

$[0001]$

[0002]

25 [0003]

For example, a methane fermentation device that decomposes organic wastes to produce biogas discharges carbon dioxide together with methane gas. The proportion of carbon dioxide in the entire biogas produced by the methane fermentation device is about two-thirds by weight, although this depends on the composition of organic wastes. Specifically, when about 2 tons of methane gas is produced, about 4 tons of carbon dioxide is simultaneously produced.

Therefore, in order to reduce the amount of carbon dioxide emission, a technique of separating carbon dioxide from biogas and using the carbon dioxide in a plant factory, a technique of mixing ash generated

from a waste incinerator with carbon dioxide to form a cement material, and the like have been developed (see PTL 1).

5 In addition, a technique for performing methanation (methane synthesis) by using carbon dioxide generated from methane fermentation and hydrogen generated by a water electrolysis device to use the generated methane as a city gas, and a technique for utilizing methane as a fuel for gas
10 engines or the like have also been developed (see PTL 2).

Furthermore, a technology in which a water electrolysis device is installed in a refuse incineration plant, ammonia is synthesized from
15 hydrogen generated by the water electrolysis device and nitrogen in the air, and the ammonia is utilized as a fuel of gas engines or the like has also been developed (see PTL 3).

20 Prior Art Reference Patent Literature
[0004]

PTL 1: JP 2006-212524 A

PTL 2: JP 2019-090084 A

PTL 3: JP 2019-216501 A

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Summary of Invention Technical Problem

[0005]

The amount of carbon dioxide to be used in plant
30 factories and cement synthesis described in PTL 1 is not large enough to help all the carbon dioxide produced in methane fermentation to be consumed. On the other hand, according to the methanation described in PTL 2, a large amount of carbon dioxide can be
35 converted into methane that is in high demand, which is commercially beneficial. Meanwhile, in order to generate hydrogen for methanation with a water electrolysis device, a large amount of electric power

and water are required. Therefore, it is conceivable to perform methanation by using electric power generated by the steam turbine and the power generator of the boiler included in a refuse incineration plant and cooling wastewater of a quench tower for reducing the temperature of the exhaust gas as described in PTL 3.

However, in order to efficiently generate hydrogen with such a water electrolysis device, water containing no impurities is needed. In this regard, in the technique of PTL 3, a quench tower, which is a so-called scrubber, is installed on the upstream side of the dust collector, and temperature-lowered cooling wastewater is supplied to the water electrolysis device. However, since this cooling wastewater contains fly ash and heavy metals in the exhaust gas and chemicals for treating the exhaust gas, it cannot be supplied to the water electrolysis device as it is. [0006]

On the other hand, wastewater of the refuse incineration plant includes wastewater created by cleaning the platform for throwing refuse collected by a refuse collection vehicle into a refuse pit, wastewater discharged from the refuse stored in the refuse pit, and wastewater discharged from an ash extruder for cooling and discharging main ash incinerated in a refuse incinerator. However, since the wastewater from the platform or the refuse pit contains organic components and the wastewater from the ash extruder contains inorganic components, the wastewater cannot be supplied to the water electrolysis device as it is. [0007]

Thus, it has been a common technical knowledge of those skilled in the art that, in a case that a water electrolysis device is arranged in a refuse incineration plant, which is a type of combustion furnace-equipped plant, to use the wastewater

generated in the plant (plant wastewater) in the water electrolysis device, all types of plant wastewater such as wastewater from a platform or a refuse pit and wastewater from an ash extruder are merged in an integrated wastewater treatment system generally provided in plants to use the water having been subjected to treatment of organic components and inorganic components in the water electrolysis device.

Further, such an integrated wastewater treatment system is also provided in a plant other than a refuse incineration plant, for example, a thermal power plant, a chemical plant, or the like as far as the plant is a combustion furnace-equipped plant including a combustion furnace and a boiler.

[0008]

The present invention has been made in view of the above-described problems, and aims to provide a hydrogen production system capable of reducing a load of water treatment on an integrated wastewater treatment system and economically producing hydrogen through electrolysis by using plant wastewater generated in a combustion furnace-equipped plant.

Solution to Problem

[0009]

A hydrogen production system according to the present invention is applicable to a combustion furnace-equipped plant, and includes: a boiler-equipped combustion system including at least a combustion furnace and a boiler that generates steam by utilizing heat from combustion in the combustion furnace; an electrolysis system including at least an ion removal device into which at least a part of boiler blowdown water discharged from the boiler is introduced and that generates separated water in which unnecessary ions are removed and concentrated water containing the unnecessary ions, and a water electrolysis device that electrolyzes the separated

water to generate hydrogen; and a wastewater treatment system including at least an inorganic wastewater treatment facility that performs inorganic water treatment of plant wastewater generated in the combustion furnace-equipped plant, the plant wastewater containing remaining boiler blowdown water.

Advantageous Effects of Invention

[0010]

10 According to the hydrogen production system of the present invention, water electrolysis is performed by using a part of boiler blowdown water of plant wastewater generated in a combustion furnace-equipped plant, which is particularly clean although it is
15 mixed with chemicals at low concentrations. Since at least part of the boiler blowdown water subjected to water electrolysis does not enter the wastewater treatment system, the load of water treatment on the wastewater treatment system can be reduced.

