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(54) **Title**: HYDROGEN GAS GENERATING SYSTEM

(54) 発明の名称 : 水素ガス発生システム

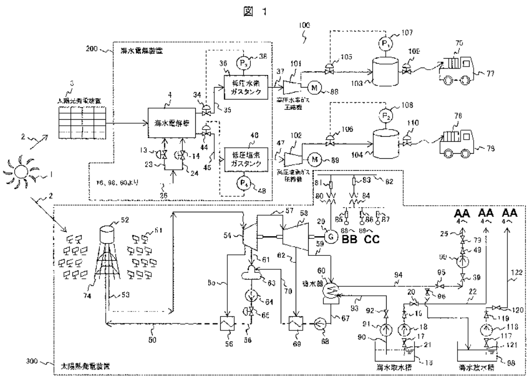

FIG. 1:
3 Photovoltaic device
4 Seawater electrolysis tank
16 Seawater intake tank
26 From 16, 98, 60
36 Low pressure hydrogen gas tank
46 Low pressure chlorine gas tank
60 Condenser
98 Seawater discharge tank
101 High pressure hydrogen gas compressor
102 High pressure chlorine gas compressor
200 Seawater electrolysis device
300 Solar heat power generating device
AA To 4
BB To 88
CC To 89

(57) **Abstract**: The present invention provides a hydrogen gas generating system that can manufacture and supply high pressure hydrogen gas in large volumes, inexpensively, and stably. This hydrogen gas generating system is provided with: a photovoltaic device (3) that is provided with solar cells and generates direct current electricity; a seawater electrolysis device (200) that generates hydrogen gas by electrolysis of seawater using the direct current electricity generated by the photovoltaic device (3); a solar heat power generating device (300) that generates alternating current electricity by rotating turbines (54, 58) by steam generated using solar heat; and a hydrogen gas compressor (101) that is driven by the alternating current electricity generated by the solar heat power generating device (300) and compresses the hydrogen gas generated by the seawater electrolysis device (200).

(57) 要約: 本発明は、高圧の水素ガスを大量、安価、かつ安定的に製造し供給することが可能な水素ガス発生システムを提供する。本発明による水素ガス発生システムは、太陽電池を備え、直流電気を発電する太陽光発電装置（３）と、太陽光発電装置（３）が発電した直流電気を用いて海水を電気分解して水素ガスを発生させる海水電解装置（２００）と、太陽熱を利用して生成した蒸気でタービン（５４、５８）を回転させて交流電気を発電する太陽熱発電装置（３００）と、太陽熱発電装置（３００）が発電した交流電気で駆動され、海水電解装置（２００）が発生させた水素ガスを圧縮する水素ガス圧縮機（１０１）とを備える。

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DESCRIPTION

TITLE OF THE INVENTION

HYDROGEN GAS GENERATING SYSTEM

FIELD OF THE INVENTION

[0001]

The invention relates to a hydrogen gas generating system for producing a hydrogen gas.

BACKGROUND OF THE INVENTION

[0002]

A hydrogen gas is used for a fuel of a fuel-cell vehicle, for example. As the production of the fuel-cell vehicle is expected to increase from now on, an increase in demand for the hydrogen gas is anticipated. Accordingly, it is desired to develop a technology for stably producing and supplying a large volume of high-pressure hydrogen gases at a low cost.

[0003]

The hydrogen gas can be produced by electrolyzing the seawater. Document 1 discloses a hydrogen gas occlusion system in which DC electricity is generated by using the sunlight and the seawater is electrolyzed with the use of the DC power, thereby producing a hydrogen gas. The hydrogen gas occlusion system includes a panel-shaped fuel cell floated on the sea by the agency of a float, and a cassette with a hydrogen-occlusion electrode incorporated therein, serving as a sinker, and electrolyzes the seawater using the DC electricity generated by the utilization of the sunlight. The hydrogen-occlusion electrode is electrically coupled to a negative terminal of the solar cell via a negative electrode. The seawater is electrolyzed by using the hydrogen-occlusion electrode and a positive electrode electrically couples to a positive terminal of the solar cell. Hydrogen that is generated through the electrolyzation of the seawater is occluded in the hydrogen-occlusion electrode. In the hydrogen gas occlusion system disclosed in Document 1, the cassette incorporating the hydrogen-occlusion electrode is removable from the system and hydrogen can be taken out by removing and heating the cassette.

DOCUMENT LIST

PATENT DOCUMENT

[0004]

Document 1: JP 2008-174771

SUMMARY OF THE INVENTION

[0005]

With a conventional method for electrolyzing seawater by using a DC power generated by the solar cell, as in Document

1, hydrogen can be produced at a low cost. However, this method is disadvantageous in that a volume of high-pressure hydrogen gases generated and available for supply will be unstable under the influence of variation in solar energy since a voltage and a current of generated electricity largely varies when the intensity of the sunlight varies.

[0006]

Further, the method in which the hydrogen gas occlusion system is floated on the sea surface, as in Document 1, is easily affected not only by movement of the sea surface due to waves and an ocean current but also by large waves due to a typhoon, etc., rendering it difficult to securely hold the hydrogen gas occlusion system. Therefore, the method may have difficulty in stably producing a large volume of hydrogen gases.

[0007]

With use of the hydrogen gas occlusion system disclosed in Document 1, it is necessary to have a multitude of the hydrogen gas occlusion systems floated on the sea surface in order to produce a large volume of hydrogen gases. The method is therefore disadvantageous in that there is the need for removing the cassette from the multitude of the hydrogen gas occlusion systems to take out the hydrogen from the hydrogen-occlusion electrode and the need for substituting a cassette incorporating the hydrogen-occlusion electrode containing no hydrogen therein for a removed cassette. So, the hydrogen gas occlusion system disclosed in Document 1 involves a challenge that much cost and labor a re required for producing and supplying the hydrogen gases.

[0008]

As described above, conventional technologies are disadvantageous in that it is difficult to stably produce and supply a large volume of the high-pressure hydrogen gases at a low cost. In certain embodiments the invention seeks to provide a hydrogen gas generating system which stably produces and supplies a large volume of high-pressure hydrogen gases at a low cost.

[0009]

According to one aspect of the present invention, a hydrogen gas generating system includes a photovoltaic power generation unit for generating DC electricity, including a fuel cell; a seawater electrolyzation unit for generating a hydrogen gas by electrolyzing seawater with the use of the DC electricity generated by the photovoltaic power generation unit; a solar thermal power generation unit for generating AC electricity by rotating a turbine with the use of a steam generated by utilizing solar heat; and a hydrogen gas compressor for compressing the hydrogen gas generated by the seawater electrolyzation unit, the hydrogen gas compressor being driven by the AC electricity generated by the solar thermal power generation unit.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0010]

In certain embodiments the invention provides a hydrogen gas generating system which stably produces and supplies a large volume of high-pressure hydrogen gases at a low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a view showing an overall configuration of a hydrogen gas generating system according to an embodiment of the present invention;

Fig. 2 is a view showing a configuration of a seawater electrolyzation unit of the hydrogen gas generating system according to the present embodiment; and

Fig. 3 is a view showing a configuration of a solar thermal power generation unit of the hydrogen gas generating system according to the present embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0012]

A hydrogen gas generating system according to the present invention is installed on the ground and includes a photovoltaic power generation unit, a seawater eletrolyzation unit to use

