storage unit **12b** includes a main storage device such as a semiconductor memory and an auxiliary storage device such as a semiconductor memory, a solid state drive, and/or a hard disk drive. The storage unit **12b** may also include removable media. The storage unit **12b** corresponds to an example of a non-transitory computer-readable storage medium.

(24) The processor of the control unit **12a** executes a computer program stored in the storage device of the storage unit **12b**, to control the fuel cell system **3**, the fuel gas storage unit **4**, the storage battery system **5**, the propulsion device **6**, and the plurality of pieces of peripheral equipment **11**.

(25) [2. Configuration of Main Units of Fuel Cell Ship]

(26) FIG. 2 is a block diagram schematically illustrating the configuration of the main units of the fuel cell ship SH of the present embodiment. In FIG. 2, the dashed line path indicates the fuel gas supply path, and the solid line path indicates the electric power supply path or the supply path of control signals output by the control unit **12a**. The fuel cell ship SH includes an electric power supply unit **100**. The electric power supply unit **100** supplies electric power to the propulsion device **6** described above.

(27) The electric power supply unit **100** includes the fuel cell system **3**. The fuel cell system **3** includes a plurality of fuel cells **31**. The fuel cell **31** generates electric power (specifically, DC electric power) by an electrochemical reaction between the fuel gas and an oxidant gas. The fuel gas is an example of fuel supplied to the fuel cell **31** from a fuel tank **41** (described later) in the fuel gas storage unit **4**. The oxidant gas is air and the oxidant is oxygen. That is, the electric power supply unit **100** has the plurality of fuel cells **31** that generate electric power by the electrochemical reaction of fuel.

(28) The fuel cell **31** is a fuel cell stack composed of a plurality of stacked cells. For example, each cell of the fuel cell **31** has a solid polymer electrolyte membrane, an anode electrode, a cathode electrode, and a pair of separators. The solid polymer electrolyte membrane is sandwiched between the anode electrode and the cathode electrode. The anode electrode is a negative electrode (fuel electrode). The anode electrode includes an anode catalyst layer and a gas diffusion layer. The

cathode electrode is a positive electrode (air electrode). The cathode electrode includes a cathode catalyst layer and a gas diffusion layer. The anode electrode, the solid polymer electrolyte membrane, and the cathode electrode form a Membrane-Electrode Assembly (MEA). The pair of separators sandwich the membrane-electrode assembly. Each separator has a plurality of grooves. Each groove of one separator forms a flow path for the fuel gas. Each groove of the other separator forms a flow path for the oxidant gas.

(29) In the configuration described above of the fuel cell **31**, hydrogen included in the fuel gas is decomposed into hydrogen ions and electrons by the catalyst on the anode electrode side.

Hydrogen ions pass through the solid polymer electrolyte membrane and move to the cathode electrode side. On the other hand, the electrons move to the cathode electrode side through an external circuit. As a result, an electric current is generated (electricity is generated). On the cathode electrode side, oxygen included in the oxidant gas combines with the electrons that flow through the external circuit and hydrogen ions that pass through the solid polymer electrolyte membrane to generate water. The generated water is discharged outside the ship via a discharge pipe **31a** (see FIG. **11**).

(30) The fuel cell **31** supplies generated electric power to the propulsion device **6** and the peripheral equipment **11**. The fuel cell **31** may indirectly supply generated electric power to the propulsion device **6** and the peripheral equipment **11** via a circuit such as a DC/DC converter or the like.

(31) The electric power supply unit **100** further includes the storage battery system **5**. The storage battery system **5** includes a storage battery **51** that stores electric power. The storage battery **51** is, for example, a lithium secondary battery, but may also be a nickel-cadmium storage battery, a nickel-hydrogen storage battery, or the like. The number of storage batteries **51** is not particularly limited, and may be one or more. That is, the electric power supply unit **100** has at least one storage battery **51**.

(32) The capacity of the storage battery **51** can be appropriately set. If there are a plurality of storage batteries **51**, the storage batteries **51** may be connected in series or in parallel. The storage battery **51** supplies stored electric power to the propulsion device **6** and the peripheral equipment **11**.

(33) As described above, by the electric power supply unit **100** having the plurality of fuel cells **31** and at least one storage battery **51**, even if one of the plurality of fuel cells **31** fails for some reason or has reached the end of its equipment life while the fuel cell ship SH is sailing, it is possible to continue generating electricity by the remaining fuel cells **31**, and the electric power generated by the remaining fuel cells **31** can be supplied to the propulsion device **6** to operate the propulsion device **6**. Even if electric power generation is stopped in all the fuel cells **31** for some reason or due to reaching the equipment life, electric power stored in at least one storage battery **51** can be supplied to the propulsion device **6** to operate the propulsion device **6**. That is, even if at least one of the fuel cells **31** fails, or even if the equipment life is reached while the fuel cell ship SH is sailing, it is possible to avoid a situation in which the fuel cell ship SH stops at sea while sailing.

(34) The fuel gas storage unit **4** of the fuel cell ship SH has the fuel tank **41**. The fuel tank **41** stores the fuel gas as fuel to be supplied to the fuel cells **31**. In the present embodiment, a plurality of the fuel tanks **41** are provided. That is, the fuel cell ship SH includes the plurality of fuel tanks **41** for storing fuel. Each of the plurality of fuel cells **31** described above is connected to at least one of the fuel tanks **41** via the fuel gas supply pipe **32** (see FIG. **11**). The fuel gas is supplied to each fuel cell **31** from the at least one of the fuel tanks **41**.

(35) Here, as illustrated in FIG. **2**, it is presumed that, for example, five fuel tanks **41** are provided in the fuel cell ship SH. For convenience of explanation, each fuel tank **41** is also referred to as an individual tank **41a** to **41e**. That is, the plurality of fuel tanks **41** include a plurality of individual tanks **41a** to **41e** for storing the fuel gas.

(36) In the present embodiment, the plurality of fuel tanks **41** particularly include the individual tanks **41a** and **41b**. The individual tanks **41a** and **41b** are connected to the same two or more fuel

cells **31** of the plurality of fuel cells **31** (for example, fuel cells **31a** and **31b** in FIG. 2).

(37) In this configuration, even if any one of the plurality of fuel cells **31** (for example, fuel cell **31a**) fails for some reason or has reached the end of its equipment life while the fuel cell ship SH is sailing, it is possible to supply the fuel gas from the individual tanks **41a** and **41b** to the remaining fuel cells **31** (for example, fuel cell **31b**) to continue electric power generation, and the fuel cell ship SH can continue sailing. Therefore, in this case, the fuel gas stored in each of the individual tanks **41a** and **41b** can be effectively used (can be used up for driving the other fuel cell **31b**).

(38) Of the plurality of fuel tanks **41**, individual tanks **41c** and **41d** are each connected to the same fuel cell **31c** and supply the fuel gas to the same fuel cell **31c**. The individual tank **41e** is connected to one fuel cell **31d** and supplies the fuel gas to only the one fuel cell **31d**.

(39) FIG. 3 is a block diagram schematically illustrating another configuration of the fuel cell ship SH. In FIG. 3, for convenience, an illustration of the fuel gas storage unit **4** illustrated in FIG. 2 is omitted. When a set formed by the propulsion device **6** and the electric power supply unit **100** is referred to as a propulsion power device **60**, the fuel cell ship SH may have two propulsion power devices **60**, as illustrated in FIG. 3, or may have three or more propulsion power devices **60** (not illustrated). That is, the fuel cell ship SH may have a plurality of sets of the propulsion device **6** and the electric power supply unit **100**. When it is necessary to particularly distinguish each propulsion power device **60**, each propulsion power device **60** is referred to as a propulsion power device **60a** and a propulsion power device **60b**. The configuration of the electric power supply unit **100** in the propulsion power device **60a** and the propulsion power device **60b** is the same as that in FIG. 2.

(40) In this configuration, even if the fuel cell **31** or the propulsion device **6** fails for some reason in any of the sets (for example, the propulsion power device **60a**) while the fuel cell ship SH is sailing, the fuel cell ship SH can continue sailing by operating another set (for example, the propulsion power device **60b**). As a result, it is possible to avoid a situation in which the fuel cell ship SH stops while sailing.

(41) [3. Operation Plan of Fuel Cell Ship]

(42) Next, the operation plan of the fuel cell ship SH will be described. Here, as an example, it is presumed that the fuel cell ship SH is equipped with six fuel cells **31**, and the fuel cells **31** mounted at the start of operation of the fuel cell ship SH are fuel cells A0, B0, C0, D0, E0 and F0.

(43) FIG. 4 is a time chart schematically illustrating a replacement plan for each fuel cell **31** as an operation plan for the fuel cell ship SH. The replacement of each fuel cell **31** is typically performed if the fuel cell ship SH enters a dock for maintenance. Here, the period when a medium-sized ship or a large ship enters a dock is generally about once every one to three years. If docking is performed only for replacement of the fuel cell **31** when the fuel cell **31** reaches the end of its life during sailing, such docking will affect the operation plan of the ship and economic efficiency of the ship is significantly impaired. Therefore, it is desirable that the timing of replacement due to the life of the fuel cell **31** coincides with the timing of entering the dock (maintenance period) of the fuel cell ship SH based on a predetermined operation plan.

(44) In the present embodiment, as illustrated in FIG. 4, by replacing two or three fuel cells **31** at the timing for entering the dock every two years planned in advance, all of the fuel cells are always maintained in an operable state. For example, the fuel cell A0 is replaced with the fuel cell A1 two years after the start of operation, and is further replaced with the fuel cell A2 four years later (six years after the start of operation). Similarly, the fuel cell B0 is replaced with the fuel cell B1 two years after the start of operation, and is further replaced with the fuel cell B2 four years later. The fuel cell C0 is replaced with the fuel cell C1 four years after the start of operation, and is further replaced with the fuel cell C2 four years later. Similarly, the fuel cell D0 is replaced with the fuel cell D1 four years after the start of operation, and is further replaced with the fuel cell D2 four years later. The fuel cell E0 is replaced with the fuel cell E1 four years after the start of operation. The fuel cell F0 is replaced with the fuel cell F1 six years after the start of operation.

(45) In FIG. 4, "High load" indicates an operation that promotes degradation of the fuel cell **31**,

that is, an operation in which the degradation progress rate of the fuel cell **31** is relatively fast with respect to the operating time (high load operation). On the other hand, “Low load” indicates an operation in which degradation of the fuel cell **31** is suppressed, that is, an operation in which the degradation progress rate of the fuel cell **31** is relatively slow with respect to the operating time (low load operation). The degradation of the fuel cell **31** refers to, for example, the degradation of the catalyst (for example, platinum) included in the electrodes (anode electrode, cathode electrode) of the fuel cell **31**.

(46) The operation pattern (high load operation/low load operation) of each fuel cell **31** is preset based on the specifications of the fuel cell **31** and the operation plan of the fuel cell ship SH. The setting of the operation pattern is updated according to the actual state of degradation of the fuel cell **31** checked each time maintenance is performed. The operation pattern of the fuel cell ship SH may be machine-learned, and the control unit **12a** may automatically determine an optimum replacement plan from the actual degradation status of the fuel cell **31**.

(47) [4. Degradation Rate of Fuel Cell]

(48) In the present embodiment, the degree of degradation of the fuel cell **31** described above is also referred to as a “degradation rate”. The degradation rate corresponds to the cell voltage when a predetermined current per unit area is passed through the cells constituting the stack of the fuel cell **31**, and takes a value of 0 to 100%. A degradation rate of 0% corresponds to the cell voltage in the initial state of the fuel cell **31** (state without degradation). The degradation rate of 100% corresponds to the cell voltage when the fuel cell **31** degrades and needs to be replaced.

(49) FIG. 5 schematically shows the relationship between the operating time T (hours) of the fuel cell **31** and the cell voltage V_c (V). The cell voltage V_c on the vertical axis indicates the voltage per cell when a current of 0.6 A (that is, 0.6 A/cm²) per unit area of the cell of the fuel cell stack is passed through the fuel cell. Here, in the initial state (operating time 0 hours) of the fuel cell **31**, $V_c = V_0 = 0.75$ V. That is, the fuel cell **31** having a cell voltage V_c of V_0 has a degradation rate of 0%. The above-mentioned current value, voltage value, and the like are examples, and are not limited to the above-mentioned values. In FIG. 5, the solid line graph indicates the change in the cell voltage when low load operation in which degradation is suppressed is performed, and the dashed line graph indicates the change in the cell voltage when high load operation in which degradation is promoted is performed.

