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Power generating system and power generating method

Abstract

In one embodiment, a power generating system includes a cooling absorption tower configured to cause an absorption liquid to absorb carbon dioxide in atmosphere. The system further includes an evaporator configured to heat the absorption liquid to release the carbon dioxide and water vapor from the absorption liquid, and discharge the absorption liquid that has released the carbon dioxide and the water vapor, and a first gas including the carbon dioxide and the water vapor. The system further includes a turbine configured to be driven by a portion of the first gas. The system further includes a generator configured to be driven by the turbine. The system further includes a capturer configured to condense the water vapor included in a remaining portion of the first gas, and capture the carbon dioxide that is included in the remaining portion of the first gas and to be a capture target.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION

(1) This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2023-105425, filed on Jun. 27, 2023, the entire contents of which are incorporated herein by reference.

FIELD

(2) Embodiments described herein relate to a power generating system and a power generating method.

BACKGROUND

(3) In order to realize a net-zero (carbon-neutral) society by 2050, there is a need for negative emission technology for capturing and storing carbon dioxide (CO.sub.2) in the atmosphere. As a method for selectively separating and capturing CO.sub.2 from the atmosphere, methods using temperature swings and pressure swings are known. In this case, it is necessary to reduce the energy required for heating and depressurization.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a schematic diagram showing a configuration of a power generating system of a first embodiment;

(2) FIG. **2** is a schematic diagram showing a configuration of a power generating system of a comparative example of the first embodiment; and

(3) FIG. **3** is a schematic diagram showing a configuration of a power generating system of a second embodiment.

DETAILED DESCRIPTION

(4) Embodiments will now be explained with reference to the accompanying drawings. In FIGS. **1** to **3**, the same configurations are given the same reference numeral, and duplicate description is omitted.

(5) As a system that handles CO.sub.2, there is known a power generating system that generates power using an absorption liquid capable of absorbing CO.sub.2. This power generating system generates power by driving a turbine with CO.sub.2 gas and water vapor (steam). Further, this power generating system circulates the CO.sub.2 gas and the water vapor in a closed cycle, and generates power without being continuously supplied with media from outside the system.

(6) As another system for handling CO.sub.2, there is known a CO.sub.2 capturing system that captures CO.sub.2 from exhaust gas using an absorption liquid capable of absorbing CO.sub.2. This CO.sub.2 capturing system requires thermal energy in releasing CO.sub.2 from the absorption liquid. Since this energy is enormous, the operating cost of the CO.sub.2 capturing system increases. Therefore, in order to spread CO.sub.2 capturing systems, it is necessary to reduce the energy used in the CO.sub.2 capturing systems. Further, when CO.sub.2 is captured from the atmosphere, a large amount of power to drive a blower fan and a large amount of thermal energy to regenerate CO.sub.2 are required, and it is also necessary to reduce this energy.

(7) In one embodiment, a power generating system includes a cooling absorption tower configured to cause an absorption liquid to absorb carbon dioxide in atmosphere. The system further includes an evaporator configured to heat the absorption liquid to release the carbon dioxide and water

vapor from the absorption liquid, and discharge the absorption liquid that has released the carbon dioxide and the water vapor, and a first gas including the carbon dioxide and the water vapor. The system further includes a turbine configured to be driven by a portion of the first gas. The system further includes a generator configured to be driven by the turbine. The system further includes a capturer configured to condense the water vapor included in a remaining portion of the first gas, and capture the carbon dioxide that is included in the remaining portion of the first gas and to be a capture target.

First Embodiment

(8) FIG. **1** is a schematic diagram showing a configuration of a power generating system of a first embodiment. The power generating system of the present embodiment is a CO.sub.2 capturing and power generating system having a function to capture (collect) CO.sub.2 from the atmosphere, and a function to generate power using this CO.sub.2.