20 Therefore, it is possible to provide a hydrogen production system capable of reducing the load of water treatment on a wastewater treatment system and economically producing hydrogen through electrolysis by using plant wastewater produced in a combustion
25 furnace-equipped plant.

Brief Description of Drawings

[0011]

FIG. 1 is a block diagram illustrating an example of a hydrogen production system of the present invention.

FIG. 2 is a block diagram illustrating a first modification of the hydrogen production system of the present invention.

35 FIG. 3 is a block diagram illustrating an example of a carbon dioxide separation device 60.

FIG. 4 is a block diagram illustrating a part of a second modification of the hydrogen production system of the present invention.

FIG. 5 is a block diagram illustrating a part of a third modification of the hydrogen production system of the present invention.

Description of Embodiments

[0012]

Hereinafter, hydrogen production systems according to an example and modifications (first, second, and third modifications) will be described with reference to FIGS. 1 to 5. In the drawings, numeric-only symbols represent physical elements such as devices, components, parts, etc. associated with the hydrogen production system. In addition, a symbol created by combining the letter F and a number represents a fluid such as a liquid or a gas generated in the hydrogen production system.

[0013]

The example and modifications described below are merely examples, and there is no intention to exclude various modifications and applications of technologies that are not explicitly described. Each configuration described below can be variously modified and implemented in a range without deviating from the gist of such configuration. In addition, each configuration described below can be chosen as necessary except for a configuration essential to the present invention, or can be combined with a known configuration.

[0014]

[1. Example and First Modification]

FIG. 1 illustrates an example of the present invention, and FIG. 2 illustrates a first modification of the present invention. The hydrogen production system 1 of the example and the first modification is a complex treatment facility including a boiler-equipped combustion system 10, a wastewater treatment

system (integrated wastewater treatment system) 30, a high-purity carbon dioxide generation system 40, an electrolysis system 50 (50' in the first modification), and a methanation system 72.

5 Since the example and the first modification are different from each other only in the configurations of electrolysis systems 50 and 50' included in the hydrogen production system 1, the example and the first modification will be described simultaneously
10 herein.

 All systems 10, 30, 40, 50 (50'), and 72 may all be provided inside one building or may be provided in separate buildings corresponding to each of the systems. In addition, all of the systems may be
15 provided at the same site, or may be provided at different sites, for example, at sites distant from each other. In the case that each of the systems are provided at sites distant from each other, the systems may be appropriately connected to each other by
20 pipelines, automobile transportation, or the like.

[0015]

[A. Basic Configuration]

 First, an outline of the above-described five systems 10, 30, 40, 50 (50), and 72 will be described,
25 and then specific configurations and effects of the respective systems will be described in detail.

 The boiler-equipped combustion system 10 is a system including at least a combustion furnace and a boiler that generates steam with heat from combustion
30 in the combustion furnace. There are various types of combustion furnace-equipped plant to which the hydrogen production system 1 is applicable, such as a refuse incineration plant, a thermal power generation plant, and a chemical plant, depending on the fuel
35 (waste, coal, or the like) to be burned in the combustion furnace and the purpose thereof.

Since the boiler-equipped combustion system 10 includes a boiler 20, boiler blowdown water F1 to be described below is discharged at all times.

Further, in the example and the first
5 modification, the boiler-equipped combustion system 10 includes a refuse incinerator 13 as an example of a combustion furnace.
[0016]

The wastewater treatment system 30 is an
10 integrated wastewater treatment system described in [Problems to be Solved by the Invention]. This system includes an organic wastewater treatment facility 31 for water treatment such as biological treatment for organic components contained in plant wastewater and
15 an inorganic wastewater treatment facility 32 for water treatment for inorganic components contained in the plant wastewater after the water treatment for the organic components. In the wastewater treatment system 30, water treatment is performed to purify wastewater
20 to such an extent that the wastewater can be discharged to the outside of the combustion furnace-equipped plant. The plant wastewater treated by the wastewater treatment system 30 may be used in the combustion furnace-equipped plant as recycled water
25 F14 which will be described below, or may be discharged to the outside of the combustion furnace-equipped plant if there is a surplus of the wastewater.

Further, since an example in which the hydrogen
30 production system 1 according to the example and the first modification is applied to a refuse incineration plant which is a type of combustion furnace-equipped plant is introduced, the wastewater treatment system 30 includes both the organic wastewater treatment
35 facility 31 and the inorganic wastewater treatment facility 32. However, in a combustion furnace-equipped plant of which plant wastewater contains no organic component, for example, a thermal power plant, the

wastewater treatment system 30 may not include such an organic wastewater treatment facility 31 but may include only the inorganic wastewater treatment facility 32.

5 [0017]

The high-purity carbon dioxide generation system 40 is a system that generates highly pure carbon dioxide without undergoing a particular concentration step. Since a large amount of highly pure carbon
10 dioxide is generated during methane fermentation as described in "Background Art", the high-purity carbon dioxide generation system 40 illustrated in FIGS. 1 and 2 includes at least a methane fermentation device 42 as an example.

15 In addition to the methane fermentation device 42, the high-purity carbon dioxide generation system 40 may be configured to include at least an alcohol fermentation device 66 (which will be described below as a second modification using FIG. 4), a gasification
20 furnace 69 (which will be described below as a third modification using FIG. 5) that gasifies woody biomass, and the like.