DC electricity generated by the photovoltaic power generation unit, a solar thermal power generation unit, and a high-pressure gas compressor to be driven by AC electricity generated by the solar thermal power generation unit. The hydrogen gas generating system can stably producing and supplying a large volume of the high-pressure hydrogen gases at a low cost by allowing the seawater electrolyzation unit to electrolyze the seawater to generate a hydrogen gas and the high-pressure gas compressor to compress the generated low-pressure hydrogen gases. Further, the hydrogen gas generating system according to the present invention can compress the low-pressure chlorine gas generated by the electrolyzation of seawater by using a high-pressure gas compressor, so that a large volume of the high-pressure chlorine gases are stably produced and supplied at a low cost. The low-pressure hydrogen gas and the low-pressure chlorine gas, generated by the electrolyzation, are once stored in respective low-pressure tanks, to be subsequently compressed by the respective high-pressure gas compressors before being stored in respective high-pressure tanks. In the present invention, because the DC electricity generated by the photovoltaic power generation unit is utilized for the electrolyzation of seawater and the AC electricity generated by the solar thermal power generation unit is utilized for the compression of the hydrogen gas and the chlorine gas, it is possible to produce and supply the high-pressure hydrogen gas and the high-pressure chlorine gas at a low cost. Furthermore, because the hydrogen gas generating system according to the present invention is installed on the ground, not on the sea surface, it is possible to stably execute the electrolyzation and the compression of the gases without being affected by waves, leading to stable produce and supply of a large volume of the high-pressure hydrogen gases and the high-pressure chlorine gases.

[0013]

As descried above, in the conventional method for electrolyzing seawater with the use of the DC power generated by the solar cell, a volume of the hydrogen gases that are generated and supplied is unstable due to variation in solar energy since the voltage and the current of the generated electricity varies according to the intensity of the sunlight. The present invention is advantageous in that it is possible to suppress the variation in energy obtained from the solar energy even if the variation occurs in the solar energy and to stably supply the high-pressure hydrogen gas and the high-pressure chlorine gas since the solar energy is converted into the energies of the high-pressure hydrogen gas and the high-pressure chlorine gas and stored in respective high-pressure tanks. Further, because the low-pressure hydrogen gas and the low-pressure chlorine gas generated by the electrolyzation of seawater are compressed by the high-pressure gas compressors utilizing the AC electricity generated by the solar thermal power generation unit, it is possible to produce a large volume of the high-pressure hydrogen gases and the high-pressure chlorine gases at a low cost.

[0014]

Thus, the hydrogen gas generating system according to the present invention, which is installed on the ground and uses seawater available at a low cost and two types of the solar energies, sunlight and solar heat, can make the most of synergistic advantageous effects of the electrolyzation of the seawater using the sun light and the solar thermal power generation using the seawater, and can stably produce and supply a large volume of the high-pressure hydrogen gases and the high-pressure chlorine gases at a low cost.

[0015]

In the hydrogen gas generating system according to the present invention, it is possible to continuously operate the seawater electrolyzation unit and the high-pressure gas compressor during the daytime to continuously produce a large volume of hydrogen gases and chlorine gases at a low price. Seawater serving as raw materials of the hydrogen gas and the chlorine gas is nearly limitlessly present in nature so that there is no possibly that the seawater will be in short supply. In the present invention, since solar energy available at no cost is utilized, a large volume of inexpensive high-pressure hydrogen gases and high-pressure chlorine gases can be produced and supplied without generating a carbon-dioxide gas by burning a fossil fuel. The produced high-pressure hydrogen gas can be supplied to, for example, a fuel-cell vehicle consuming a large volume of hydrogen gases. Although a fuel-cell vehicle is expensive at present, the fuel-cell vehicle will be mass-produced in several years and the price of it will come down, and the demand for the hydrogen gas as the fuel is expected to increase from now on. Furthermore, the chlorine gas is in demand as a raw material for various disinfectants and chemical products.

[0016]

In the hydrogen gas generating system according to the present invention, a hydrogen gas and a chlorine gas generated by the seawater electrolyzation unit are once stored in the respective low-pressure tanks as low-pressure gases without being compressed and then compressed by the respective high-pressure gas compressors. Accordingly, even if total irradiance from the sun varies due to a change in weather during the daytime, the generated power of the solar power generation (the solar cell) is varied, and then a volume or a pressure of the hydrogen gases and the chlorine gases generated from the seawater electrolyzation unit varies, a variance in pressure of the hydrogen gases and the chlorine gases in the respective low-pressure tanks can be controlled to fall within a given range dependent on the volume of the low-pressure tanks. Further, even if direct irradiance from the sun largely varies due to a change in weather during the daytime and the generated power of the solar thermal power generation is varied, and then a volume of the hydrogen gases and the chlorine gases compressed by the hydrogen gas compressors varies, a variance in the pressure of the hydrogen gases and the chlorine gases in the respective high-pressure tanks can be controlled to fall within a given range dependent on the volume of the high-pressure tanks. In the present invention, it is possible to suppress variation in the energy obtained from the solar energy by adopting the above-described method even if the solar energy varies.

[0017]

Furthermore, seawater used as a cooling water of the solar thermal power generation unit (a warm discharged water ejected from a condenser) can be used for the seawater to be electrolyzed by the seawater electrolyzation unit. By reusing a portion of the warm discharged water of the condenser of the solar thermal power generation unit for a raw material of the seawater electrolyzation unit (seawater for the electrolyzation), decomposition activity of the seawater electrolyzation unit is increased and, therefore, electric power is decreased required for the electrolyzation to produce the hydrogen gas and the chlorine gas.

[0018]

The hydrogen gas generating system according to an embodiment of the present invention is described below with reference to the drawings.
Configurations and effects of the present invention other than described above will be described in the following description of an embodiment of the invention.

EMBODIMENT
[0019]

Fig. 1 is a view showing an overall configuration of a hydrogen gas generating system 100 according to an embodiment of the present invention. The hydrogen gas generating system 100 according to the present embodiment is installed on the ground and includes, as the main elements, a photovoltaic power generation unit 3, a seawater electrolyzation unit 200, a solar thermal power generation unit 300, a high-pressure hydrogen gas compressor 101, and a high-pressure chlorine gas compressor 102. The hydrogen gas generating system 100 is capable of stably producing and supplying a large volume of high-pressure hydrogen gases and high-pressure chlorine gasses at a low cost. The photovoltaic power generation unit 3 includes a fuel cell and generates a DC power through photovoltaic power generation by the fuel cell. The seawater electrolyzation unit 200 electrolyzes seawater and produces a hydrogen gas and a chlorine gas by using the DC electricity generated by the photovoltaic power generation unit 3. The solar thermal power generation unit 300 generates AC electricity by rotating a turbine with a steam generated using solar-heat. The high-pressure hydrogen gas compressor 101 is driven by a high-pressure hydrogen gas compressor motor 88 and compresses the hydrogen gas generated by the seawater electrolyzation unit 200 with the use of the AC electricity generated by the solar thermal power generation unit 300. The high-pressure chlorine gas compressor 102 is driven by a high-pressure chlorine gas compressor motor 89 and compresses the chlorine gas generated by the seawater electrolyzation unit 200 with the use of the AC electricity generated by the solar thermal power generation unit 300.