(9) As shown in FIG. **1**, the power generating system of the present embodiment includes a heater **1**, an evaporator **2**, a gas-liquid separator **3**, a flow divider **4**, a turbine **5**, a generator **6**, a condensation absorber **7**, a pump **11**, a flow merger **12**, a flow divider **13**, a cooling absorption tower **14**, a pump **15**, a flow divider **16**, an intermediate heat exchanger **17**, a flow merger **18**, a heat exchanger **21**, a cooler **22**, and a controller **31**. The intermediate heat exchanger **17** is an example of a first heat exchanger. The heat exchanger **21** is an example of a second heat exchanger. The cooler **22** is an example of the capturer.

(10) The heater **1** supplies heat for heating an absorption liquid in the evaporator **2** to the evaporator **2**. The absorption liquid is a liquid having the action of absorbing CO.sub.2, for example, an organic solvent, a hydrophobic CO.sub.2 absorption liquid, an amine-based aqueous solution, an amino acid salt absorption liquid, or an alkaline aqueous solution, but is not limited to these examples.

(11) The evaporator **2** is supplied with the absorption liquid (rich liquid) that has absorbed CO.sub.2 from the cooling absorption tower **14** via the condensation absorber **7**, and heats the absorption liquid with the heat from the heater **1**. As a result, in the evaporator **2**, CO.sub.2 and water vapor are released from the absorption liquid. The evaporator **2** discharges the absorption liquid (lean liquid) that has released CO.sub.2 and water vapor and a mixed gas including CO.sub.2 and water vapor. In other words, a circulating medium in a gas-liquid two-phase state including the absorption liquid and the mixed gas is discharged from the evaporator **2**. This mixed gas is an example of a first gas.

(12) The gas-liquid separator **3** is supplied with the circulating medium including the absorption liquid and the mixed gas from the evaporator **2**, and separates the circulating medium into the absorption liquid and the mixed gas. The gas-liquid separator **3** discharges the mixed gas separated from the circulating medium to the flow divider **4**, and discharges the absorption liquid separated from the circulating medium to the condensation absorber **7** via the intermediate heat exchanger **17**.

(13) The flow divider **4** divides the mixed gas discharged from the gas-liquid separator **3** into a mixed gas flowing into the turbine **5** and a mixed gas flowing into the cooler **22** via the heat exchanger **21**. The mixed gas flowing into the turbine **5** is an example of a portion of the divided first gas. The mixed gas flowing into the cooler **22** via the heat exchanger **21** is an example of the remaining portion of the divided first gas.

(14) The turbine **5** is supplied with the mixed gas from the flow divider **4**, is driven by the mixed gas, and discharges the mixed gas to the condensation absorber **7**. The mixed gas rotationally drives the turbine **5** by adiabatically expanding in the turbine **5**.

(15) The generator **6** is driven by the turbine **5** to generate power. Thus, the power generating system of the present embodiment generates power using a mixed gas including CO.sub.2 gas and water vapor.

(16) The condensation absorber **7** is supplied with the high-temperature mixed gas from the turbine **5**, is supplied with the high-temperature absorption liquid from the gas-liquid separator **3** via the