(50) The degradation of the fuel cell **31** progresses as the operating time increases. As degradation of the fuel cell **31** progresses, the cell voltage V decreases as shown in FIG. 5. Here, the state of the fuel cell **31** when the cell voltage V reaches a value ($V = V_L = 0.67$ V) that is 10% lower than the initial state is defined as a degradation rate of 100%. As described above, it is desirable that the timing of reaching $V = V_L$ coincide with the maintenance date and time. The amount of decrease in the cell voltage and the cell voltage at which the degradation rate is taken to be 100% can be appropriately set according to the material, surface area, and the like of the electrodes (catalyst) of the fuel cell **31**, and are not limited to the above-mentioned “10%” and “0.67 V”.

(51) [5. Adjustment of Fuel Cell Degradation Rate (Low Output Side)]

(52) FIG. 6 illustrates the relationship between the electric power generation output P per fuel cell and a degradation progress rate D_v (%/h). The degradation progress rate D_v refers to the amount of change (amount of decrease) in the degradation rate of the fuel cell **31** per unit time.

(53) The above-mentioned low load operation refers to generating electricity in the fuel cell **31** in a region where the degradation progress rate D_v of the fuel cell **31** is low in the curve of FIG. 6. For example, an operation in which the electric power generation output P of the fuel cell **31** is 20 kW or more and 110 kW or less is a low load operation because the degradation progress rate D_v of the fuel cell **31** is equal to or less than a predetermined value D_{th} . If the fuel cell ship SH is completely stopped and the electric power generation output P of the fuel cell **31** is 0 (kW), the degradation progress rate D_v of the fuel cell **31** becomes the lowest at zero.

(54) On the other hand, high load operation refers to generating electricity in the fuel cell **31** in a

region where the degradation progress rate D_v of the fuel cell **31** is high in the curve of FIG. 6. For example, in an operation in which the electric power generation output P of the fuel cell **31** is less than 20 kW, or in an operation in which the electric power generation output P exceeds 110 kW, the degradation progress rate D_v of the fuel cell **31** becomes larger than the predetermined value D_{th} , and thus the operation is a high load operation.

(55) For example, even if the fuel cell ship SH is completely stopped, in a case where the fuel cell **31** continues to generate electric power within the range where the electric power generation output P is $0 < P \leq 20$ kW for the purpose of driving the peripheral equipment **11** such as lighting equipment or the like, it can be seen from FIG. 6 that the degradation progress rate D_v of the fuel cell **31** exceeds the predetermined value D_{th} . In this state, the fuel cell **31** is operated at high load operation, and degradation of the fuel cell **31** is promoted. In addition, frequently repeating starting and stopping of the fuel cell **31** is the high load operation promoting degradation of the fuel cell **31**, because such operation means that the operation of the fuel cell **31** in which the electric power generation output P is less than 20 kW is continued.

(56) Here, the electric power generation output P of the fuel cell **31** when the degradation progress rate D_v of the fuel cell **31** is equal to the predetermined value D_{th} is defined as P_{deg} . Based on FIG. 6, the electric power generation output P_{deg} can also be said to be a lower limit value (for example, 20 kW) of the range ($20 \leq P \leq 110$ kW) of the electric power generation output P of the fuel cell **31** in which the degradation progress rate D_v of the fuel cell **31** is equal to or less than a predetermined value (predetermined value D_{th}).

(57) Here, as can be seen in FIG. 6, in a case where $P_{deg} = 20$ kW, in a fuel cell ship SH equipped with six fuel cells **31**, if the electric power consumed by the ship (electric power requirement) is $20 \text{ kW} \times 6 = 120$ kW or less, and if each fuel cell **31** is operated so that the electric power of 120 kW or less is evenly divided among the six fuel cells **31**, degradation will be promoted in all the fuel cells **31**. That is, the fuel cell **31** to be operated at low load operation is operated at high load operation. In this case, an estimated replacement period when the fuel cell **31** operated at low load operation needs to be replaced may be earlier than the initial scheduled replacement period (maintenance period).

(58) Depending on the length of the time that the fuel cell ship SH is berthed, stopping the electric power generation may suppress the degradation or may promote the degradation. For example, if the berthing time of the fuel cell ship SH is short, the electric power generation by the fuel cell **31** will be restarted in a short time after the electric power generation is stopped. As described above, repeating the starting and stopping of electric power generation of the fuel cell **31** promotes degradation of the fuel cell **31**, because such operation means that the operation of the fuel cell **31** in which the electric power generation output P is less than 20 kW is continued. On the other hand, if the berthing time of the fuel cell ship SH is long, the amount of time during which electric power generation of the fuel cell **31** is stopped becomes long, and thus the time during which the degradation progress rate of the fuel cell **31** is zero becomes long, and as a result, the degradation of the fuel cell **31** is suppressed.

(59) Therefore, in the present embodiment, if the electric power generation output P of one of the fuel cells **31** falls below P_{deg} , the electric power generation of at least one of the fuel cells **31** is stopped to adjust the degradation progress rate D_v and the degradation rate of the fuel cell **31**. As a result, degradation of the fuel cell **31** can be promoted or suppressed, and the estimated replacement period of the fuel cell **31** can be brought closer to or coincided with the scheduled replacement period.

(60) The control unit **12a** of the present embodiment described above functions as a degradation rate control unit that adjusts the degradation rate of each of the plurality of fuel cells **31**. That is, the fuel cell ship SH of the present embodiment includes the control unit **12a** as a degradation rate control unit that adjusts the degradation rate indicating the degree of degradation of each of the plurality of fuel cells **31**.

(61) In the following, a procedure for adjusting the degradation rate of the fuel cell **31** by the control unit **12a** will be described in detail. FIG. 7 is a flowchart illustrating a flow of adjusting the degradation rate of the fuel cell **31**.

(62) First, the control unit **12a** determines whether the electric power load W (kW) consumed by the fuel cell ship SH is equal to or less than a first threshold value W_{th1} (S1). Here, the first threshold value W_{th1} is a value determined according to the above-mentioned electric power generation output P_{deg} (kW) of one fuel cell and the number of fuel cells **31** mounted N_{fc} (units), and more specifically, $W_{th1} = P_{deg} \times N_{fc}$.

(63) FIG. 8 is a graph showing the transition of the electric power load W of the fuel cell ship SH with respect to the passage of time. The electric power load W of the fuel cell ship SH is the total electric power load consumed by the fuel cell ship SH, and also includes the power consumed by the peripheral equipment **11**. As shown in FIG. 8, at the time t_1 when $W \leq W_{th1}$, the control unit **12a** starts adjusting the degradation rate of the fuel cell **31**. If $W > W_{th1}$ in S1, the control unit **12a** stands by without adjusting the degradation rate.

(64) In S1, if $W \leq W_{th1}$, the control unit **12a** then determines whether the fuel cell ship SH is berthed (S2). For example, if it is estimated, based on the operation plan of the fuel cell ship SH, that the electric power required in the ship will be smaller than a predetermined value for a certain period (for example, 48 hours), the control unit **12a** can determine that the fuel cell ship SH is berthed. On the other hand, if the above situation is not estimated, the control unit **12a** can determine that the fuel cell ship SH is not berthed.

(65) If it is determined in S2 that the fuel cell ship SH is berthed, the control unit **12a** determines whether the estimated berthing time T_s is equal to or longer than a predetermined time T_1 (for example, 48 hours) (S3). The above-mentioned estimated berthing time T_s may be a time set in advance by the operator by operating an input unit, or may be a time acquired by machine learning based on the operation plan of the fuel cell ship SH.

(66) If $T_s \geq T_1$ in S3, the control unit **12a** stops the electric power generation of the fuel cell **31** whose degradation is desired to be suppressed, or in other words, the fuel cell **31** operated in the low load operation (S4). In this case, as described above, since the electric power generation of the fuel cell **31** is stopped for a long period, degradation of the fuel cell **31** operated in low load operation is suppressed. On the other hand, the fuel cell **31** operated at high load operation continues to generate electric power, and thus degradation progresses, and as a result, degradation is promoted. In S2, if the fuel cell ship SH is not berthed, the process also advances to S4. As a result, degradation of the fuel cell **31** operated at the low load operation is suppressed, and degradation of the fuel cell **31** operated at high load operation is promoted. If there are a plurality of fuel cells **31** operated at high load operation, the control unit **12a** divides the electric power load W in S1 evenly by the number of fuel cells **31**, and causes the fuel cells **31** to output the shared electric power (S5).

(67) If $T_s < T_1$ in S3, the control unit **12a** stops the electric power generation of the fuel cell **31** whose degradation is desired to be promoted, or in other words, the fuel cell **31** operated at high load operation (S6). In this case, the fuel cell **31** operated at high load operation resumes (is planned to resume) electric power generation after a short stoppage period of electric power generation, and as a result, degradation is promoted. On the other hand, the fuel cell **31** operated in low load operation continues to generate electric power, but since repeating starting and stopping of electric power generation does not occur in a short period of time, degradation is not promoted and degradation is relatively suppressed. If there are a plurality of fuel cells **31** operated at low load operation, the control unit **12a** divides the electric power load W in S1 evenly by the number of fuel cells **31**, and causes the fuel cells **31** to output the shared electric power (S7).

(68) FIG. 9 schematically illustrates the change in the degradation rate D with respect to the operating time T of the fuel cell **31**. The solid line graph in FIG. 9 indicates the change in the degradation rate D of the fuel cell **31** operated at low load operation in which degradation is

suppressed, and the dashed line graph indicates the change in the degradation rate D of the fuel cell **31** operated at high load operation in which degradation is promoted. The degradation rate D suitable for replacing the fuel cell **31** is represented by D_{ex} . In the present embodiment, $D_{ex}=100\%$.

(69) By stopping the electric power generation of a predetermined fuel cell **31** as described above, the control unit **12a** can adjust the degradation progress rate D_v of the fuel cell **31** and adjust the degradation rate D . This makes it possible to bring an estimated replacement period T_{c1} of fuel cells **31** operated at high load operation closer to or coincided with a scheduled replacement period T_{m1} which is the timing of entering the dock, and the fuel cells **31** operated at high load operation can be replaced during maintenance at the scheduled replacement period T_{m1} . Similarly, it possible to bring an estimated replacement period T_{c2} of fuel cells **31** operated in low load operation closer to or coincided with a scheduled replacement period T_{m2} which is the timing of entering the dock, and the fuel cells **31** operated in low load operation can be replaced during maintenance at the scheduled replacement period T_{m2} .

(70) That is, when the period at which the degradation rate D of each fuel cell **31** reaches the degradation rate D_{ex} suitable for replacement due to degradation of each fuel cell **31** is defined as an estimated replacement period T_c , and when the predetermined replacement period for each fuel cell **31** is defined as a scheduled replacement period T_m , the control unit **12a**, as a degradation rate control unit, adjusts the degradation rate D of at least one of the fuel cells **31** during a predetermined period (for example, 10 years) from the start of operation so that for each of the fuel cells **31**, the estimated replacement period T_c approaches or coincides with the scheduled replacement period T_m (in the example above, so that T_{c1} approaches or coincides with T_{m1} and T_{c2} approaches or coincides with T_{m2}). As a result, the replacement work of each fuel cell **31** can be performed at the timing when the fuel cell ship SH enters the dock (for maintenance), and thus efficient operation of the fuel cell ship SH can be achieved. It is also possible to avoid a situation in which each fuel cell **31** degrades and reaches the end of its life while the fuel cell ship SH is sailing, and it becomes necessary to replace each of the fuel cells **31** while sailing.

(71) The control unit **12a** adjusts the degradation rate of the fuel cells **31** if the electric power load W consumed by the fuel cell ship SH becomes equal to or less than the first threshold value W_{th1} , which is determined according to the lower limit value P_{deg} of the electric power generation output P of the fuel cells **31** which gives the degradation progress rate D_v of the fuel cells **31** is equal to or less than the predetermined value D_{th} and the number of fuel cells **31** mounted N_{fc} (S1 to S5). In addition, the control unit **12a** changes the method of adjusting the degradation rate according to the estimated time (estimated berthing time T_s) during which the state in which the electric power load W is equal to or less than the first threshold value W_{th1} is continued (S3, S4, S6).