[0018]

The methanation system 72 is a system that uses,
25 as raw materials, at least carbon dioxide F7 generated by the high-purity carbon dioxide generation system 40 and hydrogen F4 generated by the water electrolysis device 53 of the electrolysis system 50, which will be described below, to perform methanation in the
30 methanation device 46, and thereby generates methane F12.

[0019]

The electrolysis system 50 is a system that generates hydrogen F4 in electrolysis in which boiler
35 blowdown water F1 is used. The electrolysis system 50 includes at least an ion removal device 52 for removing unnecessary ions from the boiler blowdown water F1 and the water electrolysis device 53.

Although water to be supplied to the boiler 20 is pure water F15, chemicals, for example, a cleaning agent, an anticorrosive agent (deoxidizer), a scale inhibitor, and the like are added at low

5 concentrations to adjust the water stored in the boiler 20 to be weak alkaline. For this reason, in the related art, the boiler blowdown water F1 has been mixed with other plant wastewater containing a large amount of impurities such as high-concentration
10 chemicals and ash, and treated in an integrated wastewater treatment facility.

However, because the water stored in the boiler 20 is water obtained by adding low-concentration chemicals to the pure water F15, containing no ash or
15 heavy metals, and particularly closer to the pure water F15 compared to other plant wastewater from a plant including a combustion furnace, the inventors have conceived that, if the boiler blowdown water F1 discharged from the boiler 20 at any time is used in
20 the water electrolysis device 53 requiring the pure water F15, hydrogen F4 can be generated efficiently and economically.

Therefore, the present inventors have invented the hydrogen production system 1 which basically has a
25 configuration in which the boiler blowdown water F1 is used to produce the hydrogen F4 with the water electrolysis device 53, thus can generate valuable substances such as methane F12 by using the hydrogen F4 generated by the water electrolysis device 53, and
30 further can reduce carbon dioxide F18 discharged from the combustion furnace-equipped plant, that is, the hydrogen production system 1 which can realize the decarbonized society which has become an international environmental issue in recent years.

35 The outline of the five systems 10, 30, 40, 50 (50'), and 72 included in the example and the first modification has been described above. Therefore, a

configuration and effects of each system will be described in detail below.

[0020]

[B. Detailed Configuration]

5 Now, the hydrogen production system 1 will be described in detail with reference to FIGS. 1 and 2. The example and the first modification are examples in which the hydrogen production system 1 of the present invention is applied to a refuse incineration plant
10 among combustion furnace-equipped plants as described above.

 The refuse incineration plant is a facility for incinerating refuse, for example, municipal refuse and industrial waste, in other words, wastes. The boiler-
15 equipped combustion system 10 includes a platform 11 that is a space where a refuse loading vehicle (a refuse collection vehicle, a truck, a dump truck, or the like) unloads wastes, and a refuse pit 12 (a refuse storage tank) into which the wastes unloaded
20 from the refuse loading vehicle are thrown and temporarily stored. The wastes thrown into the refuse pit 12 are transferred to a refuse incinerator 13 by a refuse crane.

 Since wastewater used to clean the platform 11
25 (platform cleaning wastewater) and wastewater exuded from the wastes stored in the refuse pit 12 (pit wastewater) generally contain organic components, the wastewater is treated as plant wastewater in the organic wastewater treatment facility 31 of the
30 wastewater treatment system 30.

[0021]

 The refuse incinerator 13 is a furnace for incinerating wastes and is, for example, a stoker furnace, a fluidized bed furnace, or the like. An ash
35 extruder 14 is a device for cooling and discharging incineration ash (main ash) remaining after incineration of wastes in the refuse incinerator 13. The wastewater discharged from the ash extruder 14

(ash extruder wastewater) is alkaline water containing ash and heavy metals, and is treated as plant wastewater in the inorganic wastewater treatment facility 32 of the wastewater treatment system 30.

5 Further, the inorganic wastewater treatment facility 32 also receives the wastewater treated in the organic wastewater treatment facility 31 and performs water treatment.

[0022]

10 Exhaust gas generated by burning the wastes in the refuse incinerator 13 passes through a flue 15, flows through a quench tower 16 for reducing the temperature of the exhaust gas, a dust removal device 17 for removing flying ash from the exhaust gas, and a
15 stack 19 in this order, and then discharged to the outside air. Here, a carbon dioxide separation device 60 for separating low-concentration carbon dioxide F18 contained in the exhaust gas is disposed in the flue 15 between the dust removal device 17 and the stack
20 19. If necessary, a denitration device, an induced blower, or the like, which is not illustrated, may be installed on the flow path of the exhaust gas.

[0023]

Dust (fly ash) removed by the dust removal device
25 17 such as a bag filter is cleaned by a fly ash cleaning device 18, and then stored in a fly ash pit, which is not illustrated, and carried out of the plant. The wastewater (cleaned wastewater) discharged from the fly ash cleaning device 18 is alkaline water
30 containing ash and heavy metals, and is treated as plant wastewater in the inorganic wastewater treatment facility 32 of the wastewater treatment system 30.

Further, if the plant wastewater (recycled water F14) treated in the inorganic wastewater treatment
35 facility 32 of the wastewater treatment system 30 is sprayed to reduce the temperature of the exhaust gas in the quench tower 16, it is excellent in terms of cost effectiveness compared to the case that tap water

is sprayed. Here, the quench tower 16 is desirably not the scrubber of PTL 3 but a quench tower 16 generally used in a refuse incineration plant, that is, a quench tower 16 in which sprayed water (for example, the recycled water F14) substantially entirely evaporates due to high-temperature exhaust gas. Since the whole sprayed water substantially evaporates, the plant wastewater is not discharged from the quench tower 16 and the load of water treatment on the wastewater treatment system 30 can be reduced.