intermediate heat exchanger **17**, and is supplied with the low-temperature absorption liquid from the cooling absorption tower **14**. The high-temperature absorption liquid is stored at the bottom of the condensation absorber **7**. On the other hand, the low-temperature absorption liquid passes through a pipe provided in the condensation absorber **7** from an inlet to an outlet of the condensation absorber **7**. Therefore, the low-temperature absorption liquid flows in the condensation absorber **7** without being mixed with the high-temperature absorption liquid. The low-temperature absorption liquid cools the high-temperature absorption liquid and the high-temperature mixed gas when flowing in the condensation absorber **7**. As a result, the water vapor included in the mixed gas is condensed into condensed water, and the condensed water is mixed into the high-temperature absorption liquid. On the other hand, the CO.sub.2 included in the mixed gas is absorbed by the high-temperature absorption liquid. The condensation absorber **7** discharges the high-temperature absorption liquid (semi-lean liquid) that has absorbed CO.sub.2 to the pump **11**.
(17) The pump **11** pressurizes the high-temperature absorption liquid discharged from the condensation absorber **7**. The absorption liquid pressurized in the pump **11** is sent to the flow merger **12**.
(18) The flow merger **12** merges the high-temperature absorption liquid supplied from the pump **11** and the low-temperature absorption liquid supplied from the flow divider **13**. The absorption liquid merged in the flow merger **12** is supplied to the cooling absorption tower **14**.
(19) The flow divider **13** divides the low-temperature absorption liquid supplied from the condensation absorber **7** into an absorption liquid flowing into the flow merger **12** and an absorption liquid flowing into the flow divider **16**.
(20) The cooling absorption tower **14** is supplied with the absorption liquid that has absorbed CO.sub.2 from the flow merger **12**, and brings the absorption liquid into contact with the atmosphere. As a result, CO.sub.2 in the atmosphere is absorbed by the absorption liquid, and the absorption liquid is deprived of heat by the atmosphere to be cooled. The cooling absorption tower **14** discharges the absorption liquid (rich liquid) that has absorbed CO.sub.2 in the atmosphere and has been cooled to the pump **15**. The cooling absorption tower **14** of the present embodiment includes a blower fan for taking the atmosphere into the cooling absorption tower **14** and bringing the taken atmosphere into contact with the absorption liquid. The cooling absorption tower **14** of the present embodiment has a makeup water function or includes a pre-humidifier for humidifying the atmosphere in advance, in preparation for the case where the moisture in the absorption liquid is taken out of the cycle system through the atmosphere due to contact between the absorption liquid and the atmosphere.
(21) The pump **15** pressurizes the low-temperature absorption liquid discharged from the cooling absorption tower **14**. The absorption liquid pressurized in the pump **15** is sent to the condensation absorber **7**. This absorption liquid is used as a coolant for cooling the high-temperature absorption liquid and the high-temperature mixed gas in the condensation absorber **7** as described above.
(22) The flow divider **16** divides the absorption liquid supplied from the flow divider **13** into an absorption liquid flowing into the flow merger **18** via the intermediate heat exchanger **17** and an absorption liquid flowing into the flow merger **18** via the heat exchanger **21**.
(23) The intermediate heat exchanger **17** performs heat exchange between the absorption liquid directed from the gas-liquid separator **3** to the condensation absorber **7** and the absorption liquid directed from the flow divider **16** to the flow merger **18**. As a result, the former absorption liquid is cooled by heat exchange, and the latter absorption liquid is heated by heat exchange. Heat exchange is carried out in a state where the former absorption liquid and the latter absorption liquid are in non-contact.
(24) The flow merger **18** merges the absorption liquid supplied from the flow divider **16** via the intermediate heat exchanger **17** and the absorption liquid supplied from the flow divider **16** via the heat exchanger **21**. The absorption liquid merged in the flow merger **18** is supplied to the