[0020]

Fig. 2 is a view showing a configuration of the seawater electrolyzation unit 200 of the hydrogen gas generating system 100 according to the present embodiment. The seawater electrolyzation unit 200 includes, as the main elements, a seawater electrolytic bath 4, a low-pressure hydrogen gas tank 36, and a low-pressure chlorine gas tank 46. The seawater electrolytic bath 4 electrolyzes seawater and produces the hydrogen gas and the chlorine gas by using the DC electricity generated by the photovoltaic power generation unit 3. The low-pressure hydrogen gas tank 36 stores the hydrogen gas generated in the seawater electrolytic bath 4 without application of pressure. The low-pressure chlorine gas tank

46 stores the chlorine gas generated in the seawater electrolytic bath 4 without application of pressure.

[0021]

Fig. 3 is a view showing a configuration of the solar thermal power generation unit 300 of the hydrogen gas generating system 100 according to the present embodiment. The solar thermal power generation unit 300 includes, as the main elements, a solar-heat receiver 52, a high-pressure steam turbine 54, an intermediate/low-pressure steam turbine 58, a generator 29, and a condenser 60. The high-pressure steam turbine 54 and the intermediate/low-pressure steam turbine 58 are rotated by a superheated steam generated by the solar-heat receiver 52, and thereby the generator 29 generates the AC electricity. The superheated steam that has rotated the steam turbines 54 and 58 is cooled by seawater in the condenser 60.

[0022]

For the seawater to be electrolyzed by the seawater electrolyzation unit 200, a warmed seawater can be used which is already used and warmed in the condenser 60 of the solar thermal power generation unit 300. Furthermore, a seawater can be used which is in a seawater-intake basin 16 for taking in seawater to be used in the condenser 60 or in a seawater-discharge basin 98 for discharging the seawater already used in the condenser 60. A large volume of the seawater for the electrolyzation can be supplied to the seawater electrolytic bath 4 in this way.

[0023]

The seawater electrolyzation unit 200 and the solar thermal power generation unit 300 of the hydrogen gas generating system 100 according to the present embodiment are described below in detail with reference to Figs. 1 to 3.

[0024]

First, the seawater electrolyzation unit 200 is described below.

[0025]

As shown in Fig. 2, the seawater electrolytic bath 4 of the seawater electrolyzation unit 200 includes a cathode-bath 9, an anode-bath 10, a hydrogen gas generator 5, and a chlorine gas generator 6. The cathode-bath 9 and the anode-bath 10 contain seawater and are connected with each other via a communication-adjust pipe 150. The communication-adjust pipe 150 includes an anode-cathode-bath flow-rate balance valve 15 and flows seawater between the cathode-bath 9 and the anode-bath 10.

[0026]

An anode-cathode-bath flow-rate balance valve 15 can control a volume of the seawater flowing through the communication-adjust pipe 150, thereby controlling seawater volumes of the cathode-bath 9 and the anode-bath 10. The electrolyzation of the seawater causes the hydrogen gas to be generated in the cathode-bath 9 and the chlorine gas to be generated in the anode-bath 10. As the electrolyzation of the seawater progresses, the volumes of the seawater of the cathode-bath 9 and the anode-bath 10 will decrease. Since the decreased volumes of the seawater are different between the cathode-bath 9 and the anode-bath 10, there occurs a difference in the seawater volume between the cathode-bath 9 and the anode-bath 10. Accordingly, the anode-cathode-bath flow-rate balance valve 15 adjusts the volume of the seawater flowing through the communication-adjust pipe 150 in response to the volume of the decrease in the seawater and controls the difference to be small between the seawater volumes of the cathode-bath 9 and the anode-bath 10.

[0027]

The hydrogen gas generator 5 includes a cathode 7 installed in the seawater contained in the cathode-bath 9 and a hydrogen gas recovery unit 27. The chlorine gas generator 6 includes an anode 8 installed in the seawater contained in the anode-bath 10 and a chlorine gas recovery unit 28. The hydrogen gas recovery unit 27 is made of, for example, a cylindrical container with the top end closed and the bottom end open, and the top part is connected to a hydrogen gas recovery unit outlet-pipe 31, and the bottom part is submerged below the seawater surface of the cathode-bath 9. The chlorine gas recovery unit 28 is made of, for example, a cylindrical container with the top end closed and the bottom end open, and the top part is connected to a chlorine gas recovery unit outlet-pipe 41, and the bottom part is submerged below the seawater surface of the anode-bath 10.

[0028]

The photovoltaic power generation unit 3 generates the DC electricity by using the radiant energy of a sunlight beam 2 radiated from the sun 1. The cathode of the photovoltaic power generation unit 3 is connected to the cathode 7 of the seawater electrolytic bath 4 via a cathode electric-wire 11. The anode of the photovoltaic power generation unit 3 is connected to the anode 8 of the seawater electrolytic bath 4 via an anode electric-wire 12. When the seawater in the seawater electrolytic bath 4 is electrolyzed by the DC electricity generated by the photovoltaic power generation unit 3, a hydrogen gas bubble 30 is generated around the cathode 7 in the hydrogen gas generator 5, and a chlorine gas bubble 40 is generated around the anode 8 in the chlorine gas generator 6.

[0029]

A hydrogen gas generated in the hydrogen gas generator 5 is recovered by the hydrogen gas recovery unit 27. The hydrogen gas recovery unit 27 collects the hydrogen gas generated by the electrolyzation above the seawater surface in the cylindrical container. The collected hydrogen gas is collected in a hydrogen gas outlet header 33 after passing through the hydrogen gas recovery unit outlet-pipe 31 and a hydrogen gas recovery unit outlet-valve 32. The collected hydrogen gas is once stored in the low-pressure hydrogen gas tank 36 as low-pressure hydrogen gas without application of pressure after passing through a low-pressure hydrogen gas tank pressure-adjust valve 34 and a low-pressure hydrogen gas tank inlet pipe 35. A pressure of the low-pressure hydrogen gas tank 36 is detected by a low-pressure hydrogen gas tank pressure gage 38. By opening/closing the low-pressure hydrogen gas tank pressure-adjust valve 34 in response to a generation volume of the hydrogen gas, the pressure of the low-pressure hydrogen gas tank 36 is controlled to fall within a predetermined range. When a predetermined volume of the hydrogen gas is accumulated in the low-pressure hydrogen gas tank 36, the hydrogen gas is sent out to the high-pressure hydrogen gas compressor 101 from the low-pressure hydrogen gas tank 36 through a hydrogen gas compressor inlet pipe 37.

[0030]

A chlorine gas generated in the chlorine gas generator 6 is recovered by the chlorine gas recovery unit 28. The chlorine gas recovery unit 28 collects the chlorine gas generated by the electrolyzation above the seawater surface in the cylindrical container. The collected chlorine gas is collected in a chlorine gas outlet header 43 after passing through the chlorine gas recovery unit outlet-pipe 41 and a hydrogen gas recovery unit outlet-valve 42. The collected hydrogen gas is once stored in the low-pressure chlorine gas tank 46 as low-pressure chlorine gas without application of pressure after passing through a low-pressure chlorine gas tank pressure-adjust valve 44 and a low-pressure chlorine gas tank inlet pipe 45. A pressure of the low-pressure chlorine gas tank 46 is detected by a low-pressure chlorine gas tank pressure gage 48. By opening/closing the low-pressure chlorine gas tank pressure-adjust valve 44 in response to a generation volume of the chlorine gases, the pressure of the low-pressure chlorine gas tank 46 is controlled to fall within a predetermined range. When a predetermined volume of the chlorine gas is accumulated in the low-pressure chlorine gas tank 46, the chlorine gas is sent out to the high-pressure chlorine gas compressor 102 from the low-pressure chlorine gas tank 46 through a chlorine gas compressor inlet pipe 47.