(72) If each fuel cell **31** is allowed to generate electricity with an equal output when the electric power load W of the ship is equal to or less than the first threshold value W_{th1} , degradation of all the fuel cells **31** is promoted. By adjusting the degradation rate when $W \leq W_{th1}$, and changing the method of adjusting the degradation rate according to the estimated berthing time T_s , degradation can be suppressed for the fuel cells **31** operated at low load operation so that the estimated replacement period T_{c2} approaches or coincides with the scheduled replacement period T_{m2} . For the fuel cell **31** operated at high load operation, degradation can be promoted so that the estimated replacement period T_{c1} can be brought closer to or coincided with the scheduled replacement period T_{m1} .

(73) The plurality of fuel cells **31** include the fuel cells **31** operated at high load operation and the fuel cells **31** operated at low load operation based on the operation plan of the fuel cell ship SH. The control unit **12a** determines whether the fuel cell ship SH is expected to berth based on the operation plan (S2), and if such berthing is not expected, the control unit **12a** stops the electric power generation of the fuel cells **31** operated at low load operation (S4). In this case, degradation of the fuel cells **31** operated at low load operation is suppressed, and thus for the fuel cells, it is

possible to reduce situations in which the estimated replacement period T_{c2} and the scheduled replacement period T_{m2} are significantly different from each other.

(74) If the estimated berthing time T_s of the fuel cell ship SH is equal to or longer than the predetermined time T_1 determined according to the operation plan, the control unit **12a** stops the electric power generation of the fuel cells **31** operated at low load operation (S3, S4). By stopping electric power generation for a long time, degradation of the fuel cells **31** operated at low load operation is suppressed. As a result, it is possible to reduce situations in which the estimated replacement period T_{c2} and the scheduled replacement period T_{m2} of the fuel cells **31** are significantly different from each other.

(75) The control unit **12a** evenly divides the electric power load W of the fuel cell ship SH by the number of the plurality of fuel cells **31** operated at high load operation, and causes each fuel cell **31** operated at high load operation to output the shared electric power (S5). In this case, it is possible to progress the degradation of the plurality of fuel cells **31** operated at high load operation at the same extent, and to align the timing at which each of the fuel cells **31** reaches the end of its life. As a result, the work of replacing the fuel cells **31** at the same time becomes very effective.

(76) The control unit **12a** stops the electric power generation of the fuel cells **31** operated at high load operation if the estimated berthing time T_s of the fuel cell ship SH is less than the predetermined time T_1 (S6). The starting and stopping of electric power generation of the fuel cells **31** during a short period of time causes the degradation of the fuel cell **31** to progress. If $T_s < T_1$, it is estimated that the fuel cells **31** operated at high load operation will be started after a short stoppage period of electric power generation (after the estimated berthing time T_s reaches the predetermined time T_1). Promoting degradation due to stopping and starting of the fuel cells **31** in a short period of time makes it possible to bring the estimated replacement period T_{c1} of the fuel cells **31** operated at high load operation closer to (or coincided with) the appropriate scheduled replacement period T_{m1} based on the operation plan, and thus replacement work can be performed at an appropriate timing.

(77) The control unit **12a** evenly divides the electric power load W of the fuel cell ship SH by the number of the fuel cells **31** operated at low load operation, and causes each fuel cell **31** operated at low load operation to output the shared electric power (S7). In this case, it is possible to progress the degradation of the plurality of fuel cells **31** operated at low load operation at the same extent, and to align the timing at which each of the fuel cells **31** reaches the end of its life. As a result, the work of replacing the fuel cells **31** at the same time becomes very effective.

(78) If degradation of the fuel cells **31** operated at high load operation has progressed more than expected and it is determined that the end of life will be reached earlier than the estimated replacement period T_{c1} , the degradation rate of the fuel cells **31** may be adjusted by temporarily switching the operation of the fuel cells **31** to low load operation.

(79) [6. Adjustment of Fuel Cell Degradation Rate (High Output Side)]

(80) As illustrated in FIG. 6 referred in the above description, the degradation progress rate D_v of the fuel cell **31** also increases when the electric power generation output P of the fuel cell **31** increases. This is because a large amount of current passed through each cell of the fuel cell **31** causes local temperature increase in the fuel cell **31** even if the fuel cell **31** is cooled by a cooling medium. Therefore, for example, if the fuel cell **31** operated at low load operation outputs electric power exceeding a rated output P_{rated} (kW), degradation is promoted even though it is desired that degradation be suppressed.

(81) Therefore, in the present embodiment, if the electric power load W of the fuel cell ship SH is large, the control unit **12a**, functioning as a degradation rate control unit, performs the following control to suppress degradation of the fuel cell **31** operated at low load operation. This aspect will be described in the following.

(82) FIG. 10 is another flowchart illustrating a flow of adjusting the degradation rate of the fuel cell **31**. First, the control unit **12a** determines whether the electric power load W consumed by the fuel

cell ship SH is equal to or greater than a second threshold value W_{th2} (S11). Here, the second threshold W_{th2} is a value determined according to the rated output $Prated$ of one fuel cell and the number of fuel cells **31** mounted N_{fc} (units), and specifically, $W_{th2}=Prated \times N_{fc}$.

(83) $Prated$, for example, is 80 (kW) (see FIG. 6), but is not limited to this value, and can be appropriately set according to the material, surface area, and the like of the electrodes of the fuel cell **31**. When the maximum output of the fuel cell **31** is represented by P_{max} (kW), $Prated < P_{max}$.

(84) In S11, if $W \geq W_{th2}$, the control unit **12a** adjusts the degradation rate of at least one of the fuel cells **31** (S12). For example, the control unit **12a** sets an electric power generation output P_{req} (kW) of the fuel cells **31** whose degradation is to be suppressed, that is, the fuel cells **31** operated at low load operation, to a value equal to or less than the rated output $Prated$ (S12). In other words, fuel cells **31** operated at low load operation are operated to output the electric power generation output P_{req} that satisfies $P_{req} \leq Prated$. As a result, the electric power generation output of fuel cells **31** operated at low load operation is suppressed to P_{req} , and thus the degradation of the fuel cells **31** is suppressed and the degradation rate is lowered. In this case, the control unit **12a** may set the electric power generation output of the fuel cells **31** operated at high load operation, to a value equal to or higher than the rated output $Prated$. In this case, the degradation rate of the fuel cells **31** operated at high load operation can be increased to promote the degradation.

(85) As described above, if the electric power load W consumed by the fuel cell ship SH is equal to or higher than the second threshold value W_{th2} determined according to the rated output $Prated$ of the fuel cells **31** and the number of fuel cells **31** mounted N_{fc} , the control unit **12a** adjusts the degradation rate of (at least one of) the fuel cells **31**. As a result, even if the electric power load W of the fuel cell ship SH is large, the degradation rate of the fuel cells **31** operated at low load operation can be lowered to suppress degradation. Therefore, it is possible to avoid situations in which degradation of the fuel cells **31** operated at low load operation is promoted even though it is desired to suppress degradation. On the other hand, for fuel cells **31** operated at high load operation, the degradation rate can be increased and the degradation can be promoted as described above.

(86) Of the plurality of fuel cells **31**, the control unit **12a** sets the electric power generation output P_{req} of the fuel cells **31** operated at low load operation, that is, the fuel cells **31** whose degradation is to be suppressed, to a value equal to or less than the rated output $Prated$ (S12). As a result, even if the electric power load W of the fuel cell ship SH is large, degradation of the fuel cells **31** operated at low load operation can be reliably suppressed.

(87) [7. Internal Structure of Fuel Cell Ship]

(88) Next, the internal structure of the above-described fuel cell ship SH will be described in detail. FIG. 11 is an explanatory diagram schematically illustrating the internal structure of the fuel cell ship SH. In FIG. 11, the air flow is indicated by a dashed line arrow. Each member is illustrated in FIG. 11 in which the right side of the drawing is the bow side and the left side of the drawing is the stern side. However, the position of each member is not limited to the position illustrated in FIG. 11 as long as the connection relationship between each member is maintained.

(89) The fuel cell ship SH includes an engine room **13** and a fuel room **14**. The engine room **13** and the fuel room **14** are arranged below a deck **1a** of the hull **1**. In other words, the engine room **13** and the fuel room **14** are arranged between the deck **1a** and a bottom plate **1b** of the hull **1**. The bottom plate **1b** is located between the deck **1a** and the ship bottom portion **1c** (see FIG. 1).

(90) The engine room **13** is located on the bow side with respect to the fuel room **14**. Below the deck **1a**, partition walls $W1$, $W2$ and $W3$ are located in order from the bow side to the stern side. The engine room **13** is separated from other spaces by the partition walls $W1$ and $W2$. The fuel room **14** is separated from other spaces by the partition walls $W2$ and $W3$. The partition walls $W1$ to $W3$ are made of, for example, fiber reinforced plastics (FRP), but may be iron plates.

(91) (7-1. Configuration of Fuel Cell System)

(92) The fuel cell system **3** of the fuel cell ship SH is located in the engine room **13**. The fuel cell

system 3 includes the above-described fuel cells 31, the fuel gas supply pipe 32, and a fuel cell side shutoff valve 33. The fuel cell side shutoff valve 33 is an example of peripheral equipment 11 (see FIG. 1).

(93) The fuel gas supply pipe 32 is a fuel supply pipe for supplying, to the anode electrode of the fuel cell 31, the fuel gas stored in the fuel tank 41 (described later) of the fuel gas storage unit 4.

(94) The fuel cell side shutoff valve 33 is an example of a shutoff valve SV that opens or closes the flow path of the fuel gas supply pipe 32. The opening and closing of the fuel cell side shutoff valve 33 is controlled by the control unit 12a (see FIG. 1). Specifically, the fuel cell side shutoff valve 33 switches between supplying the fuel gas from the fuel tank 41 to the fuel cells 31 and stopping the supply of fuel gas based on the control of the control unit 12a. Although only one fuel cell side shutoff valve 33 is provided in the fuel gas supply pipe 32 in a fuel cell compartment 30 (described later), two or more may be provided.

(95) The fuel cell ship SH further includes the fuel cell compartment 30. The fuel cell compartment 30 is a housing body for housing the fuel cell 31, and is arranged in the engine room 13. In FIG. 11, for convenience, only one fuel cell compartment 30 is illustrated. However, the fuel cell ship SH of the present embodiment has the plurality of fuel cells 31 as described above (see FIG. 2 and the like), and thus a plurality of fuel cell compartments 30 are provided corresponding to each fuel cell 31.

(96) The fuel cell compartment 30 has a hollow shape. For example, the fuel cell compartment 30 has a hollow and substantially rectangular parallelepiped shape. In this case, the outer walls of the fuel cell compartment 30 include, for example, a top wall 30a, a bottom wall 30b, a front wall (not illustrated), a back wall (not illustrated), a side wall 30c, and a side wall 30d. However, the top surface, bottom surface, front surface, back surface, and side surfaces of the fuel cell compartment 30 can be arbitrarily determined. The shape of the fuel cell compartment 30 is not particularly limited as long as the fuel cell compartment 30 has a space that can house the fuel cell 31. The fuel cell compartment 30 can also be considered as a container, chamber, or box for housing the fuel cell 31. The material of the outer wall of the fuel cell compartment 30 is, for example, FRP, but may be an iron plate.

(97) A cell compartment air supply port 30e with an opening is provided on the side wall 30d of the fuel cell compartment 30. The cell compartment air supply port 30e is connected to a cell compartment air supply pipe 35, which will be described later. The cell compartment air supply port 30e may be provided on an outer wall other than the side wall 30d in the fuel cell compartment 30.

(98) On the other hand, a cell compartment exhaust port 30f with an opening is provided on the side wall 30c of the fuel cell compartment 30. The cell compartment exhaust port 30f communicates with a duct compartment 90, which will be described later. The cell compartment exhaust port 30f may be provided on an outer wall other than the side wall 30c in the fuel cell compartment 30.

(99) The fuel cell compartment 30 has an interior that is a closed space, with the exception of the cell compartment air supply port 30e and the cell compartment exhaust port 30f.

(100) A part of the fuel gas supply pipe 32 described above and the fuel cell side shutoff valve 33 are housed in the fuel cell compartment 30. The fuel cell compartment 30 further houses a cell compartment internal gas detector 34a and a cell compartment internal fire detector 34b.