evaporator **2**.
(25) The heat exchanger **21** performs heat exchange between the mixed gas directed from the flow divider **4** to the cooler **22** and the absorption liquid directed from the flow divider **16** to the flow merger **18**. As a result, the mixed gas is cooled by heat exchange, and the absorption liquid is heated by heat exchange. Heat exchange is carried out in a state where the mixed gas and the absorption liquid are in non-contact.
(26) The cooler **22** is supplied with the mixed gas from the flow divider **4** via the heat exchanger **21**, and cools the mixed gas. As a result, the water vapor included in the mixed gas is condensed into condensed water, and the concentration of water vapor included in the mixed gas decreases. That is, the mixed gas including CO.sub.2 and water vapor changes into a capture target gas including high-purity CO.sub.2. The cooler **22** captures the capture target gas including CO.sub.2 that is to be a capture target in the power generating system of the present embodiment. CO.sub.2 included in the capture target gas discharged from the cooler **22** may be liquefied inside or outside the power generating system of the present embodiment.
(27) The controller **31** controls various operations of the power generating system of the present embodiment. The controller **31** controls, for example, liquid sending by the pumps **11** and **15**, power generation by the turbine **5** and the generator **6**, and operations of the condensation absorber **7**, the cooling absorption tower **14**, and the cooler **22**.
(28) Note that the power generating system of the present embodiment may not include some of the components shown in FIG. **1**. For example, the power generating system of the present embodiment may not include the flow divider **16**, the flow merger **18**, and the heat exchanger **21**.
(29) FIG. **2** is a schematic diagram showing a configuration of a power generating system of a comparative example of the first embodiment. The power generating system of this comparative example has a function to generate power using CO.sub.2, but does not have a function to capture CO.sub.2 from the atmosphere.
(30) Similar to the power generating system of the first embodiment, the power generating system of this comparative example includes the heater **1**, the evaporator **2**, the gas-liquid separator **3**, the turbine **5**, the generator **6**, the condensation absorber **7**, the intermediate heat exchanger **17**, and the controller **31**. The power generating system of this comparative example further includes a pump **41**, a cooler **42**, and a pump **43**.
(31) The pump **41** pressurizes the absorption liquid discharged from the condensation absorber **7**. The absorption liquid pressurized in the pump **41** is sent to the evaporator **2** via the intermediate heat exchanger **17**.
(32) The cooler **42** is a component corresponding to the cooling absorption tower **14**. The cooler **42** supplies a coolant different from the absorption liquid to the condensation absorber **7**. The coolant passes through the pipe provided in the condensation absorber **7** from the inlet to the outlet of the condensation absorber **7**. Therefore, the coolant flows in the condensation absorber **7** without being mixed with the absorption liquid. The coolant cools the absorption liquid and the mixed gas when flowing in the condensation absorber **7**. As a result, the water vapor included in the mixed gas is condensed into condensed water, and the condensed water is mixed into the absorption liquid. On the other hand, the CO.sub.2 included in the mixed gas is absorbed by the absorption liquid. The condensation absorber **7** discharges the absorption liquid (rich liquid) that has absorbed CO.sub.2 to the pump **41**.
(33) The pump **43** pressurizes the coolant discharged from the condensation absorber **7**. The coolant pressurized in the pump **43** is sent to the cooler **42**, cooled in the cooler **42**, and discharged from the cooler **42** to the pump **41** again.
(34) Further details of the power generating system of the present embodiment will be described below with reference back to FIG. **1**.
(35) The power generating system of the present embodiment has a function to capture CO.sub.2 from the atmosphere and a function to generate power using this CO.sub.2. Therefore, the power