[0031]

The seawater to be electrolyzed in the seawater electrolytic bath 4 of the seawater electrolyzation unit 200 is supplied from at least one of the seawater-intake basin 16, the seawater-discharge basin 98, and the condenser 60 of the solar thermal power generation unit 300, as shown in Figs. 2 and 1. The seawater-intake basin 16 is a facility for containing the seawater to be used in the condenser 60. The seawater used in the condenser 60 is taken in from the seawater-intake basin

16. The seawater-discharge basin 98 is a facility for containing the seawater already used in the condenser 60. The seawater already used in the condenser 60 is discharged into the seawater-discharge basin 98. The seawater is supplied from the seawater-intake basin 16 by use of a seawater pump 18 installed in the vicinity of the seawater-intake basin 16, from the seawater-discharge basin 98 by use of a seawater pump 118 installed in the vicinity of the seawater-discharge basin 98, and from the condenser 60 by use of a seawater boost pump 99.

[0032]

The seawater in the seawater-intake basin 16 flows through a seawater-pump inlet pipe 21, passing through a seawater-pump inlet valve 17, to the seawater pump 18 to be boosted. The boosted seawater is sent out to a seawater header 26, passing through a seawater-pump outlet check-valve 19, a seawater-pump outlet valve 20, and a seawater-pump outlet pipe 22.

[0033]

The seawater in the seawater-discharge basin 98 flows through a seawater-pump inlet-pipe 121, passing through a seawater-pump inlet-valve 117, to the seawater pump 118 to be boosted. The boosted seawater is sent out to the seawater header 26, passing through a seawater-pump outlet check-valve 119, a seawater-pump outlet-valve 120, and a seawater-pump outlet-pipe 122.

[0034]

The seawater supplied from the condenser 60 to the seawater electrolytic bath 4 is a warm seawater obtained by cooling the steam in the condenser 60. As shown in Figs. 1 and 3, the seawater ejected from the condenser 60 (the warm discharged-water) flows through a condenser-outlet circulating-water pipe 94. The most of the seawater flows through a seawater-discharge basin circulating-water valve 96 and a seawater-discharge basin inlet-pipe 97 to the seawater-discharge basin 98 and is subsequently discharged into the sea. The remainder of the seawater is taken out from the condenser-outlet circulating-water pipe 94 at a seawater-electrolyzation-unit seawater take-out valve 95, passes through a seawater boost pump inlet-valve 39, and is boosted by a seawater boost pump 99. The boosted seawater (the warm discharged-water) passes through a seawater boost pump outlet check-valve 49 and a seawater boost pump outlet-valve 79 and flows through a seawater boost pump outlet pipe 25 to the seawater header 26.

[0035]

As shown in Fig. 2, these seawaters delivered to the seawater header 26 are divided into two systems, one flowing through a cathode-bath seawater flow-rate control valve inlet pipe 23, and the other flowing through an anode-bath seawater flow-rate control valve inlet pipe 24. The seawater flowing through the cathode-bath seawater flow-rate control valve inlet pipe 23 is delivered to the cathode-bath 9 after passing through a cathode-bath seawater flow-rate control valve 13. The seawater flowing through the anode-bath seawater flow-rate control valve inlet pipe 24 is delivered to the anode-bath 10 after passing through an anode-bath seawater flow-rate control valve 14.

[0036]

Next, the solar thermal power generation unit 300 is described below.

[0037]

Fig. 3 shows the solar thermal power generation unit 300 adopting a tower-style solar-heat collecting method. However, the solar thermal power generation unit 300 can adopt any solar-heat collecting method (for example, trough-type, Fresnel-type, and a combination of several types, etc.) in the hydrogen gas generating system according to the present invention.

[0038]

As shown in Figs. 3 and 1, in the solar thermal power generation unit 300, the solar-heat energy conveyed from the sun 1 with the sunlight beam 2 is reflected by a multitude of heliostats 51 disposed around a tower 74 and collected in the solar-heat receiver 52. A feed-water heated by the steam at a high-pressure heater 56 and flowed through a solar-heat collector feed-water pipe 50 is supplied to the tower 74. The steam extracted from the high-pressure steam turbine 54 flows into the high-pressure heater 56 after passing through a high-pressure heater extraction pipe 55. The extracted steam heats the feed-water flowed into the high-pressure heater 56 by a feed-water pump 64.

[0039]

The feed-water supplied to the tower 74 is heated by the solar-heat energy at the solar-heat receiver 52 and is turned into the superheated steam. The superheated steam flows through a solar-heat collector outlet header 53, rotates the high-pressure steam turbine 54, flows through a communication pipe 57, and rotates the intermediate/low-pressure steam turbine 58. These steam turbines rotates the generator 29 directly connected to the turbines, thereby generating the AC electricity. The AC electricity is transmitted to a high-pressure system bus 82 via a main transformer 80 and a main circuit-breaker 81.

[0040]

The steam exhausted from the intermediate/low-pressure steam turbine 58 flows through a low-pressure steam turbine exhaust-pipe 59 and flows into the condenser 60. The steam flowed into the condenser 60 is cooled by the seawater flowed through a condenser-inlet circulating-water pipe 93 and turned into a steam condensate. The steam condensate flows through a steam-condensate pipe 67 into a steam-condensate pump 68, is boosted in the steam-condensate pump 68, is heated by a low-pressure heater 69, enters a deaerator 63 after passing through a deaerator-inlet pipe 70, and is heated and deaerated by the deaerator 63. In order to heat the steam condensate, the steam extracted from the intermediate/low-pressure steam turbine 58 flows into the low-pressure heater 69 via a low-pressure steam extraction pipe 62. In order to heat and deaerate the steam condensate, the steam extracted from the high-pressure steam turbine 54 flows into the deaerator 63 via a deaerator steam-extraction pipe 61. The steam condensate deaerated in the deaerator 63 is boosted by a feed-water pump 64, passes through a feed-water flow-rate adjust valve 65 and a feed-water pump outlet-pipe 66, and flows to the high-pressure heater 56 where the steam condensate turns into the feed water to be supplied to the tower 74. That is, water flowed from the deaerator 63 to the high-pressure heater 56 is heated by the steam extracted from the high-pressure steam turbine 54, flows through the solar-heat collector feed-water pipe 50, is sent to the tower 74, and turns into the superheated steam by the solar-heat energy.