(101) The cell compartment internal gas detector 34a is a fuel gas detector arranged inside the fuel cell compartment 30. For example, if the fuel gas is hydrogen gas, the cell compartment internal gas detector 34a includes a hydrogen gas detection sensor.

(102) The cell compartment internal gas detector 34a is arranged on an inner surface of the top wall 30a located at an upper part of the fuel cell compartment 30. Hydrogen gas as the fuel gas is lighter than air and rises. Therefore, by arranging the cell compartment internal gas detector 34a on the top wall 30a of the fuel cell compartment 30, a leaked fuel gas can be reliably detected by the cell

compartment internal gas detector **34a** even if the fuel gas leaks in the fuel cell compartment **30**. The installation position of the cell compartment internal gas detector **34a** may be located on the most downstream side of the flow path through which the fuel gas flows when the fuel gas leaks in the fuel cell compartment **30**.

(103) If the cell compartment internal gas detector **34a** detects the fuel gas in the fuel cell compartment **30**, a detection signal is sent from the cell compartment internal gas detector **34a** to the control unit **12a**. As a result, the control unit **12a** can control the fuel cell side shutoff valve **33** provided in the fuel gas supply pipe **32** to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**.

(104) The cell compartment internal fire detector **34b** is a fire detector arranged inside the fuel cell compartment **30**. The cell compartment internal fire detector **34b** includes, for example, one or more sensors among a smoke sensor for detecting smoke, a heat sensor for detecting heat, and a flame sensor for detecting flame. The cell compartment internal fire detector **34b** may include a thermocouple type fire detector.

(105) The cell compartment internal fire detector **34b** is arranged on an inner surface of the top wall **30a** located at an upper part of the fuel cell compartment **30**. In the unlikely event that a fire occurs inside the fuel cell compartment **30**, the cell compartment internal fire detector **34b** detects the fire and outputs a detection signal indicating that a fire has occurred to the control unit **12a** (see FIG. 2). In this case, the control unit **12a** can control the fuel cell side shutoff valve **33** to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**. As a result, in the fuel cell compartment **30**, the risk of explosion due to ignition of the fuel gas can be reduced as much as possible.

(106) The cell compartment air supply pipe **35** is connected to the fuel cell compartment **30**. The cell compartment air supply pipe **35** extends from the cell compartment air supply port **30e** of the fuel cell compartment **30**, to the deck **1a** and is exposed from the upper surface of the deck **1a**.

(107) A cell compartment air supply device **36** and a cell compartment external gas detector **37** are arranged at an end portion on the deck **1a** side of the cell compartment air supply pipe **35**. The cell compartment air supply device **36** and the cell compartment external gas detector **37** are located above the deck **1a**.

(108) The cell compartment air supply device **36** includes, for example, an inexpensive non-explosion-proof air supply fan, but may include an explosion-proof air supply fan. The drive of the cell compartment air supply device **36** is controlled by the control unit **12a**. One or more filters (not illustrated) may be arranged in the cell compartment air supply device **36**. The filter removes, for example, dust or sea salt particles.

(109) The cell compartment air supply device **36** supplies air outside the fuel cell compartment **30** to the inside of the fuel cell compartment **30** via the cell compartment air supply pipe **35** and the cell compartment air supply port **30e**. The air inside the fuel cell compartment **30** is discharged to the duct compartment **90** via the cell compartment exhaust port **30f**. In this way, the inside of the fuel cell compartment **30** is ventilated. As a result, it is possible to prevent combustible gas (for example, the fuel gas leaking from the fuel cell **31**) from being retained in the fuel cell compartment **30**.

(110) The cell compartment external gas detector **37** detects combustible gas (for example, hydrogen gas floating around the hull **1**) flowing into the fuel cell compartment **30** from the outside. The cell compartment external gas detector **37** is, for example, a combustible gas sensor such as a hydrogen gas sensor. The cell compartment external gas detector **37** is arranged on a side opposite to the cell compartment air supply pipe **35** with respect to the cell compartment air supply device **36**, that is, on the upstream side of the air flow from the outside to the inside of the fuel cell compartment **30**. The cell compartment external gas detector **37** may include a gas sensor that detects a combustible gas other than hydrogen gas. Examples of combustible gases other than hydrogen gas include methane, ethane, propane, and carbon monoxide.

(111) The cell compartment external gas detector **37** outputs, for example, a detection signal

indicating the concentration of combustible gas to the control unit **12a**. As a result, the control unit **12a** can determine, based on the detection signal, whether the concentration of the combustible gas is equal to or higher than a standard value. Then, if the concentration is equal to or higher than the standard value, the control unit **12a** can control the fuel cell side shutoff valve **33** to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**. The above-mentioned standard value may be determined based on experiments and/or experience.

(112) The fuel cell ship SH further includes a cooling medium tank **38** and a cooling medium pipe **39**. The cooling medium tank **38** stores cooling medium for cooling the fuel cells **31**. The cooling medium is, for example, an antifreeze liquid having low electrical conductivity. The antifreeze liquid is, for example, a liquid obtained by mixing pure water and ethylene glycol in a predetermined ratio. The cooling medium tank **38** is sealed, but an upper portion may be open.

(113) The cooling medium pipe **39** is a pipe for circulating the cooling medium between the fuel cells **31** and a heat exchanger (not illustrated). A circulation pump (not illustrated) is also provided at a location along the cooling medium pipe **39**. The fuel cells **31** are cooled by driving the circulation pump to supply the cooling medium from the heat exchanger to the fuel cells **31** via the cooling medium pipe **39**. The cooling medium supplied for cooling the fuel cells **31** is also supplied, via the cooling medium pipe **39**, to the cooling medium tank **38**, at which a volume change due to a temperature change of the cooling medium is absorbed and the amount of the cooling medium liquid is monitored.

(114) A cooling tank internal gas detector **38a** is provided in an upper portion inside the cooling medium tank **38**. The cooling tank internal gas detector **38a** is a fuel gas detector that detects the fuel gas existing in the cooling medium tank **38**. As the fuel gas existing in the cooling medium tank **38**, for example, a fuel gas which is leaked in the fuel cell **31** and then enters into the cooling medium tank **38** via the cooling medium pipe **39** can be considered. The fuel gas detection result (for example, fuel gas concentration information) by the cooling tank internal gas detector **38a** is sent to the control unit **12a**. As a result, the control unit **12a** determines, based on the detection result of the cooling tank internal gas detector **38a**, whether there is a fuel gas leak in the fuel cells **31**, and if there is a leak, the control unit **12a** can, for example, perform control to stop electric power generation by the fuel cells **31**.

(115) (7-2. Configuration of Fuel Gas Storage Unit)

(116) The fuel gas storage unit **4** of the fuel cell ship SH has the above-described fuel tank **41**, a gas filling pipe **42**, and a tank side shutoff valve **43**. The tank side shutoff valve **43** is an example of the peripheral equipment **11**.

(117) The fuel tank **41** stores the fuel gas as fuel to be supplied to the fuel cells **31**. In FIG. **11**, for convenience, only one fuel tank **41** is illustrated, but the number of fuel tanks **41** is not particularly limited and there may be a plurality of the fuel tanks **41** (see FIG. **2**).

(118) The gas filling pipe **42** is a pipe for replenishing the fuel tank **41** with the fuel gas or filling the fuel tank **41** with an inert gas. One end side of the gas filling pipe **42** is connected to the fuel tank **41**. The other end side of the gas filling pipe **42** is branched into two, and these ends are connected to a fuel gas filling port **82** and an inert gas filling port **84**, respectively. The fuel gas filling port **82** and the inert gas filling port **84** are provided in the duct compartment **90** (particularly an upper duct compartment **80**) described later.

(119) The above-mentioned inert gas is, for example, nitrogen gas. For example, if the fuel gas remains in the fuel tank **41** when performing maintenance such as inspection or repair of the fuel cell ship SH in the dock (dry dock), there is a danger that an explosion may occur when the fuel gas ignites for some reason. Therefore, at the time of maintenance of the fuel cell ship SH, the fuel tank **41** is filled with the inert gas, and the fuel gas is removed from the fuel tank **41**. As a result, it is possible to avoid the danger of explosion.

(120) In the fuel gas supply pipe **32** described above, a side opposite to the connection side with the fuel cell **31** is connected to the fuel tank **41**. That is, the fuel tank **41** and the fuel cell **31** are

connected via the fuel gas supply pipe **32**.

(121) The tank side shutoff valve **43** is an example of a shutoff valve SV that opens or closes the flow path of the fuel gas supply pipe **32**. The opening and closing of the tank side shutoff valve **43** is controlled by the control unit **12a**. More specifically, the tank side shutoff valve **43** switches between supplying the fuel gas from the fuel tank **41** to the fuel cells **31** and stopping the supply of fuel gas based on the control of the control unit **12a**. Although only one tank side shutoff valve **43** is provided in the fuel gas supply pipe **32** in a tank compartment **40** described later, two or more tank side shutoff valves **43** may be provided.

(122) That is, it can be said that the fuel gas supply pipe **32** connecting the fuel tank **41** and the fuel cell **31** has at least two shutoff valves SV. The at least two shutoff valves SV include the fuel cell side shutoff valve **33** and the tank side shutoff valve **43**.

(123) The fuel cell ship SH further includes the tank compartment **40**. The tank compartment **40** is a housing body that houses at least one fuel tank **41**. The tank compartment **40** is arranged in the fuel room **14**. The number of tank compartments **40** is not particularly limited, and may be one or more.

(124) The tank compartment **40** has a hollow shape. For example, the tank compartment **40** has a hollow and substantially rectangular parallelepiped shape. In this case, the outer walls of the tank compartment **40** include, for example, a top wall **40a**, a bottom wall **40b**, a front wall (not illustrated), a back wall (not illustrated), a side wall **40c**, and a side wall **40d**. However, the top surface, bottom surface, front surface, back surface, and side surfaces of the tank compartment **40** can be arbitrarily determined. The shape of the tank compartment **40** is not particularly limited as long as the tank compartment **40** has a space that can house at least one fuel tank **41**. The tank compartment **40** can also be considered as a container, chamber, or box for housing the fuel tank **41**. The material of the outer wall of the tank compartment **40** is, for example, FRP, but may be an iron plate.

(125) A tank compartment air supply port **40e** with an opening is provided on the side wall **40c** of the tank compartment **40**. The tank compartment air supply port **40** is connected to a tank compartment air supply pipe **45** described later. The tank compartment air supply port **40e** may be provided on an outer wall other than the side wall **40c** in the tank compartment **40**.

(126) On the other hand, a tank compartment exhaust port **40f** with an opening is provided on the top wall **40a** of the tank compartment **40**. The tank compartment exhaust port **40f** communicates with a vent pipe **10**. The vent pipe **10** is a pipe for guiding air inside the tank compartment **40** to the outside of the ship. The tank compartment exhaust port **40f** may be provided on an outer wall other than the top wall **40a** in the tank compartment **40**.

(127) The tank compartment **40** has an interior that is a closed space except for the tank compartment air supply port **40e** and the tank compartment exhaust port **40f**.

(128) A part of the fuel gas supply pipe **32** described above and the tank side shutoff valve **43** are housed in the tank compartment **40**. The tank compartment **40** further houses a tank compartment internal gas detector **44a** and a tank compartment internal fire detector **44b**.

(129) The tank compartment internal gas detector **44a** is a fuel gas detector arranged inside the tank compartment **40**. For example, if the fuel gas is hydrogen gas, the tank compartment internal gas detector **44a** includes a hydrogen gas detection sensor.

(130) The tank compartment internal gas detector **44a** is arranged on the top wall **40a** located at the upper part of the tank compartment **40** to be close to the tank compartment exhaust port **40f** or inside the tank compartment exhaust port **40f**. In the unlikely event that the fuel gas leaks from the fuel tank **41** in the tank compartment **40**, the leaked fuel gas goes toward the vent pipe **10** through the tank compartment exhaust port **40f**. That is, the tank compartment exhaust port **40f** is located on the most downstream side of the flow path through which the fuel gas flows when the fuel gas leaks inside the tank compartment **40**. Therefore, by arranging the tank compartment internal gas detector **44a** at a position near the tank compartment exhaust port **40f** or inside the tank

compartment exhaust port **40f**, a fuel gas leaked in the tank compartment **40** can be reliably detected by the tank compartment internal gas detector **44a** located on the most downstream side of the flow path, regardless of where the fuel gas leaks.