In addition, if dust (fly ash) is cleaned with the plant wastewater (the recycled water F14) treated in the inorganic wastewater treatment facility 32 of the wastewater treatment system 30 in the fly ash cleaning device 18, it is excellent in terms of cost effectiveness, compared to a case that dust is cleaned with tap water.

[0024]

The boiler 20 includes a water purifying device 27 that produces pure water F15 from tap water, industrial water, or the like, a chemical adding device 28 that adds chemicals such as a cleaning agent, an anticorrosive agent (deoxidizer), or a scale inhibitor to the pure water F15 produced by the water purifying device 27, a steam drum 21 that stores the pure water F15 with the chemicals added thereto, a waste heat recovery unit 22 such as a heat transfer tube or a superheater tube that converts water stored in the steam drum 21 into steam using the heat of exhaust gas, a steam turbine 23 that rotates an impeller with the steam generated by the exhaust heat collector 22 and supplied to the steam drum 21, a power generator 24 that generates power with a rotational force of the impeller of the steam turbine 23, a condenser 25 that converts the steam (waste steam) after rotating the impeller of the steam turbine 23 into water, and a deaerator 26 that removes dissolved gases (oxygen, carbon dioxide, etc.) from

the condensate generated by the condenser 25 and supplies the condensate to the steam drum 21.

5 The boiler blowdown water F1 is discharged from a blow pipe 29 disposed below the steam drum 21 at any time.

Further, since the waste steam has a high temperature, if the waste steam is appropriately supplied to and used in a device that needs to be heated in the plant, such as the carbon dioxide
10 separation device 60, the methanation device 46, and a pretreatment device 41 (in a case of solubilization or hydrothermal treatment), which will be described below, it is excellent in terms of cost effectiveness, compared to heating using electric power purchased
15 from an electric power company.
[0025]

The electric power generated by the power generator 24 is used to operate various electric products (the water electrolysis device 53, the
20 electrolysis device 54, the methanation device 46, and the like) disposed in the plant, and the surplus electric power may be sold to the electric power company. A substantially power-independent combustion furnace-equipped plant can be constructed by
25 appropriately designing the plant such that no electric power is to be sold to the electric power company or a small amount of electric power is to be sold and thus all or most of the electric power is supplied to various electric products disposed in the
30 plant to which the hydrogen production system 1 is applicable.

In addition, if plant wastewater (the recycled water F14) treated in the inorganic wastewater treatment facility 32 of the wastewater treatment
35 system 30 is supplied to the water purifying device 27 and pure water F15 is produced in the water purifying device 27, it is excellent in terms of cost

effectiveness, compared to a case that tap water is supplied thereto.

[0026]

For example, the carbon dioxide separation device
5 60 is a device that separates carbon dioxide using an amine solution as illustrated in FIG. 3. If possible in design, the carbon dioxide separation device 60 may have a configuration similar to that of a carbon dioxide separation membrane 45 which will be described
10 below.

The carbon dioxide separation device 60 of FIG. 3 includes an absorber 61, a heat exchanger 62, a desorber 63, and a reheater 64.

[0027]

15 The absorber 61 is a device for absorbing the carbon dioxide F18 contained in the exhaust gas into an amine solution. A relatively low-temperature amine solution is injected toward the exhaust gas inside the absorber 61. The amine-solution that has absorbed the
20 carbon dioxide F18 falls downward inside the absorber 61 and is introduced into the heat exchanger 62. In addition, the exhaust gas from which the carbon dioxide F18 has been removed flows out from above the absorber 61 and is discharged into the atmosphere
25 through the stack 19.

The heat exchanger 62 is a device for raising the temperature of the amine solution flowing out from the absorber 61. A relatively high-temperature amine solution flowing out from the desorber 63, which will
30 be described below, is introduced into the heat exchanger 62 as a heat source. The heat of the high-temperature amine solution is transferred to the low-temperature amine solution inside the heat exchanger 62. The amine solution (amine solution containing the
35 carbon dioxide F18) heated here is introduced into the desorber 63.

The desorber 63 is a device for desorbing the carbon dioxide F18 from the amine solution. The amine

solution introduced into the desorber 63 is sprayed to the inside of the desorber 63. As a result, the carbon dioxide F18 absorbed in the amine solution is desorbed, flows out from above the desorber 63, and is
5 stored in a carbon dioxide storage tank 49.

The desorber 63 is provided with the reheater 64 for heating the amine solution introduced into the desorber 63 while circulating the amine solution. In the reheater 64, for example, the waste steam of the
10 steam turbine 23 may be used to raise the temperature of the amine solution.

Due to the carbon dioxide separation device 60 and the carbon dioxide storage tank 49, the discharge amount of the carbon dioxide F18 contained in the
15 exhaust gas to the outside of the combustion furnace-equipped plant can be greatly reduced.
[0028]

Each configuration of the boiler-equipped combustion system 10 has been described above in
20 detail. Since each configuration of the wastewater treatment system 30 has already been described in the section for outline description, description thereof will be omitted.

Next, each configuration of the high-purity
25 carbon dioxide generation system 40 will be described in detail.