[0041]

The seawater (the cooling water) flowing into the condenser 60 after flowing through the condenser-inlet circulating-water pipe 93 is taken out from the seawater-intake basin 16. The seawater in the seawater-intake basin 16 is taken out through a circulating-water pump inlet-pipe 90, is boosted by a circulating-water pump 91, passes through a circulating-water pump outlet-valve 92, flows through the condenser-inlet circulating-water pipe 93, and flows into the condenser 60. The seawater (the cooling water) flowed into the condenser 60 cools the steam flowed into the condenser 60. As described above, the cooling water (the warm discharged-water) heated by cooling the steam flows through the condenser-outlet circulating-water pipe 94. A portion of the cooling water passes through the seawater-discharge basin circulating-water valve 96 and the seawater-discharge basin inlet pipe 97 and flows to the seawater-discharge basin 98. A portion of the remainder of the cooling water flows through the seawater-electrolyzation-unit seawater take-out valve 95 and the seawater boost pump inlet valve 39, is boosted by the seawater boost pump 99, flows through the seawater boost pump outlet check-valve 49, the seawater boost pump outlet valve 79, and the seawater boost pump outlet pipe 25, is supplied to the seawater electrolytic bath 4, and is used as the seawater to be electrolyzed in the seawater electrolytic bath 4.

[0042]

Referring to Fig. 1, the hydrogen gas generating system 100 according to the present embodiment is described below on the basis of description given on the seawater electrolyzation unit 200 and the solar thermal power generation unit 300. The hydrogen gas generating system 100 further includes a high-pressure hydrogen gas tank 103 and a high-pressure chlorine gas tank 104, as described later on.

[0043]

The AC electricity generated by the generator 29 of the solar thermal power generation unit 300 is boosted in voltage at the main transformer 80 and subsequently transmitted to the high-pressure system bus 82 after passing through the main circuit-breaker 81. A portion of the AC electricity passes through a house circuit-breaker 83 and drops in voltage at a house transformer 84. A portion of the AC electricity with the dropped voltage passes through a high-pressure hydrogen gas compressor circuit-breaker 85 and is transmitted to a high-pressure hydrogen gas compressor motor 88. Another portion of the AC electricity with the dropped voltage passes through a high-pressure chlorine gas compressor circuit-breaker 86 and is transmitted to a high-pressure chlorine gas compressor motor 89. Another portion of the AC electricity with the dropped voltage passes through an auxiliary circuit-breaker 87 and is transmitted to the motors of auxiliary devices of the seawater electrolyzation unit 200 and the solar thermal power generation unit 300.

[0044]

The high-pressure hydrogen gas compressor motor 88 drives the high-pressure hydrogen gas compressor 101. The high-pressure hydrogen gas compressor 101 is connected to the low-pressure hydrogen gas tank 36and a high-pressure hydrogen gas tank 103, compressing the hydrogen gas stored in the low-pressure hydrogen gas tank 36, and storing the compressed hydrogen gas in the high-pressure hydrogen gas tank 103. The hydrogen gas is compressed up to a pressure corresponding to usage thereof, for example, up to a high pressure of about 7 to 70 MPa.

[0045]

The high-pressure chlorine gas compressor motor 89 drives the high-pressure chlorine gas compressor 102. The high-pressure chlorine gas compressor 102 is connected to the low-pressure chlorine gas tank 46and a high-pressure chlorine gas tank 104, compressing the chlorine gas stored in the low-pressure chlorine gas tank 46, and storing the compressed chlorine gas is the high-pressure chlorine gas tank 104. The chlorine gas is compressed up to a pressure corresponding to usage thereof.

[0046]

For compressions of the hydrogen gas and the chlorine gas, an abundance of electric power, on the order of MW, is required. In the hydrogen gas generating system 100 according to the present embodiment, such an abundance of electric power is acquired from the solar energy, not from a fossil fuel. Therefore, it is possible to produce a large volume of the high-pressure hydrogen gas and the high-pressure chlorine gas at a low cost with substantial reduction in generation of carbon-dioxide gas.

[0047]

The high-pressure hydrogen gas delivered from the high-pressure hydrogen gas compressor 101 is stored in the high-pressure hydrogen gas tank 103 after passing through a high-pressure hydrogen gas-tank pressure-adjust valve 105. A pressure of the high-pressure hydrogen gas tank 103 is detected by a high-pressure hydrogen gas-tank pressure-gage 107. By opening/closing the high-pressure hydrogen gas-tank pressure-adjust valve 105 and altering a flow rate of the hydrogen gas flowing into the high-pressure hydrogen gas tank 103, the pressure of the high-pressure hydrogen gas tank 103 is controlled to fall within a predetermined range. Further higher-pressure hydrogen gas can be obtained by taking out hydrogen gas from the intermediate stage of the high-pressure hydrogen gas compressor 101 and cooling the taken hydrogen gas using a coolant, such as seawater, etc. The high-pressure hydrogen gas stored in the high-pressure hydrogen gas tank 103 is taken out by using a high-pressure hydrogen gas take-out adjust-valve 109 and is stored in a high-pressure hydrogen gas cylinder 75. The high-pressure hydrogen gas cylinder 75 is carried out by using a high-pressure hydrogen gas transport vehicle 77. The hydrogen gas generating system according to the present invention is capable of supplying the high-pressure hydrogen gas to users in a way described above.

[0048]

The high-pressure chlorine gas delivered from the high-pressure chlorine gas compressor 102 is stored in the high-pressure chlorine gas tank 104 after passing through a high-pressure chlorine gas-tank pressure-adjust valve 106. A pressure of the high-pressure chlorine gas tank 104 is detected by a high-pressure chlorine gas-tank pressure-gage 108. By opening/closing the high-pressure chlorine gas-tank pressure-adjust valve 106 and altering a flow rate of the chlorine gas flowing into the high-pressure chlorine gas tank 104, the pressure of the high-pressure chlorine gas tank 104 is controlled to fall within a predetermined range. Further higher-pressure chlorine gas can be obtained by taking out chlorine gas from the intermediate stage of the high-pressure chlorine gas compressor 102 and cooling the taken chlorine gas using a coolant, such as seawater, etc. The high-pressure chlorine gas stored in the high-pressure chlorine gas tank 104 is taken out by using a high-pressure chlorine gas take-out adjust-valve 110 and is stored in a high-pressure chlorine gas cylinder 76. The high-pressure chlorine gas cylinder 76 is carried out by using a high-pressure chlorine gas transport vehicle 78. The hydrogen gas generating system according to the present invention is capable of supplying the high-pressure chlorine gas to users in a way described as above.

[0049]

As described above, the hydrogen gas generating system 100 according to the present embodiment utilizes the AC electricity generated with use of the solar-heat energy without burning the fossil fuel as a power supply for driving the high-pressure hydrogen gas compressor 101 and the high-pressure chlorine gas compressor 102, therefore the system 100 can generate the AC electricity without releasing a carbon-dioxide gas due to combustion of the fossil fuel into the atmosphere.

[0050]

Further, the hydrogen gas generating system 100 according to the present embodiment utilizes a portion of the seawater (the warm discharged water) heated by cooling the steam in the condenser 60 as the seawater to be electrolyzed in the seawater electrolytic bath 4, as shown in Figs. 1 to 3. The system 100 has an advantage in that energy consumed in the electrolyzation of seawater can be reduced by using the warm seawater as the seawater to be electrolyzed.