(131) If the tank compartment internal gas detector **44a** detects the fuel gas inside the tank compartment **40**, a detection signal is sent from the tank compartment internal gas detector **44a** to the control unit **12a**. As a result, the control unit **12a** can control the tank side shutoff valve **43** and the fuel cell side shutoff valve **33** provided in the fuel gas supply pipe **32** to stop the supply of fuel gas from the fuel tank **41** to the fuel cells **31**, and can also open a release valve **72** to release the high-pressure hydrogen remaining inside the pipe.

(132) The tank compartment internal fire detector **44b** is a fire detector arranged inside the tank compartment **40**. The tank compartment internal fire detector **44b** includes, for example, one or more sensors among a smoke sensor for detecting smoke, a heat sensor for detecting heat, and a flame sensor for detecting flame. The tank compartment internal fire detector **44b** may include a thermocouple type fire detector.

(133) The tank compartment internal fire detector **44b** is arranged on an inner surface of the top wall **40a** located at an upper part of the tank compartment **40**. In the unlikely event that a fire occurs inside the tank compartment **40**, the tank compartment internal fire detector **44b** detects the fire and outputs a detection signal indicating that a fire has occurred to the control unit **12a**. In this case, the control unit **12a** can control the tank side shutoff valve **43** and the fuel cell side shutoff valve **33** to stop the supply of fuel gas from the fuel tank **41** to the fuel cells **31**, and can also open a release valve **72** to release the high-pressure hydrogen remaining inside the pipe. As a result, in the tank compartment **40**, the risk of explosion due to ignition of the fuel gas can be reduced as much as possible.

(134) The tank compartment air supply pipe **45** is connected to the tank compartment **40**. The tank compartment air supply pipe **45** extends from the tank compartment air supply port **40e** of the tank compartment **40** to the deck **1a**, and is exposed from an upper surface of the deck **1a**.

(135) A tank compartment air supply device **46** and a tank compartment external gas detector **47** are arranged at an end portion on the deck **1a** side of the tank compartment air supply pipe **45**. The tank compartment air supply device **46** and the tank compartment external gas detector **47** are located above the deck **1a**.

(136) The tank compartment air supply device **46** includes, for example, an inexpensive non-explosion-proof air supply fan, but may include an explosion-proof air supply fan. The drive of the tank compartment air supply device **46** is controlled by the control unit **12a**. One or more filters (not illustrated) may be arranged in the tank compartment air supply device **46**. The filter removes, for example, dust or sea salt particles.

(137) The tank compartment air supply device **46** supplies air outside the tank compartment **40** to the inside of the tank compartment **40** via the tank compartment air supply pipe **45** and the tank compartment air supply port **40e**. The air inside the tank compartment **40** is discharged to the vent pipe **10** via the tank compartment exhaust port **40f**. In this way, the inside of the tank compartment **40** is ventilated. As a result, even if the fuel gas leaks from the fuel tank **41** in the tank compartment **40**, the retention of the fuel gas can be suppressed.

(138) The tank compartment external gas detector **47** detects combustible gas (for example, hydrogen gas floating around the hull **1**) flowing into the tank compartment **40** from the outside. The tank compartment external gas detector **47** is, for example, a combustible gas sensor such as a hydrogen gas sensor. The tank compartment external gas detector **47** is arranged on a side opposite to the tank compartment air supply pipe **45** with respect to the tank compartment air supply device **46**, that is, on the upstream side of the air flow from the outside to the inside of the tank compartment **40**. The tank compartment external gas detector **47** may include a gas sensor that detects a combustible gas other than hydrogen gas.

(139) The tank compartment external gas detector **47** outputs, for example, a detection signal

indicating the concentration of combustible gas to the control unit **12a**. As a result, the control unit **12a** can determine, based on the detection signal, whether the concentration of the combustible gas is equal to or higher than a standard value. If the concentration is equal to or greater than a standard value, the control unit **12a** can control the tank side shutoff valve **43** and the fuel cell side shutoff valve **33** to stop the supply of fuel gas from the fuel tank **41** to the fuel cells **31**, and can also open the release valve **72** to release the high-pressure hydrogen remaining inside the pipe. The above-mentioned standard value may be determined based on experiments and/or experience.

(140) (7-3. Duct Compartment)

(141) The fuel cell ship SH further includes a lower duct compartment **70** and an upper duct compartment **80**. Here, the lower duct compartment **70** and the upper duct compartment **80** are collectively referred to as a duct compartment **90**. The duct compartment **90** is a housing body that houses various pipes. For example, the duct compartment **90** houses a part of the fuel gas supply pipe **32**. The inside of the lower duct compartment **70** and the inside of the upper duct compartment **80** communicate with each other via a duct communication portion **91**. In the following, details of the lower duct compartment **70** and the upper duct compartment **80** will be described.

(142) <7-3-1. Lower Duct Compartment>

(143) The lower duct compartment **70** is located below the deck **1a**. More specifically, the lower duct compartment **70** is arranged in the engine room **13**. In the engine room **13**, the lower duct compartment **70** is located on the stern side with respect to the fuel cell compartment **30**. That is, below the deck **1a**, the lower duct compartment **70** is located between the fuel cell compartment **30** and the tank compartment **40**. The lower duct compartment **70** houses a part of the fuel gas supply pipe **32** and a part of the gas filling pipe **42**.

(144) Here, the “part of the fuel gas supply pipe **32**” housed in the lower duct compartment **70** refers to a portion of the fuel gas supply pipe **32** located between the fuel cell compartment **30** and the tank compartment **40**. The “part of the gas filling pipe **42**” housed in the lower duct compartment **70** refers to a portion of the gas filling pipe **42** located between the tank compartment **40** and the upper duct compartment **80**.

(145) The material of the lower duct compartment **70** is, for example, FRP, but may be an iron plate. The lower duct compartment **70** has a hollow shape. For example, the lower duct compartment **70** has a hollow and substantially rectangular parallelepiped shape. In this case, the outer walls of the lower duct compartment **70** include, for example, a top wall **70a**, a bottom wall **70b**, a front wall (not illustrated), a back wall (not illustrated), a side wall **70c**, and a side wall **70d**. However, the top surface, bottom surface, front surface, back surface, and side surfaces of the lower duct compartment **70** can be arbitrarily determined. The shape of the lower duct compartment **70** is not particularly limited as long as the lower duct compartment **70** has a space that can house a part of the fuel gas supply pipe **32** and the like. The lower duct compartment **70** can also be regarded as a container, a chamber, or a box for housing a part of the fuel gas supply pipe **32** and the like.

(146) A lower duct compartment air supply port **70e** with an opening is provided in the side wall **70d** of the lower duct compartment **70**. The lower duct compartment air supply port **70e** is connected to a lower duct compartment air supply pipe **74** described later. The lower duct compartment air supply port **70e** may be provided on an outer wall other than the side wall **70d** in the lower duct compartment **70**.

(147) On the other hand, a lower duct compartment communication port **70f** with an opening is provided in the top wall **70a** of the lower duct compartment **70**. The lower duct compartment communication port **70f** communicates with the duct communication portion **91** described above. The lower duct compartment communication port **70f** may be provided on an outer wall other than the top wall **70a** in the lower duct compartment **70**.

(148) A cell compartment communication port **70g** with an opening is provided in the side wall **70d** of the lower duct compartment **70**. The cell compartment communication port **70g** is connected to

the cell compartment exhaust port **30f** of the fuel cell compartment **30** described above via a communication pipe **92**. As a result, the air inside the fuel cell compartment **30** flows into the lower duct compartment **70** via the cell compartment exhaust port **30f**, the communication pipe **92**, and the cell compartment communication port **70g**. The cell compartment communication port **70g** may be provided on an outer wall other than the side wall **70d** in the lower duct compartment **70**.

(149) The communication pipe **92** includes, for example, a double pipe having an inner pipe and an outer pipe. Examples of the inner pipe include the fuel gas supply pipe **32**. The outer pipe is located on the outside of the inner pipe in the radial direction. The gas inside the fuel cell compartment **30** travels between the inner pipe and the outer pipe of the communication pipe **92**, from the cell compartment exhaust port **30f** to the cell compartment communication port **70g** of the lower duct compartment **70**.

(150) The lower duct compartment **70** has a closed space inside except for the lower duct compartment air supply port **70e**, the lower duct compartment communication port **70f**, and the cell compartment communication port **70g**.

(151) The lower duct compartment **70** houses a part of a fuel gas discharge pipe **71**. The fuel gas discharge pipe **71** is a pipe provided by branching from the fuel gas supply pipe **32** located in the lower duct compartment **70**. For example, the fuel gas discharge pipe **71** is provided by branching from the fuel gas supply pipe **32** between the two shutoff valves SV.

(152) More specifically, the fuel gas discharge pipe **71** is provided by branching from the fuel gas supply pipe **32** between the tank side shutoff valve **43** in the tank compartment **40** and the fuel cell side shutoff valve **33** in the fuel cell compartment **30**. The fuel gas discharge pipe **71** extends from the inside of the lower duct compartment **70** to the inside of the upper duct compartment **80** via the lower duct compartment communication port **70f** and the duct communication portion **91**, and further communicates with the inside of the vent pipe **10**. Therefore, the “part of the fuel gas discharge pipe **71**” housed in the lower duct compartment **70** refers to a portion of the fuel gas discharge pipe **71** located between the point of the branching from the fuel gas supply pipe **32** and the upper duct compartment **80**.

(153) The lower duct compartment **70** further houses the release valve **72**. The release valve **72** is an on-off valve installed in the fuel gas discharge pipe **71** to open or close the flow path of the fuel gas discharge pipe **71**. The release valve **72** is an example of peripheral equipment **11**. The opening and closing of the release valve **72** are controlled by the control unit **12a**. The release valve **72** may be installed in the upper duct compartment **80**.

(154) The lower duct compartment **70** further houses a lower duct compartment internal gas detector **73**. The lower duct compartment internal gas detector **73** is a fuel gas detector arranged inside the lower duct compartment **70**. For example, if the fuel gas is hydrogen gas, the lower duct compartment internal gas detector **73** includes a hydrogen gas detection sensor.

(155) The lower duct compartment internal gas detector **73** is arranged on the top wall **70a** located at an upper portion of the lower duct compartment **70** to be close to the lower duct compartment communication port **70f** or inside the lower duct compartment communication port **70f**. In the unlikely event that the fuel gas leaks from the fuel gas supply pipe **32** in the lower duct compartment **70**, the leaked fuel gas goes toward the upper duct compartment **80** through the lower duct compartment communication port **70f**. That is, the lower duct compartment communication port **70f** is located on the most downstream side of the flow path through which the fuel gas flows when the fuel gas leaks in the lower duct compartment **70**. Therefore, by arranging the lower duct compartment internal gas detector **73** at a position close to the lower duct compartment communication port **70f** or inside the lower duct compartment communication port **70f**, a fuel gas leaked in the lower duct compartment **70** can be reliably detected by the lower duct compartment internal gas detector **73** located on the most downstream side of the flow path, regardless of where the fuel gas leaks.

(156) If the lower duct compartment internal gas detector **73** detects the fuel gas in the lower duct

compartment **70**, a detection signal is sent from the lower duct compartment internal gas detector **73** to the control unit **12a**. As a result, the control unit **12a** can control the shutoff valves SV provided in the fuel gas supply pipe **32** to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**.

(157) The lower duct compartment **70** may further house a fire detector that detects a fire inside the lower duct compartment **70**.

(158) The lower duct compartment air supply pipe **74** is connected to the lower duct compartment **70**. The lower duct compartment air supply pipe **74** extends from the lower duct compartment air supply port **70e** of the lower duct compartment **70** to the deck **1a** and is exposed from the upper surface of the deck **1a**.

(159) A lower duct compartment air supply device **75** and a lower duct compartment external gas detector **76** are arranged at an end portion on the deck **1a** side of the lower duct compartment air supply pipe **74**. The lower duct compartment air supply device **75** and the lower duct compartment external gas detector **76** are located above the deck **1a**.