generating system of the present embodiment has a structure in which a CO.sub.2 capturing system is incorporated into the power generating system.
(36) In general, CO.sub.2 capturing systems require thermal energy in releasing CO.sub.2 from the absorption liquid. Since this energy is enormous, the operating cost of the CO.sub.2 capturing system increases. Therefore, in order to spread CO.sub.2 capturing systems, it is necessary to reduce the energy used in the CO.sub.2 capturing systems. Further, when CO.sub.2 is captured from the atmosphere, a large amount of power to drive a blower fan and a large amount of thermal energy to regenerate CO.sub.2 are required, and it is also necessary to reduce this energy.
(37) On the other hand, the present embodiment not only captures CO.sub.2 from the atmosphere, but also generates power using this CO.sub.2. This makes it possible to use the energy (power) obtained by generating power as energy for capturing CO.sub.2, and therefore makes it possible to reduce the energy required for capturing CO.sub.2. For example, the energy provided externally to the power generating system of the present embodiment for capturing CO.sub.2 can be made less than the energy provided externally to general CO.sub.2 capturing systems for capturing CO.sub.2.
(38) Further, the present embodiment makes it possible to reduce greenhouse gases such as CO.sub.2 in the atmosphere by capturing CO.sub.2 from the atmosphere and generating power without burning fossil fuels.
(39) Further, the present embodiment makes it possible to efficiently capture high-purity CO.sub.2 gas by capturing CO.sub.2 from the atmosphere through causing an absorption liquid to absorb CO.sub.2 in the atmosphere and releasing CO.sub.2 from the absorption liquid.
(40) As described above, the present embodiment makes it possible to realize a power generating system (a CO.sub.2 capturing and power generating system) that appropriately handles CO.sub.2.
Second Embodiment
(41) FIG. **3** is a schematic diagram showing a configuration of a power generating system of a second embodiment.
(42) The power generating system of the present embodiment has a structure similar to the structure of the power generating system of the first embodiment. However, the power generating system of the present embodiment does not include the flow divider **4**, the flow divider **16**, the flow merger **18**, the heat exchanger **21**, and the cooler **22**, but includes a vacuum pump **51**.
(43) Therefore, the mixed gas discharged from the gas-liquid separator **3** in the present embodiment is supplied only to the turbine **5**. Further, the absorption liquid from the flow divider **13** to the evaporator **2** in the present embodiment is supplied to the evaporator **2** only via the intermediate heat exchanger **17**.
(44) Further, the condensation absorber **7** in the present embodiment includes an outlet **7***a* for discharging (extracting) gas from the condensation absorber **7**. In the condensation absorber **7**, the water vapor included in the mixed gas is condensed into condensed water, and the concentration of water vapor included in the mixed gas decreases. That is, as in the case of the cooler **22** of the first embodiment, the mixed gas including CO.sub.2 and water vapor changes into a capture target gas including high purity CO.sub.2 in the condensation absorber **7**. The condensation absorber **7** discharges, from the outlet **7***a*, the capture target gas including CO.sub.2 that is to be a capture target in the power generating system of the present embodiment. Note that in the condensation absorber **7**, a portion of the CO.sub.2 is absorbed by the absorption liquid, and the remaining CO.sub.2 is discharged from the outlet **7***a*. The condensation absorber **7** of the present embodiment is an example of the capturer.
(45) The vacuum pump **51** is installed for discharging (extracting) the capture target gas from the outlet **7***a* of the condensation absorber **7**. The CO.sub.2 included in the capture target gas that has passed through the vacuum pump **51** may be liquefied inside or outside the power generating system of the present embodiment.
(46) The present embodiment makes it possible to use the energy (power) obtained by generating power as energy for capturing CO.sub.2, and therefore makes it possible to reduce the energy

required for capturing CO_2, as in the first embodiment.
(47) Further, the present embodiment makes it possible to reduce greenhouse gases such as CO_2 in the atmosphere by capturing CO_2 from the atmosphere and generating power without burning fossil fuels.
(48) Further, the present embodiment makes it possible to efficiently capture high-purity CO_2 gas by capturing CO_2 from the atmosphere through causing an absorption liquid to absorb CO_2 in the atmosphere and releasing CO_2 from the absorption liquid.
(49) As described above, the present embodiment makes it possible to realize a power generating system (a CO_2 capturing and power generating system) that appropriately handles CO_2, as in the first embodiment.
(50) While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel systems and methods described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the systems and methods described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