[0051]

In general, seawater in nature is available at no cost. A massive volume of seawater exists on Earth, and therefore, it can be said that seawater can be unlimitedly found as far as used for a raw material for the electrolyzation. Accordingly, the hydrogen gas generating system 100 according to the present embodiment also can send out the seawater taken out from the seawater-intake basin 16 directly to the seawater electrolytic bath 4 without using the seawater as cooling water of the solar thermal power generation unit 300, as shown in Figs. 1 to 3. A method for sending out the seawater taken out from the seawater-intake basin 16 directly to the seawater electrolytic bath 4 has an advantage in that a large volume of seawater can be used for the electrolyzation, leading to a mass production of the hydrogen gas and the chlorine gas.

EXPLANATION OF REFERENCE CHARACTERS

[0052]

1: the sun,

2: sunlight beam,

3: photovoltaic power generation unit,

4: seawater electrolytic bath,

5: hydrogen gas generator,

6: chlorine gas generator,

7: cathode of seawater electrolytic bath,

8: anode of seawater electrolytic bath,

9: cathode-bath,

10: anode-bath,

11: cathode electric-wire,

12: anode electric-wire,

13: cathode-bath seawater flow-rate control valve,

14: anode-bath seawater flow-rate control valve, 15: anode-cathode-bath flow-rate balance valve,

16: seawater-intake basin,

17: seawater-pump inlet valve,

18: seawater pump,

19: seawater-pump outlet check-valve,

20: seawater-pump outlet valve,

21: seawater-pump inlet pipe,

22: seawater-pump outlet pipe,

23: cathode-bath seawater flow-rate control valve inlet pipe,

24: anode-bath seawater flow-rate control valve inlet pipe,

25: seawater boost pump outlet pipe,

26: seawater header,

27: hydrogen gas recovery unit,

28: chlorine gas recovery unit,

29: generator,

30: bubble of hydrogen gas,

31: hydrogen gas recovery unit outlet-pipe,

32: hydrogen gas recovery unit outlet-valve,

33: hydrogen gas outlet header,

34: low-pressure hydrogen gas tank pressure-adjust valve,

35: low-pressure hydrogen gas tank inlet pipe,

36: low-pressure hydrogen gas tank,

37: hydrogen gas compressor inlet pipe,

38: low-pressure hydrogen gas tank pressure gage,

39: seawater boost pump inlet-valve,

40: bubble of chlorine gas,

41: chlorine gas recovery unit outlet-pipe,

42: hydrogen gas recovery unit outlet-valve,

43: chlorine gas outlet header,

44: low-pressure chlorine gas tank pressure-adjust valve,

45: low-pressure chlorine gas tank inlet pipe,

46: low-pressure chlorine gas tank,

47: chlorine gas compressor inlet,

48: low-pressure chlorine gas pressure gage,

49: seawater boost pump outlet check-valve,

50: solar-heat collector feed-water pipe,

51: heliostat,

52: solar-heat receiver

53: solar-heat collector outlet header,

54: high-pressure steam turbine,

55: high-pressure heater extraction pipe,

56: high-pressure heater,

57: communication pipe,

58: intermediate/low-pressure steam turbine,

59: low-pressure steam turbine exhaust-pipe,

60: condenser,

61: deaerator steam-extraction pipe,

62: low-pressure steam extraction pipe,

63: deaerator,

64: feed-water pump,

65: feed-water flow-rate adjust valve,

66: feed-water pump outlet-pipe,

67: steam-condensate pipe,

68: steam-condensate pump,

69: low-pressure heater,

70: deaerator-inlet pipe,

74: tower,

75: high-pressure hydrogen gas cylinder,

76: high-pressure chlorine gas cylinder,

77: high-pressure hydrogen gas transport vehicle,

78: high-pressure chlorine gas transport vehicle,

79: seawater boost pump outlet-valve,

80: main transformer,

81: main circuit-breaker,

82: high-pressure system bus,

83: house circuit-breaker,

84: house transformer,

85: high-pressure hydrogen gas compressor circuit-breaker,

86: high-pressure chlorine gas compressor circuit-breaker,

87: auxiliary circuit-breakers,

88: high-pressure hydrogen gas compressor motor,

89: high-pressure chlorine gas compressor motor,

90: circulating-water pump inlet-pipe

91: circulating-water pump,

92: circulating-water pump outlet-valve, 93: condenser-inlet circulating-water pipe,

94: condenser-outlet circulating-water pipe,

95: seawater-electrolyzation-unit seawater take-out valve,

96: seawater-discharge basin circulating-water valve,

97: seawater-discharge basin inlet-pipe,

98: seawater-discharge basin,

99: seawater boost pump,

100: hydrogen gas generating system,

101: high-pressure hydrogen gas compressor,

102: high-pressure chlorine gas compressor,

103: high-pressure hydrogen gas tank,

104: high-pressure chlorine gas tank、

105: high-pressure hydrogen gas-tank pressure-adjust valve,

106: high-pressure chlorine gas-tank pressure-adjust valve,

107: high-pressure hydrogen gas-tank pressure-gage,

108: high-pressure chlorine gas-tank pressure-gage,

109: high-pressure hydrogen gas take-out adjust-valve,

110: high-pressure chlorine gas take-out adjust-valve,

117: seawater-pump inlet-valve,

118: seawater pump,

119: seawater-pump outlet check-valve,

120: seawater-pump outlet-valve,

121: seawater-pump inlet-pipe,

122: seawater-pump outlet-pipe

150: communication-adjust pipe,

200: seawater electrolyzation unit,

300: solar thermal power generation unit.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

2015247080 05 Sep 2017

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A hydrogen gas generating system comprising:

a photovoltaic power generation unit for generating DC electricity, including a fuel cell;

a seawater electrolyzation unit for generating a hydrogen gas by electrolyzing seawater with the use of the DC electricity generated by the photovoltaic power generation unit, including a first hydrogen gas tank;

a solar thermal power generation unit for generating AC electricity by rotating a turbine with the use of a steam generated by utilizing solar heat;

a hydrogen gas compressor for compressing the hydrogen gas generated by the seawater electrolyzation unit, the hydrogen gas compressor being driven by the AC electricity generated by the solar thermal power generation unit; and

a second hydrogen gas tank,

wherein the seawater electrolyzation unit stores the generated hydrogen gas in the first hydrogen gas tank; and

wherein the hydrogen gas compressor compresses the hydrogen gas stored in the first hydrogen gas tank and stores the compressed hydrogen gas in the second hydrogen gas tank.

2. The hydrogen gas generating system according to claim 1,

wherein the solar thermal power generation unit further includes a condenser for cooling the steam used for rotating the turbine with the use of seawater, and

wherein the seawater electrolyzation unit, to which a portion of the seawater ejected from the condenser is supplied, electrolyzes the supplied seawater.

3. The hydrogen gas generating system according to claim 1,

wherein the solar thermal power generation unit further includes a condenser for cooling the steam used for rotating the turbine with the use of seawater, and a seawater-intake basin for containing the seawater to be used for cooling the steam in the condenser, and

wherein the seawater electrolyzation unit, to which the seawater contained in the seawater-intake basin is supplied, electrolyzes the supplied seawater.

4. The hydrogen gas generating system according to claim 1,

wherein the solar thermal power generation unit further includes a condenser for cooling the steam used for rotating the turbine with the use of seawater, and a seawater-discharge basin for containing the seawater used for cooling the steam in the condenser, and

wherein the seawater electrolyzation unit, to which the seawater contained in the seawater-discharge basin is supplied, electrolyzes the supplied seawater.