In the hydrogen production system 1 of the example and the first modification, the high-purity carbon dioxide generation system 40 is described as a
30 system that generates high-purity carbon dioxide F7 through methane fermentation. In particular, organic matter contained in the wastes carried into the refuse incineration plant is used here as raw materials for the methane fermentation. Since the organic matter
35 contained in the wastes is used as a raw material, no cost is required for the raw material, which is excellent in terms of cost effectiveness.

The pretreatment device 41 is a device that performs pretreatment (for example, crushing, solubilization, hydrothermal treatment, or the like) for removing unfermentable substances from the raw materials and adjusting the properties of fermentable substances. The raw material is transferred from, for example, the refuse pit 12.

The raw material appropriately pre-treated in the pretreatment device 41 is introduced into the methane fermentation device 42.

[0029]

The methane fermentation device 42 is a device that ferments the raw material pretreated by the pretreatment device 41 into methane to generate biogas F8 and discharges a fermentation residue F9. The methane fermentation may be carried out in a dry or wet mode.

In the biogas F8, at least two types that are methane F6 (CH_4) and carbon dioxide F7 (CO_2) are contained as main components accounting for most of the biogas F8.

The biogas F8 generated in the methane fermentation device 42 is introduced into the carbon dioxide separation membrane 45, and the fermentation residue F9 is transferred to a dehydrator 43. The dehydrator 43 is, for example, a trommel.

The dehydrator 43 is a device that dehydrates the fermentation residue F9 to be separated into a filtrate F10 and a residue (dehydrated sludge). The filtrate F10 separated here is transferred to a water treatment device 51 of the electrolysis systems 50 and 50'. In addition, the residue (dehydrated sludge) is transferred to the refuse pit 12 by a conveyor 44 and incinerated in the refuse incinerator 13.

[0030]

The carbon dioxide separation membrane 45 is a device with a separation membrane built therein that separates the carbon dioxide F7 from the biogas F8.

For the separation membrane, for example, a polymer membrane such as a hollow fiber membrane, a dendrimer membrane, a polyethylene glycol membrane, or a polyvinyl alcohol membrane can be used.

5 The carbon dioxide F7 separated by the carbon dioxide separation membrane 45 does not contain nitrogen oxides and particulate matter, unlike exhaust gases of combustion furnaces and internal combustion engines, but is a high-purity carbon dioxide F7
10 containing no impurities, in other words, an extremely clean carbon dioxide F7. Thus, the carbon dioxide F7 can be used directly as a raw material for the methanation device 46 of the methanation system 72 or as a raw material for photosynthesis of plants in a
15 plant-growing facility 48 without purification treatment or filtering treatment. The carbon dioxide F7 may be stored in the carbon dioxide storage tank 49.

[0031]

20 In the example and the first modification, carbon dioxide generated from methane fermentation in the methane fermentation device 42 may be stored in the carbon dioxide storage tank 49 or used as a raw material for the methanation device 46 or the plant-
25 growing facility 48, and thus the amount of carbon dioxide F7 discharged to the outside of the combustion furnace-equipped plant can be significantly reduced.

 Further, the plant-growing facility 48 includes a storage facility for storing the carbon dioxide F7 (a
30 carbon dioxide tank or a carbon dioxide cylinder), and a building and a facility for supplying the carbon dioxide F7 to plants that grow by photosynthesis to grow the plants (a plant factory, a greenhouse for cultivation, a water tank for cultivation, or the
35 like). In the plant-growing facility 48, for example, algae, flowers, vegetables, fruits, ornamental plants, succulent plants, trees, and the like can be cultivated.

[0032]

On the other hand, the residual gas from which the carbon dioxide F7 has been separated by the carbon dioxide separation membrane 45 is substantially
5 methane F6 ("second methane" in the claims). The methane F6 is stored in a gas cylinder or the like or is supplied to a methane gas utilization facility 47 for use. As the methane gas utilization facility 47, for example, a facility for introducing city gas into
10 gas pipes (gas pipe introduction facility), a home, a business, or a factory in which a gas water heater for supplying hot water by burning city gas, a gas heating device, a gas engine (gas power generator), or the like is installed can be exemplified.

15 The exhaust gas generated when the methane F6 is burned in the gas engine may be introduced into the refuse incinerator 13 as a gas for exhaust gas recirculation (EGR) to reduce the amount of nitrogen oxides (NOx) contained in the exhaust gas generated in
20 the refuse incinerator 13. In addition, when the gas engine generates electric power by using the methane F6 as a fuel, the electric power can be utilized as electric power for operating the methanation device 46, the water electrolysis device 53, the electrolysis
25 device 54, and the like, similar to electric power generated by the steam turbines 23 and the power generator 24.

Further, although the residual gas from which the carbon dioxide F7 has been separated by the carbon
30 dioxide separation membrane 45 is substantially the methane F6, the residual gas may contain a trace amount of sulfur component or the like. Therefore, in this case, an impurity gas removal device such as a desulfurization device, which is not illustrated, may
35 be used to remove impurity gases other than the methane F6 from the residual gas to obtain the methane F6.

[0033]

Next, the methanation system 72 will be described in detail.