1. A power generating system comprising: a cooling absorption tower configured to cause an absorption liquid to absorb carbon dioxide in atmosphere; an evaporator configured to heat the absorption liquid to release the carbon dioxide and water vapor from the absorption liquid, and discharge the absorption liquid that has released the carbon dioxide and the water vapor, and a first gas including the carbon dioxide and the water vapor; a turbine configured to be driven by a portion of the first gas; a generator configured to be driven by the turbine; and a capturer configured to condense the water vapor included in a remaining portion of the first gas, and capture the carbon dioxide that is included in the remaining portion of the first gas and to be a capture target.
2. The system of claim 1, wherein the capturer condenses the water vapor included in the remaining portion of the first gas discharged from the evaporator, and captures the carbon dioxide that is included in the remaining portion of the first gas and to be the capture target.
3. The system of claim 1, wherein the capturer is a cooler configured to cool the first gas to condense the water vapor included in the first gas.
4. The system of claim 1, further comprising a condensation absorber configured to cool the first gas discharged from the turbine to condense the water vapor included in the first gas, cause the absorption liquid discharged from the evaporator to absorb the carbon dioxide included in the first gas, and discharge the absorption liquid that has absorbed the carbon dioxide to the cooling absorption tower.
5. The system of claim 4, wherein the cooling absorption tower cools the absorption liquid that has absorbed the carbon dioxide in atmosphere, and supplies the absorption liquid that has absorbed the carbon dioxide and has been cooled to the evaporator via the condensation absorber, and the cooler cools the first gas discharged from the turbine with the absorption liquid supplied from the cooling absorption tower.
6. The system of claim 5, further comprising a first heat exchanger configured to perform heat exchange between the absorption liquid directed from the evaporator to the condensation absorber and a portion of the absorption liquid directed from the cooling absorption tower to the evaporator via the condensation absorber.
7. The system of claim 5, further comprising a second heat exchanger configured to perform heat exchange between the remaining portion of the first gas directed from the evaporator to the

capturer and a remaining portion of the absorption liquid directed from the cooling absorption tower to the evaporator via the condensation absorber.

8. The system of claim 1, wherein the capturer condenses the water vapor included in the first gas discharged from the turbine, and discharges the carbon dioxide that is included in the first gas and to be the capture target.

9. The system of claim 1, wherein the capturer is a condensation absorber configured to cool the first gas discharged from the turbine to condense the water vapor included in the first gas, cause the absorption liquid discharged from the evaporator to absorb a portion of the carbon dioxide included in the first gas, and discharge a remaining portion of the carbon dioxide included in the first gas as the capture target.

10. The system of claim 9, further comprising a pump configured to discharge the carbon dioxide as the capture target from the condensation absorber.

11. The system of claim 9, wherein the condensation absorber discharges the absorption liquid that has absorbed the portion of the carbon dioxide to the cooling absorption tower, the cooling absorption tower causes the absorption liquid to absorb the carbon dioxide in atmosphere, cools the absorption liquid, and supplies the absorption liquid that has absorbed the carbon dioxide and has been cooled to the evaporator via the condensation absorber, and the condensation absorber cools the first gas discharged from the turbine with the absorption liquid supplied from the cooling absorption tower.

12. The system of claim 11, further comprising a first heat exchanger configured to perform heat exchange between the absorption liquid directed from the evaporator to the condensation absorber and the absorption liquid directed from the cooling absorption tower to the evaporator via the condensation absorber.

13. The system of claim 1, further comprising a gas-liquid separator configured to separate the absorption liquid and the first gas discharged from the evaporator, and discharge the first gas separated from the absorption liquid, wherein the turbine is driven by the portion of the first gas discharged from the gas-liquid separator, and the capturer condenses the water vapor included in the remaining portion of the first gas discharged from the gas-liquid separator, and discharges the carbon dioxide that is included in the remaining portion of the first gas and to be the capture target.

14. The system of claim 1, further comprising a heater configured to supply heat for heating the absorption liquid to the evaporator.

15. A power generating method comprising: causing an absorption liquid at a cooling absorption tower to absorb carbon dioxide in atmosphere; heating the absorption liquid in an evaporator to release the carbon dioxide and water vapor from the absorption liquid, and discharging, from the evaporator, the absorption liquid that has released the carbon dioxide and the water vapor, and a first gas including the carbon dioxide and the water vapor; driving a turbine by the first gas; driving a generator by the turbine; and condensing, in a condensation absorber, the water vapor included in the first gas, and capturing, from a capturer, the carbon dioxide that is included in the first gas and to be a capture target.