5. The hydrogen gas generating system according to claim 1,

wherein the seawater electrolyzation unit further generates a chlorine gas by electrolyzing seawater with the use of the DC electricity generated by the photovoltaic power generation unit, and

wherein the hydrogen gas generating system further includes a chlorine gas compressor for compressing the chlorine gas generated by the seawater electrolyzation unit, the chlorine gas compressor being driven by the AC electricity generated by the solar thermal power generation unit.

6. The hydrogen gas generating system according to claim 1,

wherein the seawater electrolyzation unit includes a cathode-bath for generating the hydrogen gas by electrolyzing seawater, and an anode-bath for generating a chlorine gas by electrolyzing seawater with the use of the DC electricity generated by the photovoltaic power generation unit,

wherein the cathode-bath and the anode-bath are connected with each other by a pipe which seawater flows through, and

wherein the pipe includes a valve for controlling a volume of seawater flowing through the pipe.

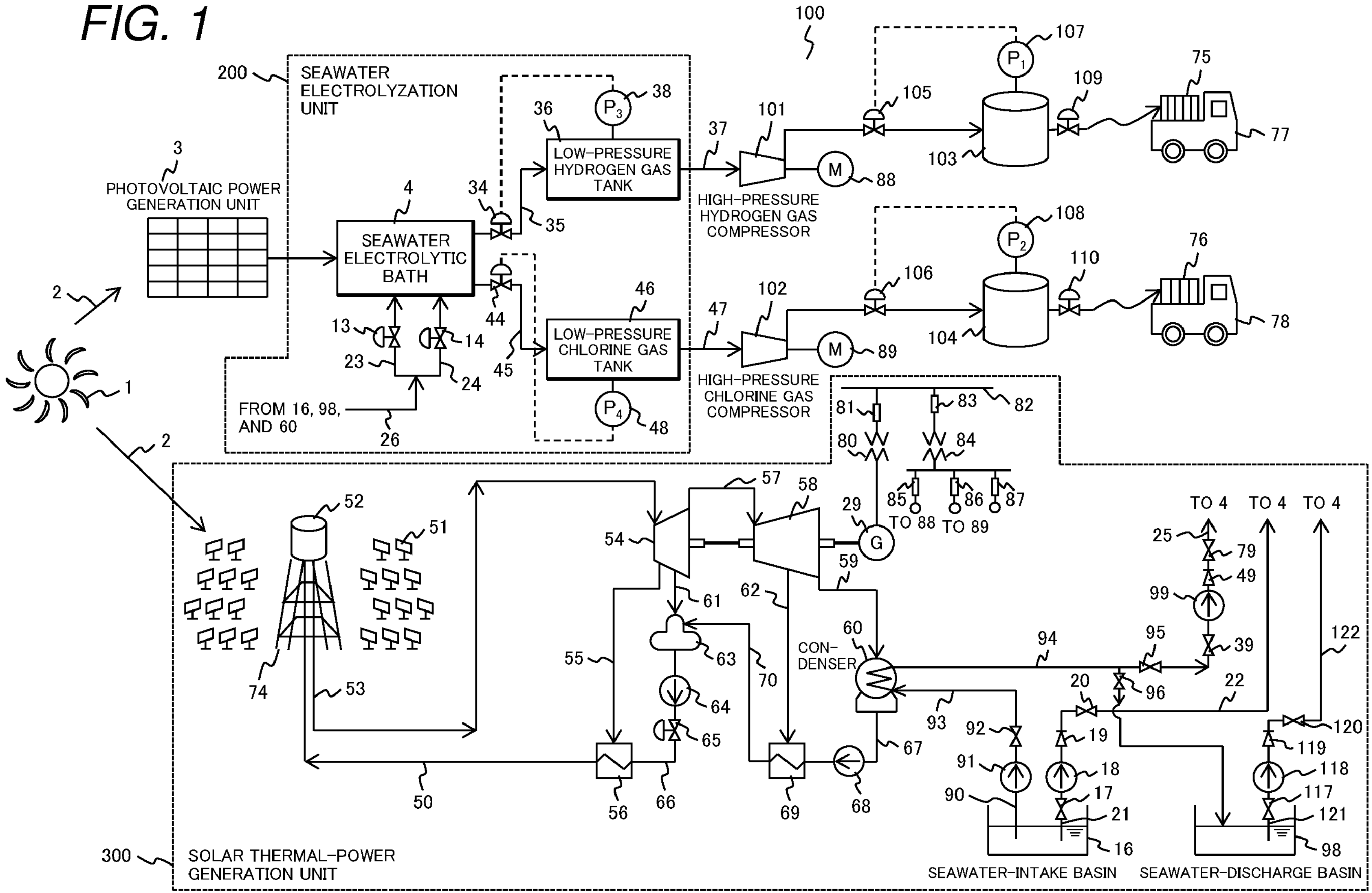
7. The hydrogen gas generating system according to claim 5,

wherein the seawater electrolyzation unit includes a first choline gas tank for storing the generated chlorine gas,

wherein the hydrogen gas generating system further includes a second chlorine gas tank, and

wherein the chlorine gas compressor compresses the chlorine gas stored in the first chlorine gas tank and stores the compressed chlorine gas in the second chlorine gas tank.