The methanation device 46 included in the methanation system 72 is a device that synthesizes the carbon dioxide F7 and the hydrogen F4 generated by the water electrolysis device 53, which will be described below, to generate methane F12 ("first methane" in the claims). Here, for example, the methane F12 and pure water F13 are synthesized from the carbon dioxide F7 and the hydrogen F4 through a methanization reaction or a Sabatier reaction via a co-electrolysis reaction (this synthesis technique is referred to as methanation). The methanation device 46 is provided with a reactor (catalytic container) containing a catalyst for methane synthesis to generate the methane F12 therein. The temperature and pressure in the reactor are controlled within a range in which catalytic activity suitable for a desired reaction is obtained, for example, at about 250°C and about 20 to 30 atm. Waste steam from the steam turbine 23 can be used for heating and pressurization of the methanation device 46.

Further, since about 20 to 30 atm is a relatively high pressure, the methanation device 46 has been developed to have a lower pressure in recent years so that methanation can be performed at a lower pressure. [0034]

Electric power generated by the steam turbine 23 and the power generator 24 or the gas engine can be used as electric power for operating the methanation device 46 as described above.

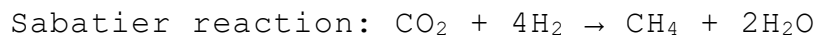
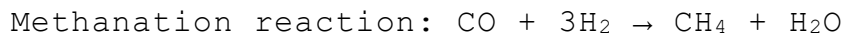
The methane F12 synthesized by the methanation device 46 is supplied to the methane gas utilization facility 47 for use or storage. In addition, the pure water F13 generated by the methanation device 46 may be introduced into the steam drum 21 as it is without passing through the water purifying device 27.

This makes it possible to reduce operation costs for the combustion furnace-equipped plant in terms of electric power for operating the devices and pure water production.

5 [0035]

Chemical reaction formulas relating to the methane synthesis in the methanation device 46 are exemplified below.

Co-electrolytic reaction:



[0036]

Now, finally, the electrolysis systems 50 and 50' will be described in detail. The electrolysis systems 50 and 50' use the filtrate F11 biologically treated by the water treatment device 51 to perform electrolysis in the water electrolysis device 53 or the electrolysis device 54 different from the water electrolysis device 53 to produce sodium hypochlorite solutions F16 and F17.

Since the electrolysis systems 50 and 50' have different configurations in the example and the first modification, the electrolysis system 50 in the example will be described first, and then the electrolysis system 50' in the first modification will be described.

The electrolysis system 50 in the example includes the water treatment device 51, the ion removal device 52, the water electrolysis device 53, and the electrolysis device 54.

The water treatment device 51 is an organic-based water treatment device 51 (biological treatment device) that performs biological treatment of the filtrate F10 being separated by the dehydrator 43 of the high-purity carbon dioxide generation system 40 and containing organic components.

Although the water treatment device 51 performs biological treatment in the same manner as the organic wastewater treatment facility 31 of the wastewater treatment system 30, the amount of the filtrate F10 is smaller than the amount of plant wastewater treated by the organic wastewater treatment facility 31. Thus, the water treatment device 51 is significantly smaller and less expensive than the organic wastewater treatment facility 31. A filtrate F11 biologically treated in the water treatment device 51 is introduced into the ion removal device 52.

[0037]

The ion removal device 52 is a device which receives supply of at least a part of the boiler blowdown water F1 discharged from the steam drum 21 as needed and separates the boiler blowdown water F1 into separated water F2 (pure water) containing no unnecessary ions and concentrated water F3 containing unnecessary ions. Since the boiler blowdown water F1 and the filtrate F11 biologically treated in the water treatment device 51 are introduced into the ion removal device 52 illustrated in FIG. 1, unnecessary ions are removed from the liquid in which the boiler blowdown water F1 and the filtrate F11 are mixed.

The filtrate F11 contains sodium ions (Na^+) and chloride ions (Cl^-) that have not been removed in the biological treatment of the water treatment device 51. On the other hand, in a case that a phosphoric acid-based chemical is contained in the anticorrosive agent to be added by the chemical adding device 28, phosphate ions (PO_4^{3-}) are contained in the boiler blowdown water F1.

Thus, when the mixed liquid is supplied to the ion removal device 52, a concentrated water F3 containing sodium ions (Na^+), chloride ions (Cl^-), and phosphate ions (PO_4^{3-}) and a separated water F2 that is pure water from which these unnecessary ions have been removed are generated.

[0038]

Further, the remaining portion of the boiler
blowdown water F1 that has not been supplied to the
ion removal device 52 is introduced into the inorganic
wastewater treatment facility 32 of the wastewater
5 treatment system 30 and subjected to inorganic water
treatment.

Since the recycled water F14 treated in the
inorganic wastewater treatment facility 32 of the
10 wastewater treatment system 30 is sprayed in an
important device in the plant, for example, the quench
tower 16 for cooling the exhaust gas, it is desirable
to introduce not all but a part of the boiler blowdown
water F1 into the ion removal device 52 so as not to
15 cause a situation in which the recycled water F14
becomes insufficient. However, if possible in terms of
design, the entire amount of the boiler blowdown water
F1 discharged from the steam drum 21 at any time, not
the part of the boiler blowdown water F1, may be
20 supplied to the ion removal device 52 and used as a
raw material for hydrogen production. In this case,
the "remaining portion of the boiler blowdown water
F1" is naturally 0, and the boiler blowdown water F1
is not supplied to the wastewater treatment system 30,
25 but the entire amount of the boiler blowdown water F1
is supplied to the ion removal device 52 and used as a
raw material for hydrogen production.