(160) The lower duct compartment air supply device **75** includes, for example, an inexpensive non-explosion-proof air supply fan, but may include an explosion-proof air supply fan. The drive of the lower duct compartment air supply device **75** is controlled by the control unit **12a**. One or more filters (not illustrated) may be arranged in the lower duct compartment air supply device **75**. The filter removes, for example, dust or sea salt particles.

(161) The lower duct compartment air supply device **75** supplies the air outside the lower duct compartment **70** (duct compartment **90**) to the inside of the lower duct compartment **70** via the lower duct compartment air supply pipe **74** and the lower duct compartment air supply port **70e**. The air inside the lower duct compartment **70** is discharged to the upper duct compartment **80** through the lower duct compartment communication port **70f**. In this way, the inside of the lower duct compartment **70** is ventilated. As a result, even if the fuel gas leaks from the fuel gas supply pipe **32** in the lower duct compartment **70**, retention of the fuel gas can be suppressed.

(162) The lower duct compartment external gas detector **76** detects combustible gas (for example, hydrogen gas floating around the hull **1**) flowing into the duct compartment **90** from the outside. The lower duct compartment external gas detector **76** is, for example, a combustible gas sensor such as a hydrogen gas sensor. The lower duct compartment external gas detector **76** is arranged on a side opposite to the lower duct compartment air supply pipe **74** with respect to the lower duct compartment air supply device **75**, that is, on the upstream side of the air flow from the outside to the inside of the duct compartment **90**. The lower duct compartment external gas detector **76** may include a gas sensor that detects a combustible gas other than hydrogen gas.

(163) The lower duct compartment external gas detector **76** outputs, for example, a detection signal indicating the concentration of combustible gas to the control unit **12a**. As a result, the control unit **12a** can determine, based on the detection signal, whether the concentration of the combustible gas is equal to or higher than a standard value. Then, if the concentration is equal to or higher than the standard value, the control unit **12a** can control the shutoff valves SV to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**. The above-mentioned standard value may be determined based on experiments and/or experience.

(164) <7-3-2. Upper Duct Compartment>

(165) The upper duct compartment **80** is located on the deck **1a**. More specifically, the upper duct compartment **80** is arranged on the deck **1a** to cover an area partially including the lower duct compartment **70** and the tank compartment **40**. The upper duct compartment **80** houses a part of the fuel gas discharge pipe **71** and a part of the gas filling pipe **42**.

(166) Here, the “part of the fuel gas discharge pipe **71**” housed in the upper duct compartment **80** refers to a portion of the fuel gas discharge pipe **71** that extends from the lower duct compartment **70** toward the vent pipe **10**. The “part of the gas filling pipe **42**” housed in the upper duct compartment **80** refers to a portion of the gas filling pipe **42** that extends from the lower duct

compartment **70** to the fuel gas filling port **82** described later.

(167) The material of the upper duct compartment **80** is, for example, FRP, but may be an iron plate. The upper duct compartment **80** has a hollow shape. For example, the upper duct compartment **80** has a hollow and substantially rectangular parallelepiped shape. In this case, the outer walls of the upper duct compartment **80** include, for example, a top wall **80a**, a bottom wall **80b**, a front wall (not illustrated), a back wall (not illustrated), a side wall **80c**, and a side wall **80d**. However, the top surface, bottom surface, front surface, back surface, and side surfaces of the upper duct compartment **80** can be arbitrarily determined. The shape of the upper duct compartment **80** is not particularly limited as long as the upper duct compartment **80** has a space that can house a part of the fuel gas discharge pipe **71** and the like. The upper duct compartment **80** can also be regarded as a container, a chamber, or a box for housing the part of the fuel gas discharge pipe **71** and the like.

(168) The fuel gas discharge pipe **71**, as described above, communicates with the inside of the vent pipe **10**. Thus, when the release valve **72** is opened, the gas inside the fuel gas discharge pipe **71** (for example, the fuel gas) flows from an end portion **71a** of the fuel gas discharge pipe **71** into the vent pipe **10** and is released from the vent pipe **10** to outside the ship. Here, it is desirable that, in the vent pipe **10**, the end portion **71a** of the fuel gas discharge pipe **71** faces upward, that is, faces the open port side of the vent pipe **10**. In this case, the discharge direction of gas discharged from the end portion **71a** of the fuel gas discharge pipe **71** is upward.

(169) For example, if the fuel gas is discharged sideways from the end portion **71a** of the fuel gas discharge pipe **71**, the discharged fuel gas reaches the inner wall surface of the vent pipe **10** and then flows downward. This may result in unwanted detection by the tank compartment internal gas detector **44a** in the tank compartment **40**. By the end portion **71a** of the fuel gas discharge pipe **71** facing upward inside the vent pipe **10** as described above, it is possible to reduce unwanted detection by the tank compartment internal gas detector **44a** due to the fuel gas discharged from the end portion **71a**.

(170) An upper duct compartment air supply port **80e** with an opening is provided in the bottom wall **80b** of the upper duct compartment **80**. The upper duct compartment air supply port **80e** communicates with the duct communication portion **91**. Therefore, the upper duct compartment **80** communicates with the lower duct compartment **70** via the upper duct compartment air supply port **80e**, the duct communication portion **91**, and the lower duct compartment communication port **70f**. The upper duct compartment air supply port **80e** may be provided on an outer wall other than the bottom wall **80b** in the upper duct compartment **80**.

(171) The upper duct compartment **80** has a vent pipe communication portion **81**. The vent pipe communication portion **81** is a pipe by which the inside of the upper duct compartment **80** communicates with the vent pipe **10**. In FIG. **11**, the vent pipe communication portion **81** is illustrated as having a shape bent upward from the horizontal orientation, but the shape of the vent pipe communication portion **81** is not limited to the shape in FIG. **11**. The reason why the vent pipe communication portion **81** is bent upward is similar to the reason why the end portion **71a** of the fuel gas discharge pipe **71** is bent upward. That is, the vent pipe communication portion **81** is bent upward to reduce unwanted detection by the tank compartment internal gas detector **44a** due to the fuel gas discharged from the vent pipe communication portion **81**, which will be described later.

(172) The vent pipe **10** extends upward from the tank compartment **40** and passes through the interior of the upper duct compartment **80**. More specifically, the vent pipe **10** passes through the bottom wall **80b** of the upper duct compartment **80**, enters the inside of the vent pipe **10**, and passes through the top wall **80a**. The vent pipe communication portion **81** is provided in the upper duct compartment **80** to penetrate through the side wall of the vent pipe **10**. As a result, the upper duct compartment **80** communicates with the vent pipe **10** via the vent pipe communication portion **81**.

(173) Therefore, the air inside the upper duct compartment **80** is discharged to the outside of the ship through the vent pipe communication portion **81** and the vent pipe **10**. In this way, it is

possible to ventilate the inside of the upper duct compartment **80**. If the fuel gas leaks from the fuel gas discharge pipe **71** in the upper duct compartment **80**, the leaked fuel gas is discharged to the outside of the ship through the vent pipe communication portion **81** and the vent pipe **10**. In this way, it is possible to prevent the leaked fuel gas from being retained in the upper duct compartment **80**.

(174) The upper duct compartment **80** and the lower duct compartment **70** communicate with each other via the duct communication portion **91**. As a result, (1) air taken into the inside of the lower duct compartment **70** via the lower duct compartment air supply pipe **74**, (2) a fuel gas leaked from the fuel gas supply pipe **32** in the lower duct compartment **70** for some reason, and (3) air or a fuel gas discharged from the fuel cell compartment **30** to the lower duct compartment **70** via the communication pipe **92** can be discharged to the outside of the ship via the upper duct compartment **80** and the vent pipe **10**. In this way, it is possible to suppress the retention of the fuel gas inside the lower duct compartment **70** and inside the fuel cell compartment **30**.

(175) The fuel gas filling port **82** and a fuel gas check valve **83** are provided in the upper duct compartment **80**. The fuel gas filling port **82** is connected to the gas filling pipe **42**. The fuel gas check valve **83** is provided in the gas filling pipe **42**. More specifically, the fuel gas check valve **83** is located between the point where an inert gas pipe **87** (described later) branches from the gas filling pipe **42** and the fuel gas filling port **82**.

(176) The fuel gas supplied from the fuel gas filling port **82** travels through the fuel gas check valve **83** and the gas filling pipe **42**, and is supplied to the fuel tank **41** in the tank compartment **40**. As a result, the fuel gas is filled in the fuel tank **41** and stored. The fuel gas check valve **83** is provided to prevent backflow of the fuel gas from the fuel tank **41** side to the fuel gas filling port **82**.

(177) The upper duct compartment **80** is further provided with the inert gas filling port **84**, an on-off valve **85**, an inert gas check valve **86**, and the inert gas pipe **87**. The inert gas filling port **84** is connected to the inert gas pipe **87**. The inert gas pipe **87** is provided by branching from the gas filling pipe **42** in the upper duct compartment **80**. The on-off valve **85** and the inert gas check valve **86** are provided in the inert gas pipe **87**. In the inert gas pipe **87**, the on-off valve **85** is located between the inert gas filling port **84** and the inert gas check valve **86**.

(178) The on-off valve **85** opens or closes the flow path of the inert gas pipe **87**. In a configuration in which the inert gas check valve **86** is provided in the inert gas pipe **87**, installation of the on-off valve **85** may be omitted.

(179) When inert gas is supplied to the inert gas filling port **84** and the on-off valve **85** opens the flow path of the inert gas pipe **87** in a state in which the fuel gas is not supplied to the fuel gas filling port **82**, the inert gas is supplied to the fuel tank **41** in the tank compartment **40** through the inert gas check valve **86**, and via the inert gas pipe **87** and the gas filling pipe **42**. In addition, the tank side shutoff valve **43** opens the flow path of the fuel gas supply pipe **32**, the fuel cell side shutoff valve **33** closes the flow path of the fuel gas supply pipe **32**, and the release valve **72** opens the flow path of the fuel gas discharge pipe **71**, whereby the fuel gas remaining in the fuel tank **41** is discharged to the vent pipe **10** via the fuel gas supply pipe **32** and the fuel gas discharge pipe **71**. As a result, the fuel gas can be removed from the fuel tank **41** (purge process).

(180) There may be a pipe from the gas filling pipe **42** that is directly connected to the fuel gas supply pipe **32** between the fuel tank **41** and the tank side shutoff valve **43** (tank method). In this configuration, when performing a purge process for the fuel tank **41** using the inert gas, it is necessary to fill the fuel tank **41** with the inert gas in a state in which the tank side shutoff valve **43** is closed, and after that, to open the tank side shutoff valve **43** for the purpose of facilitating the release of the inert gas from the fuel tank **41**.

(181) The fuel gas filling port **82** and the inert gas filling port **84** are provided in the upper duct compartment **80** as described above. More specifically, the fuel gas filling port **82** and the inert gas filling port **84** are located at a boundary surface between the inside and the outside of the upper

duct compartment **80**. That is, “the fuel gas filling port **82** and the inert gas filling port **84** are provided in the upper duct compartment **80**” includes a case where the fuel gas filling port **82** and the inert gas filling port **84** are provided at the boundary surface of the upper duct compartment **80**. (182) An upper duct compartment internal gas detector **88** is housed in the upper duct compartment **80**. The upper duct compartment internal gas detector **88** is a fuel gas detector arranged inside the upper duct compartment **80**. For example, if the fuel gas is hydrogen gas, the upper duct compartment internal gas detector **88** includes a hydrogen gas detection sensor.

(183) The upper duct compartment internal gas detector **88** is arranged on the top wall **80a** located in an upper portion of the upper duct compartment **80**. Hydrogen gas as the fuel gas is lighter than air and rises. Therefore, if the fuel gas leaks in the upper duct compartment **80**, the leaked fuel gas can be reliably detected by the upper duct compartment internal gas detector **88**. To more reliably detect the fuel gas leaked in the upper duct compartment **80**, the upper duct compartment internal gas detector **88** may be arranged at a position close to the vent pipe communication portion **81**.

(184) If the upper duct compartment internal gas detector **88** detects the fuel gas in the upper duct compartment **80**, a detection signal is sent from the upper duct compartment internal gas detector **88** to the control unit **12a**. As a result, the control unit **12a** can control the shutoff valves SV provided in the fuel gas supply pipe **32** to stop the supply of fuel gas from the fuel tank **41** to the fuel cell **31**.