FIG. 1



100
200
SEAWATER ELECTROLYZATION UNIT
3
PHOTOVOLTAIC POWER GENERATION UNIT
4
SEAWATER ELECTROLYTIC BATH
LOW-PRESSURE HYDROGEN GAS TANK
LOW-PRESSURE CHLORINE GAS TANK
HIGH-PRESSURE HYDROGEN GAS COMPRESSOR
HIGH-PRESSURE CHLORINE GAS COMPRESSOR
FROM 16, 98, AND 60
TO 88
TO 89
TO 4
TO 4
TO 4
CON-DENSER
SEAWATER-INTAKE BASIN
SEAWATER-DISCHARGE BASIN
300
SOLAR THERMAL-POWER GENERATION UNIT
1
2
13
14
16
17
18
19
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21
22
23
24
25
26
29
34
35
36
37
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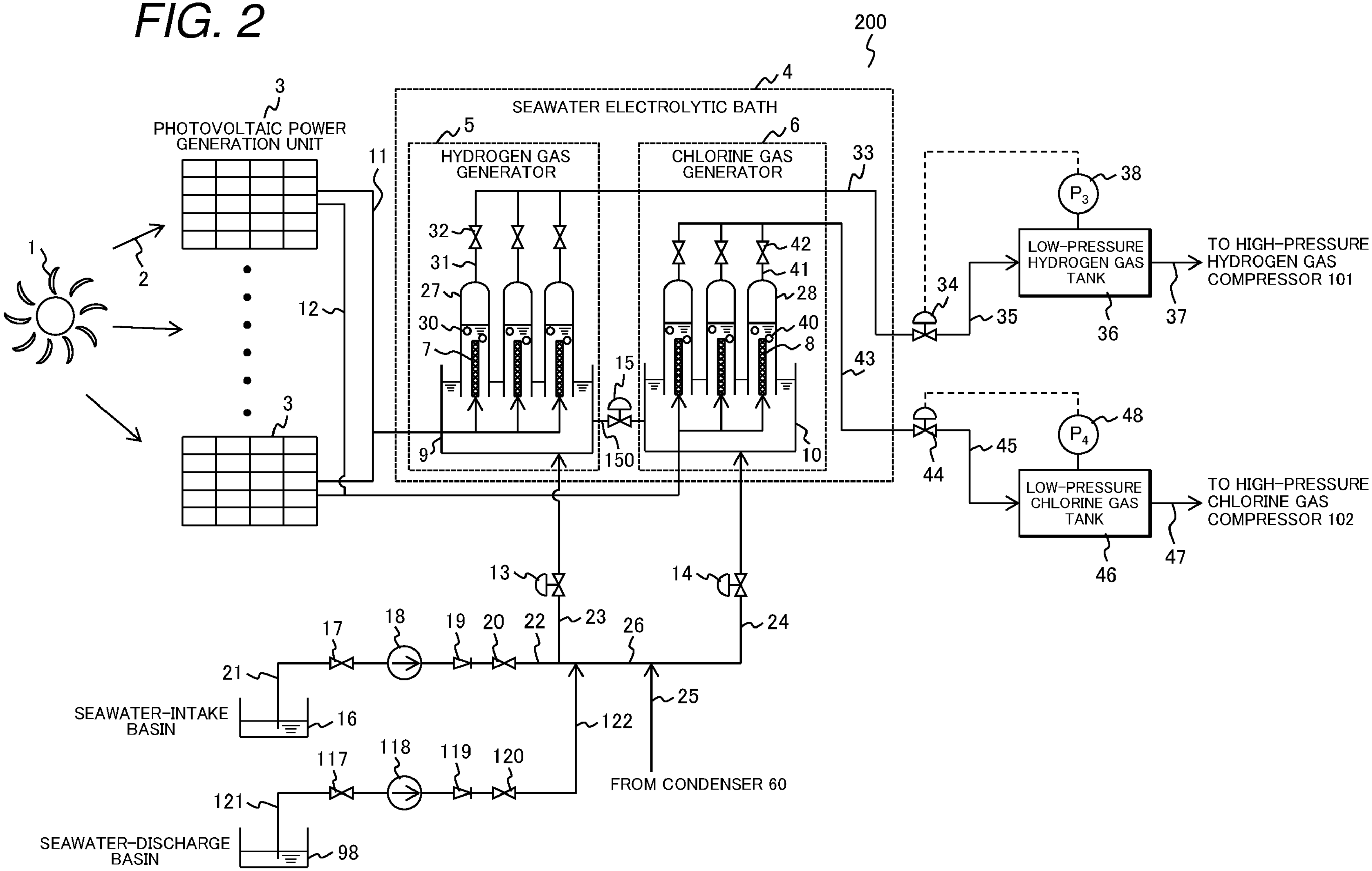
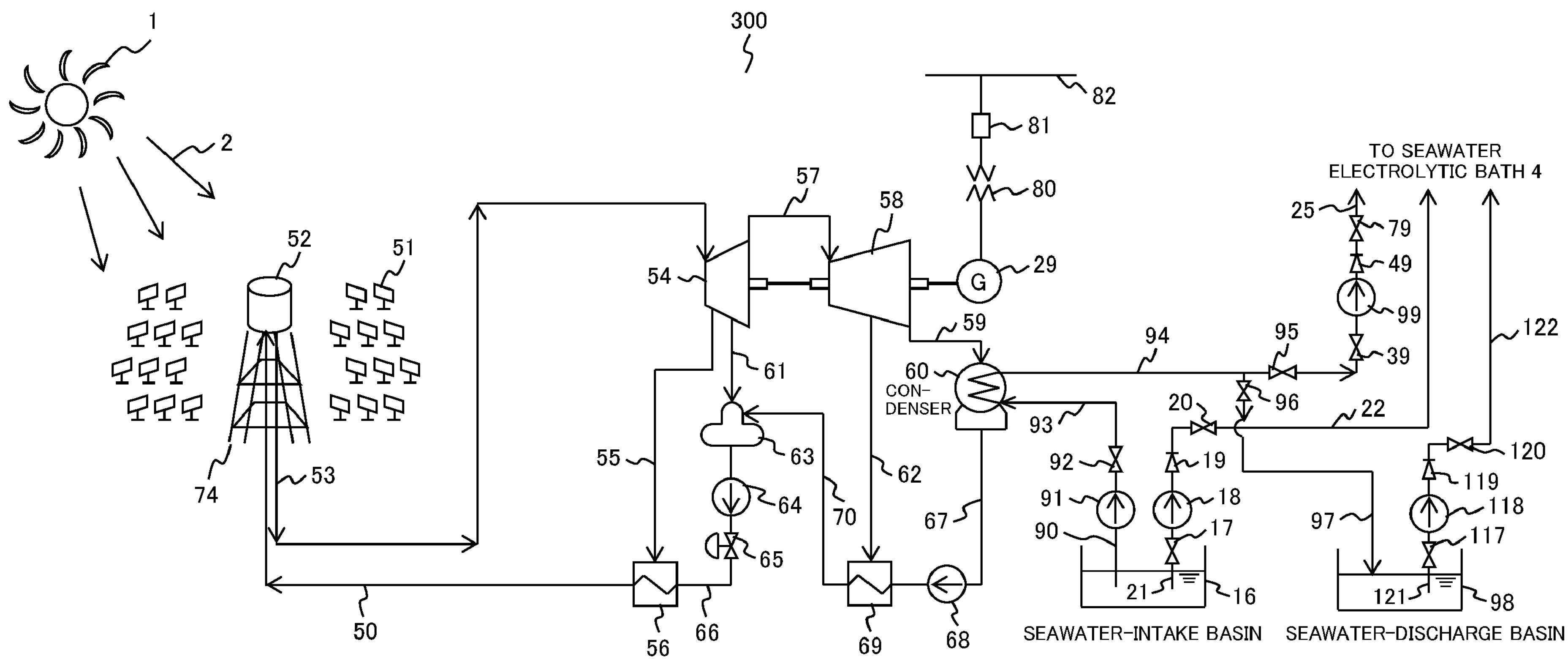
121
122

FIG. 2



1
2
3
PHOTOVOLTAIC POWER GENERATION UNIT
3
11
12
200
4
SEAWATER ELECTROLYTIC BATH
5
HYDROGEN GAS GENERATOR
6
CHLORINE GAS GENERATOR
33
32
31
27
30
7
9
15
150
42
41
28
40
8
10
43
38
P3
34
35
LOW-PRESSURE HYDROGEN GAS TANK
36
37
TO HIGH-PRESSURE HYDROGEN GAS COMPRESSOR 101
48
P4
44
45
LOW-PRESSURE CHLORINE GAS TANK
46
47
TO HIGH-PRESSURE CHLORINE GAS COMPRESSOR 102
13
14
17
18
19
20
22
23
26
24
21
SEAWATER-INTAKE BASIN
16
25
122
FROM CONDENSER 60
117
118
119
120
121
SEAWATER-DISCHARGE BASIN
98

FIG. 3


300
1
2
52
51
74
53
50
57
58
54
29
82
81
80
59
60
CON-
DENSER
61
55
63
62
70
64
65
56
66
69
68
67
94
95
96
93
92
91
90
20
19
18
17
21
16
SEAWATER-INTAKE BASIN
TO SEAWATER
ELECTROLYTIC BATH 4
25
79
49
99
39
22
97
120
119
118
117
121
98
122
SEAWATER-DISCHARGE BASIN