[0039]

The ion removal device 52 includes, for example,
30 a reverse osmosis (RO) membrane and an ion exchange
resin. The RO membrane is a membrane that allows
hydrogen ions (H^+) and hydroxide ions (OH^-) in water to
pass therethrough and prevents other unnecessary ions
from passing therethrough. In addition, the ion
35 exchange resin is gel-like synthetic resin beads for
replacing unnecessary ions in water with hydrogen ions
or hydroxide ions.

The separated water F2 is supplied to the water electrolysis device 53, and the concentrated water F3 is supplied to the electrolysis device 54 different from the water electrolysis device 53.

5 [0040]

The water electrolysis device 53 is a device that electrolyzes the separated water F2 (pure water). Since the water electrolysis device 53 is a device for electrolyzing pure water, the pure water F13 generated
10 in the methanation device 46 may be supplied to the water electrolysis device 53 in addition to the separated water F2 to increase the amount of hydrogen production amount, although this operation is not illustrated. Further, if the amount of water is
15 insufficient only with the separated water F2 generated from the boiler blowdown water F1 as a raw material to produce a predetermined amount of hydrogen F4 in the water electrolysis device 53, the pure water F13 and F15 other than the separated water F2, the
20 pure water F13 produced in the methanation device 46 and the pure water F15 produced in the water purifying device 27, may be mixed and supplied to the water electrolysis device 53.

Here, in general, a water electrolysis device
25 includes a heating device for heating pure water at room temperature in order to perform electrolysis efficiently. However, the water electrolysis device 53 in the example or the modification does not need to include a heating device. This is because the
30 temperature of the boiler blowdown water F1 that is a raw material for hydrogen production in the water electrolysis device 53 is high and the temperature of the separated water F2 separated by the ion removal device 52 can be adjusted to a temperature higher than
35 room temperature (about 70°C to 90°C). Therefore, the water electrolysis device 53 can electrolyze pure water and a mixed liquid having a temperature higher than room temperature not only in a case that pure

water other than the above-described separated water F2 is mixed but also in a case that the filtrate F11 is mixed with the separated water F2 (the electrolysis system 50' in the first modification to be described below). Thus, the water electrolysis device 53 can efficiently produce hydrogen even without a heating device, and thus this configuration is excellent in cost effectiveness. Of course, in the case that the temperature of the pure water or the mixed liquid can be adjusted to a temperature higher than room temperature but is not insufficient to reach a predetermined temperature suitable for hydrogen production, the heating device may be added to the water electrolysis device 53, and for example, the above-described waste steam may be supplied to the heating device for heating.

For electric power for operating the water electrolysis device 53, electric power generated by the steam turbine 23, the power generator 24, or the above-described gas engine can be used. In addition, since the separated water F2 to be supplied to the water electrolysis device 53 is generated from the boiler blowdown water F1 which is plant wastewater, there is no need to separately purchase raw materials because it is free of charge. Therefore, the hydrogen F4, which is a valuable substance, can be economically produced from the boiler blowdown water F1 which is the plant wastewater.

[0041]

In the water electrolysis device 53, the separated water F2 is electrolyzed to produce the hydrogen F4 (H_2) and oxygen F5 (O_2). The hydrogen F4 is introduced into the methanation device 46. In addition, the oxygen F5 may be discharged into the atmosphere, or may be mixed with the combustion air supplied into the refuse incinerator 13 to promote combustion of the wastes.

Further, since at least a part of the boiler blowdown water F1 is used as a raw material for the water electrolysis device 53, the load of water treatment on the inorganic wastewater treatment facility 32 can be reduced as compared to the past case that the entire amount of the boiler blowdown water F1 is introduced into the inorganic wastewater treatment facility 32 of the wastewater treatment system 30.

10 [0042]

The electrolysis device 54 is a device that electrolyzes the concentrated water F3, and can generate the sodium hypochlorite solution F16 (NaClO solution) by using sodium ions and chloride ions contained in the concentrated water F3.

For electric power for operating the electrolysis device 54, electric power generated by the steam turbine 23, the power generator 24, or the above-described gas engine can be used.

20 For example, the sodium hypochlorite solution F16 generated in the electrolysis device 54 may be sprayed as a disinfectant for the platform 11 and roads of a refuse incineration plant which is a combustion furnace-equipped plant, or may be poured into
25 containers such as buckets and PET bottles so as to be carried and used for disinfection cleaning of rooms and facilities in the plant.

Both the filtrate F10 of the methane fermentation device 42 and the boiler blowdown water F1 are plant wastewater, and the sodium hypochlorite solution F16 is produced in the electrolysis device 54 using the plant wastewater as a raw material that does not require raw material costs, and thus this point is excellent in terms of cost effectiveness. Furthermore,
30 the sanitary condition of the combustion furnace-equipped plant can be well maintained with the economically produced sodium hypochlorite solution F16 and the work environment can be improved.

[0043]

Chemical reaction formulas relating to the formation of sodium hypochlorite are exemplified below.

5 Anode: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}$

Cathode: $2\text{Na}^+ + 2\text{H}_2\text{O} + 2\text{e} \rightarrow 2\text{NaOH} + \text{H}_2$

In solution: $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{NaCl} + \text{H}_2\text{O}$

[0044]

Since the electrolysis system 50 in the example
10 has been described above, next, the electrolysis
system 50' in the first modification will be
described.