(185) The upper duct compartment **80** may further house a fire detector that detects a fire inside the upper duct compartment **80**.

(186) (7-4. Supplementary Information about Vent Pipe)

(187) Inside the vent pipe **10**, a vent pipe internal gas detector **10a** is provided further on the downstream side than a discharge port **81a** of the vent pipe communication portion **81**. The downstream side refers to the downstream side in the air flow direction when the air inside the tank compartment **40** flows inside the vent pipe **10** and is discharged to the outside of the ship. For example, if the fuel gas is hydrogen gas, the vent pipe internal gas detector **10a** includes a diffusion type or suction type hydrogen gas detection sensor. A detection signal from the vent pipe internal gas detector **10a** is sent to the control unit **12a**.

(188) For example, in a state where the control unit **12a** outputs a signal (closing signal) for closing the release valve **72**, if the vent pipe internal gas detector **10a** detects the fuel gas even though the tank compartment internal gas detector **44a** and the upper duct compartment internal gas detector **88** do not detect the fuel gas, it is possible to determine that the release valve **72** is not completely blocking the flow path of the fuel gas discharge pipe **71**, that is, the release valve **72** is malfunctioning. In this case, by sending a notification to the outside, for example, the control unit **12a** can prompt a maintenance person to inspect, repair, or replace the release valve **72**. The notification to the outside includes a monitor display, output of an alarm sound, transmission of information to an external terminal, and the like.

(189) [8. Power Generation Control of Fuel Cell Based on Anomaly Detection]

(190) As described above, the fuel cell ship SH of the present embodiment includes the plurality of fuel cells **31**, and also includes the plurality of fuel cell compartments **30** for housing the fuel cells **31**. Therefore, a plurality of cell compartment air supply devices **36** for supplying air in the fuel cell compartments **30** are also provided corresponding to each fuel cell compartment **30**.

Accordingly, it can be said that the fuel cell ship SH of the present embodiment has the following configuration. That is, the fuel cell ship SH includes the plurality of fuel cell compartments **30** each including one of the plurality of fuel cells **31** separately installed, and the plurality of cell compartment air supply devices **36** each supplying air to the inside of one of the plurality of fuel cell compartments **30**.

(191) The above-described control unit **12a** of the present embodiment also functions as an electric power generation control unit that controls the electric power generation of the plurality of fuel cells **31**. Particularly, if at least one of the plurality of cell compartment air supply devices **36** stops,

the control unit **12a** stops the electric power generation of the fuel cell **31** installed in the fuel cell compartment **30** to which the cell compartment air supply device **36** that has stopped supplied air. (192) Determining whether the cell compartment air supply device **36** has stopped can be performed by the control unit **12a** constantly or periodically monitoring signal output by the cell compartment air supply devices **36** during operation. For example, if the above-mentioned signal is not received even though the fuel cell **31** is operating (generating electric power), the control unit **12a** can determine that the cell compartment air supply device **36** has stopped due to a failure or the like. That is, the control unit **12a** can determine whether the cell compartment air supply device **36** has stopped based on the above-mentioned signal output by the cell compartment air supply devices **36** during operation.

(193) In this control, if the cell compartment air supply device **36** has stopped for some reason (for example, a failure), ventilation of the fuel cell compartment **30** to which the cell compartment air supply device **36** that has stopped supplied air cannot be performed, and thus it becomes impossible to deal with fuel gas leak in the fuel cell compartment **30**. Therefore, if the cell compartment air supply device **36** has stopped, the control unit **12a** as the electric power generation control unit stops the electric power generation of the fuel cell **31** in the fuel cell compartment **30** to which air was supplied by the cell compartment air supply device **36** that has stopped. As a result, the risk of fuel gas leakage in the fuel cell compartment **30** due to the operation of the fuel cell **31** can be reduced even a little, and efforts can be made to ensure safety.

(194) As described above, the fuel cell ship SH of the present embodiment includes at least one tank compartment **40** in which the fuel tank **41** for housing the fuel gas is installed, and the tank compartment air supply device **46** that supplies air to the inside of the tank compartment **40**. In this configuration, if the tank compartment air supply device **46** stops, the control unit **12a** stops electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, to which the fuel gas is supplied from the fuel tank **41** installed in the tank compartment **40** to which the tank compartment air supply device **46** that has stopped supplied air.

(195) For example, in the configuration illustrated in FIG. 2, if the tank compartment air supply device **46** that supplies air into the tank compartment **40** housing the fuel tank **41a** has stopped due to a failure, the control unit **12a** as the electric power generation control unit stops the electric power generation of the fuel cells **31a** and **31b** to which the fuel gas is supplied from the fuel tank **41a**.

(196) The power consumption of the tank compartment air supply device **46** can be monitored or signal output during operation can be constantly or periodically monitored by the control unit **12a** to determine whether the tank compartment air supply device **46** has stopped. For example, if the above-mentioned signal is not received even though the fuel cell **31** is operating (generating electric power), the control unit **12a** can determine that the tank compartment air supply device **46** has stopped due to a failure or the like. That is, the control unit **12a** can determine whether the tank compartment air supply device **46** has stopped based on the above-mentioned signal output by the tank compartment air supply device **46** during operation.

(197) If the tank compartment air supply device **46** has stopped for some reason (for example, a failure), ventilation of the inside of the tank compartment **40** to which the tank compartment air supply device **46** that has stopped supplied air cannot be performed. In this case, it becomes impossible to deal with fuel gas leakage in the tank compartment **40**. Therefore, if the tank compartment air supply device **46** stops, the control unit **12a** stops electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, to which the fuel gas is supplied from the fuel tank **41** in the tank compartment **40** to which the tank compartment air supply device **46** that has stopped supplied air. As a result, the possibility of fuel gas leaking in the tank compartment **40** due to the supply of the fuel gas to the fuel cell **31** can be reduced even a little, and efforts can be made to ensure safety.

(198) As described above, the fuel cell ship SH of the present embodiment includes the plurality of

fuel cell compartments **30**. Therefore, the plurality of cell compartment internal gas detectors **34a** and cell compartment external gas detectors **37** are also provided corresponding to each fuel cell compartment **30**. That is, the fuel cell ship SH includes the plurality of fuel cell compartments **30** each including one of the plurality of fuel cells **31** separately installed, the plurality of cell compartment internal gas detectors **34a** that are respectively arranged inside the plurality of fuel cell compartments **30** and that detect the fuel gas, and the plurality of cell compartment external gas detectors **37** that are respectively arranged outside the plurality of fuel cell compartments **30** and that detect the fuel gas flowing into the fuel cell compartments **30**.

(199) If at least one of the plurality of cell compartment internal gas detectors **34a** and the plurality of cell compartment external gas detectors **37** reacts to the fuel gas or the combustible gas or fails, the control unit **12a** as the electric power generation control unit of the present embodiment stops electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, in the fuel cell compartment **30** in which the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** that has reacted or failed is arranged.

(200) Determining whether the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** has failed can be performed by the control unit **12a** constantly or periodically monitoring signals output from the cell compartment internal gas detectors **34a** and the cell compartment external gas detectors **37** during operation (when normal). For example, if the above-mentioned signal is not received even though the fuel cell **31** is operating (generating electric power), the control unit **12a** can determine that the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** has failed (stopped). That is, the control unit **12a** can determine, based on the above signals output by the cell compartment internal gas detectors **34a** and the cell compartment external gas detectors **37** during operation, whether the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** has failed (stopped).

(201) If the cell compartment internal gas detector **34a** detects the fuel gas (reacts to the fuel gas), there is a high possibility that a fuel gas leak has occurred in the fuel cell compartment **30**. If the cell compartment external gas detector **37** detects combustible gas (reacts to combustible gas), there is a high possibility that combustible gas is flowing into the inside from the outside of the fuel cell compartment **30** and retained inside. In these cases, in terms of safety, driving the fuel cell **31** installed in that fuel cell compartment **30** is not preferable (there is a risk of explosion for some reason). If the cell compartment air supply device **36** is not explosion-proof, there is a risk that the cell compartment air supply device **36** will explode.

(202) If the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** fails, it is not possible to detect a fuel gas leak inside the fuel cell compartment **30** or inflow of combustible gas from the outside to the inside of the fuel cell compartment **30**. Therefore, in terms of safety, driving the fuel cell **31** in this state is not preferable.

(203) Stopping, when at least one of the plurality of cell compartment internal gas detectors **34a** and the plurality of cell compartment external gas detectors **37** reacts or fails, electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, in the fuel cell compartment **30** in which the cell compartment internal gas detector **34a** or the cell compartment external gas detector **37** that has reacted or failed is correspondingly arranged (inside or outside thereof), by the control unit **12a** as the electric power generation control unit, makes it possible to ensure safety.

(204) The fuel cell ship SH of this embodiment, as described above, includes at least one tank compartment **40** in which the fuel tank **41** for housing the fuel gas is installed, the tank compartment internal gas detector **44a** which is arranged inside the tank compartment **40** and detects the fuel gas, and the tank compartment external gas detector **47** that is arranged outside the tank compartment **40** and detects combustible gas flowing into the inside of the tank compartment **40**. In this configuration, if at least one of the tank compartment internal gas detector **44a** and the tank compartment external gas detector **47** reacts to the fuel gas or the combustible gas or fails, the

control unit **12a** stops electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, to which the fuel gas is supplied from the fuel tank **41** in the tank compartment **40** in which the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** that has reacted or failed is arranged.

(205) For example, in the configuration illustrated in FIG. 2, if the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** arranged corresponding to the tank compartment **40** housing the fuel tank **41c** reacts to the fuel gas or combustible gas, the control unit **12a**, as an electric power generation control unit, stops the electric power generation of the fuel cell **31c** to which the fuel gas is supplied from the fuel tank **41c**. In addition, for example, if the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** arranged corresponding to the tank compartment **40** housing the fuel tank **41c** fails, the control unit **12a** also stops the electric power generation of the fuel cell **31c** to which the fuel gas is supplied from the fuel tank **41c**.

(206) Determining whether the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** has failed can be performed by monitoring the power consumption of the tank compartment internal gas detectors **44a** and the tank compartment external gas detectors **47**, or by the control unit **12a** constantly or periodically monitoring signals output from the tank compartment internal gas detectors **44a** and tank compartment external gas detectors **47** during operation (when normal). For example, if the above-mentioned signal is not received even though the fuel cell **31** is operating (generating electric power), the control unit **12a** can determine that the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** has failed (stopped). That is, the control unit **12a** can determine, based on the above signals output by the tank compartment internal gas detectors **44a** and the tank compartment external gas detectors **47** during operation, whether the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** has failed (stopped).

(207) If the tank compartment internal gas detector **44a** detects the fuel gas (reacts to the fuel gas), there is a high possibility that a fuel gas leak has occurred in the tank compartment **40**. If the tank compartment external gas detector **47** detects combustible gas (reacts to combustible gas), there is a high possibility that combustible gas is flowing into the inside from the outside of the tank compartment **40** and retained inside. In these cases, in terms of safety, driving the fuel cell **31** to which the fuel gas is supplied from the tank compartment **40** is not preferable (there is a risk of explosion for some reason). If the tank compartment air supply device **46** is not explosion-proof, there is a risk that the tank compartment air supply device **46** will explode.

(208) If the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** fails, it is not possible to detect a fuel gas leak inside the tank compartment **40** or inflow of combustible gas from the outside to the inside of the tank compartment **40**. Therefore, in terms of safety, driving the fuel cell **31** in this state is not preferable.

(209) Stopping, when at least one of the tank compartment internal gas detectors **44a** and the tank compartment external gas detectors **47** reacts or fails, electric power generation of a fuel cell **31** of the plurality of fuel cells **31**, to which the fuel gas is supplied from the fuel tank **41** in the tank compartment **40** in which the tank compartment internal gas detector **44a** or the tank compartment external gas detector **47** that has reacted or failed is correspondingly arranged (inside or outside thereof), by the control unit **12a** as the electric power generation control unit, makes it possible to ensure safety.

(210) In the present embodiment, the duct compartments **90** forming a pair are provided on the starboard side and the port side of the fuel cell ship SH, respectively. In this configuration, if, in at least one of the duct compartments **90**, at least one of the lower duct compartment internal gas detector **73**, the upper duct compartment internal gas detector **88**, and the lower duct compartment external gas detector **76** reacts to the fuel gas or combustible gas or fails, it is desirable that the control unit **12a** stops electric power generation of a fuel cell **31**, of the plurality of fuel cells **31**, to

which the fuel gas is supplied from the fuel tank **41** via the duct compartment **90** in which the lower duct compartment internal gas detector **73**, the upper duct compartment internal gas detector **88**, or the lower duct compartment external gas detector **76** which has reacted or failed is arranged. (211) If the lower duct compartment internal gas detector **73** or the upper duct compartment internal gas detector **88** detects the fuel gas (reacts to the fuel gas), it is highly possible that a fuel gas leak has occurred in the duct compartment **90**. If the lower duct compartment external gas detector **76** detects combustible gas (reacts to combustible gas), there is a high possibility that combustible gas is flowing into the inside from the outside of the duct compartment **90** and retained inside. In these cases, in terms of safety, driving the fuel cell **31** to which the fuel gas is supplied from the tank compartment **40** through the duct compartment **90** is not preferable (there is a risk of explosion for some reason). If the lower duct compartment air supply device **75** is not explosion-proof, there is a risk that the lower duct compartment air supply device **75** will explode. The electric power generation of the fuel cell **31** selected as described above can be stopped to ensure safety.

(212) [9. Limitation of Electric Power Input to Propulsion Device]

(213) In the fuel cell ship SH equipped with the plurality of fuel cells **31**, as described above, even in a case of an emergency shutdown of at least one of the fuel cells **31** due to fuel gas leakage or other event in the hull **1** during sailing, at least one of the electric power output from the other fuel cells **31** and the electric power supplied by the storage battery **51** can drive the propulsion device **6** to continue sailing.

(214) Here, in a case where the electric power input from the fuel cell **31** to the propulsion device **6** is rapidly reduced due to an emergency shutdown of the fuel cell **31**, if the electric power output from the storage battery **51** is low, the sailing speed of the fuel cell ship SH is rapidly reduced, making it easier for persons on the ship to fall over. This is because the fuel cell ship SH that sails at sea and in rivers, receives a large amount of resistance from the water surface during sailing, unlike vehicles traveling on a road.

(215) Therefore, in the fuel cell ship SH equipped with the plurality of fuel cells **31**, at least one storage battery **51**, and the propulsion device **6**, as in the present embodiment, the control unit **12a** may monitor temperature information of the storage battery **51** and the state of charge (SOC) data, and based on the above temperature information and SOC data, calculate electric power that can be output from the storage battery **51**, and set an upper limit value of the electric power as the upper limit value of the input power value (proportional to at least one of the rotational speed and the torque) supplied to the propulsion device **6**.

(216) For example, in the configuration illustrated in FIG. 2, as described above, if a fuel gas leak is detected in the tank compartment **40** housing the fuel tank **41b**, the control unit **12a** stops the electric power generation of the fuel cells **31a** and **31b** to which the fuel gas is supplied from the fuel tank **41b**. In this case, it is necessary for the fuel cells **31c**, **31d** and **31e** and the storage battery **51** to supply electric power for operating the propulsion device **6**. If the fuel cells **31c**, **31d** and **31e** are stopped for some reason, it is necessary to supply electric power for operating the propulsion device **6** with only the storage battery **51**.

(217) Therefore, during normal operation (normal sailing), it is desirable that the control unit **12a** sets the upper limit value of the electric power value input to the propulsion device **6** (particularly the propulsion motor **6b**) from at least one of the fuel cells **31** and the storage battery **51**, as the output upper limit value of the storage battery **51**. In this case, even if, for example, emergency shutdown of all of the fuel cells **31** occurs for some reason, the propulsion device **6** can continue to operate with the electric power output from the storage battery **51** without rapidly reducing the sailing speed of the fuel cell ship SH. That is, even if emergency shutdown of the fuel cells **31** occurs during sailing, it is possible to prevent a sudden decrease in sailing speed. As a result, it is possible to reduce the risk that persons on the ship fall over when emergency shutdown of the fuel cells **31** occurs.

(218) [10. Other]

(219) In the present embodiment, the fuel gas is used as the fuel supplied from the fuel tank **41** to the fuel cell **31**, but the fuel is not limited to a gas and may be a liquid. When a liquid fuel is used, if the liquid fuel leaks from a pipe, the leaked liquid fuel vaporizes and becomes a gas (a fuel gas).

(220) In the present embodiment, a configuration in which the fuel cell ship SH has the duct compartment **90** has been described, but the duct compartment **90** need not be installed. For example, by providing vent pipes corresponding to each of the tank compartment **40** and the fuel cell compartment **30**, the installation of the duct compartment **90** can be omitted (this is because it is not necessary to provide a flow path from the fuel cell compartment **30** to the vent pipe **10**).

(221) Embodiments of the present invention have been described above; however, the scope of the present invention is not limited to these embodiments, and can be extended or modified without departing from the gist of the invention.

INDUSTRIAL APPLICABILITY

(222) The present invention can be used, for example, in a fuel cell ship.

REFERENCE SIGNS LIST

(223) **1** Hull **6** Propulsion device **12a** Control unit (degradation rate control unit, electric power generation control unit) **31** Fuel cell **41** Fuel tank **41a** Individual tank (fuel tank) **41b** Individual tank (fuel tank) **51** Storage battery **100** Electric power supply unit SH Fuel cell ship

Claims

1. A fuel cell ship, the fuel cell ship comprising: a propulsion device configured to generate a propulsive force on a hull by electric power; an electric power supply unit configured to supply the electric power to the propulsion device, wherein the electric power supply unit includes a plurality of fuel cells configured to generate electric power by an electrochemical reaction of fuel and at least one storage battery; and a degradation rate control unit configured to: adjust a degradation rate of the plurality of fuel cells when an electric power load consumed by the fuel cell ship is equal to or less than a first threshold value, wherein the first threshold value is determined according to: a lower limit value of a range of electric power generation output of the plurality of fuel cells in which a degradation progress rate of the plurality of fuel cells is equal to or less than a predetermined value, and a quantity of fuel cells of the plurality of the fuel cells; and change a method of adjusting the degradation rate according to an estimated time during which a state continues where the electric power load is equal to or less than the first threshold value.
2. The fuel cell ship according to claim 1, comprising a plurality of sets of the propulsion device and the electric power supply unit.
3. The fuel cell ship according to claim 1, further comprising a plurality of fuel tanks configured to store the fuel, wherein the plurality of fuel tanks include a first fuel tank and a second fuel tank that are each connected to a same two or more fuel cells of the plurality of fuel cells.
4. The fuel cell ship according to claim 1, wherein the degradation rate indicates a degree of degradation of the plurality of fuel cells, the degradation rate control unit is configured to adjust the degradation rate of at least one fuel cell of the plurality of fuel cells so that an estimated replacement period approaches or coincides with a scheduled replacement period, the estimated replacement period is a period when the degradation rate of each fuel cell of the plurality of fuel cells reaches a degradation rate suitable for replacement due to degradation of each of the plurality of fuel cells, and the scheduled replacement period is a predetermined replacement period of each of the plurality of fuel cells.
5. The fuel cell ship according to claim 1, wherein if the electric power load consumed by the fuel cell ship is equal to or greater than a second threshold value determined according to a rated output of a respective fuel cell of the plurality of fuel cells and a quantity of fuel cells of the plurality of the fuel cells, the degradation rate control unit is configured to: adjust the degradation rate of the

plurality of fuel cells, and set, to a value equal to or less than the rated output, the electric power generation output of a fuel cell of the plurality of the fuel cells whose degradation is to be suppressed.

6. The fuel cell ship according to claim 1, further comprising: a plurality of fuel cell compartments each including one of the plurality of fuel cells separately installed; a plurality of cell compartment air supply devices each configured to supply air to inside of one of the plurality of fuel cell compartments; and an electric power generation control unit configured to control electric power generation of the plurality of fuel cells, wherein, if at least one of the plurality of cell compartment air supply devices stops, the electric power generation control unit is configured to stop electric power generation of the fuel cell installed in the fuel cell compartment to which the cell compartment air supply device that has stopped supplied air.

7. The fuel cell ship according to claim 6, further comprising: at least one tank compartment installed with a fuel tank configured to store the fuel; and a tank compartment air supply device configured to supply air to an inside of the at least one tank compartment, wherein if the tank compartment air supply device stops, the electric power generation control unit is configured to stop electric power generation of a fuel cell of the plurality of fuel cells to which the fuel is supplied from the fuel tank installed in the at least one tank compartment to which the tank compartment air supply device that has stopped supplied air.

8. The fuel cell ship according to claim 1, further comprising: a plurality of fuel cell compartments each including one of the plurality of fuel cells separately installed; a plurality of cell compartment internal gas detectors, each of which is arranged inside a respective one of the plurality of fuel cell compartments and is configured to detect a fuel gas that is the fuel in a gaseous state; a plurality of cell compartment external gas detectors, each of which is arranged outside a respective one of the plurality of fuel cell compartments and is configured to detect a combustible gas flowing into the respective one of the plurality of fuel cell compartments; and an electric power generation control unit configured to control electric power generation of the plurality of fuel cells, wherein, if at least one of the plurality of cell compartment internal gas detectors or the plurality of cell compartment external gas detectors reacts to the fuel gas or the combustible gas or fails, the electric power generation control unit is configured to stop electric power generation of a fuel cell of the plurality of fuel cells that is in the fuel cell compartment in which the at least one of the plurality of cell compartment internal gas detectors or the plurality of cell compartment external gas detectors that has reacted or failed is arranged.

9. The fuel cell ship according to claim 8, further comprising: at least one tank compartment installed with a fuel tank configured to store the fuel; a tank compartment internal gas detector that is arranged inside the tank compartment and configured to detect a fuel gas being the fuel in a gaseous state; and a tank compartment external gas detector that is arranged outside the tank compartment and configured to detect combustible gas flowing into the tank compartment, wherein, if at least one of the tank compartment internal gas detector and the tank compartment external gas detector reacts to the fuel gas or the combustible gas or fails, the electric power generation control unit is configured to stop electric power generation of a fuel cell of the plurality of fuel cells, to which the fuel is supplied from the fuel tank in the tank compartment in which the tank compartment internal gas detector or the tank compartment external gas detector that has reacted or failed is arranged.

10. A fuel cell ship, the fuel cell ship comprising: a propulsion device configured to generate a propulsive force on a hull by electric power; an electric power supply unit configured to supply the electric power to the propulsion device, wherein the electric power supply unit includes a plurality of fuel cells configured to generate electric power by an electrochemical reaction of fuel and at least one storage battery; a plurality of fuel cell compartments each including one fuel cell of the plurality of fuel cells separately installed; a plurality of cell compartment air supply devices each configured to supply air to an inside of one of the plurality of fuel cell compartments; and an

electric power generation control unit configured to control electric power generation of the plurality of fuel cells, wherein, if at least one of the plurality of cell compartment air supply devices stops, the electric power generation control unit is configured to stop electric power generation of the respective fuel cell installed in the fuel cell compartment to which the cell compartment air supply device that has stopped was supplying air.

11. A fuel cell ship, the fuel cell ship comprising: a propulsion device configured to generate a propulsive force on a hull by electric power; an electric power supply unit configured to supply the electric power to the propulsion device, wherein the electric power supply unit includes a plurality of fuel cells configured to generate electric power by an electrochemical reaction of fuel and at least one storage battery; a plurality of fuel cell compartments each including one fuel cell of the plurality of fuel cells separately installed; a plurality of cell compartment internal gas detectors, each of which is arranged inside a respective one of the plurality of fuel cell compartments and is configured to detect a fuel gas, wherein the fuel gas is the fuel in a gaseous state; a plurality of cell compartment external gas detectors, each of which is arranged outside a respective one of the plurality of fuel cell compartments and is configured to detect a combustible gas flowing into the respective one of the plurality of fuel cell compartments; and an electric power generation control unit configured to control electric power generation of the plurality of fuel cells, wherein, if at least one of the plurality of cell compartment internal gas detectors or the plurality of cell compartment external gas detectors reacts to the fuel gas or the combustible gas or fails, the electric power generation control unit is configured to stop electric power generation of a respective fuel cell of the plurality of fuel cells that is in the fuel cell compartment in which the at least one of the plurality of cell compartment internal gas detectors or the plurality of cell compartment external gas detectors that has reacted or failed is arranged.