A difference of the electrolysis system 50' from
the electrolysis system 50 is that the electrolysis
15 system 50' does not include the electrolysis device 54
and the filtrate F11 is directly supplied to the water
electrolysis device 53. In the electrolysis system
50', only the boiler blowdown water F1 is supplied to
the ion removal device 52, and the separated water F2
20 generated by the ion removal device 52 is supplied to
the water electrolysis device 53. In addition, the
concentrated water F3 is supplied to the inorganic
wastewater treatment facility 32 of the wastewater
treatment system 30 and is subjected to water
25 treatment.

Since the separated water F2 and the filtrate F11
are mixed and introduced in the water electrolysis
device 53 of the electrolysis system 50', the hydrogen
F4 and the sodium hypochlorite solution F17 are
30 produced through electrolysis in the water
electrolysis device 53.

Like the electrolysis system 50, the electrolysis
system 50' can also economically produce the sodium
hypochlorite solution F17. In addition, the sanitary
35 condition of the combustion furnace-equipped plant can
be well maintained with the economically produced
sodium hypochlorite solution F17 and the work
environment can be improved.

[0045]

The example and the first modification have been described above.

In the hydrogen production system 1 of the
5 example or the first modification, for example, when
about 30 tons of organic matter is input into the
methane fermentation device 42, the amount of methane
F6 produced is about 1.9 tons, and the amount of
carbon dioxide F7 produced is about 3.5 tons. Here, in
10 a case that the recovery rate of the methane F6 in the
carbon dioxide separation membrane 45 is, for example,
about 92% (the performance varies depending on the
type and the like of the carbon dioxide separation
membrane 45), if the entire amount of the carbon
15 dioxide F7 is introduced into the methanation device
46, about 3.45 tons of the carbon dioxide F7 and about
0.1 tons of the methane components are introduced into
the methanation device 46. In addition, the amount of
methane F6 separated by the carbon dioxide separation
20 membrane 45 is about 1.8 tons.

On the other hand, since about 5.65 tons of the
separated water F2 is obtained from about 6 tons of
the boiler blowdown water F1 in the ion removal device
52, about 0.63 tons of hydrogen F4 is obtained in the
25 water electrolysis device 53.

In a case that the entire amount of the hydrogen
F4 and the carbon dioxide F7 is used for methanation
in the methanation device 46, about 1.4 tons of the
methane F12 and about 2.8 tons of pure water F13 are
30 produced.

Thus, a total of 3.2 tons of methane F6 and F12,
which are valuable substances, can be obtained from
the methane F6 (second methane) and the methane F12
(first methane), and the amount of carbon dioxide F7
35 emitted can be reduced to substantially zero.

In addition, by providing the carbon dioxide
separation device 60, the carbon dioxide F18 contained

in the exhaust gas of the combustion furnace can also be recovered.

Furthermore, electric power generated by the boiler-equipped combustion system 10 can be supplied to devices that need electric power, such as the methanation device 46 and the water electrolysis device 53 in the hydrogen production system 1.
[0046]

Therefore, in the hydrogen production system 1 of the example and the first modification, the raw material cost for the boiler blowdown water F1 that is plant wastewater can be zero, the raw material cost for the carbon dioxide F7 used for methanation can be zero, and the cost for the electric power for operating the methanation device 46, the water electrolysis device 53, and the like can be substantially zero, and therefore, the methane F12 which is a valuable substance can be produced at low cost using the hydrogen F4 produced by the water electrolysis device 53, and the carbon dioxide F18 discharged from the combustion furnace-equipped plant can be reduced. In other words, the hydrogen production system 1 according to the example and the first modification can be said to be a hydrogen production system 1 that enables realization of the decarbonization society, which is a recent environmental issue in the world.

[0047]

[2. Second Modification and Third Modification]

Next, a hydrogen production system 1 in which the high-purity carbon dioxide generation system 40 included in the hydrogen production system 1 of the example and the first modification is replaced with a high-purity carbon dioxide generation system 40' as another example will be described as a second modification with reference to FIG. 4. In addition, a hydrogen production system 1 in which the boiler-equipped combustion system 10 included in the hydrogen

production system 1 of the example and the first modification is replaced with a boiler-equipped combustion system 10' as another example and the high-purity carbon dioxide generation system 40 included in the hydrogen production system 1 of the example and the first modification is replaced with a high-purity carbon dioxide generation system 40'' as another example will be described as a third modification with reference to FIG. 5.

In the hydrogen production system 1 of the second modification and the third modification, among the five systems 10, 30, 40, 50 (50'), and 72, the other systems that are not changed in the other examples may be the same as those of the example or the first modification.

The same configurations as those described in the example and the first modification are denoted by the same reference signs, and descriptions of the configurations and effects will be omitted. In addition, since inflow and outflow of a liquid or a gas, transfer of an object, and the like may be the same for the same configuration as the configuration illustrated in the example and the first modification, illustration of some of the inflow, outflow, and transfer is omitted.

[0048]

[A. Second Modification]

A hydrogen production system 1 according to a second modification will be described with reference to FIG. 4. The hydrogen production system 1 of the second modification differs from the hydrogen production system 1 of the example or the first modification in terms of the high-purity carbon dioxide generation system 40'.

Similar to the high-purity carbon dioxide generation system 40, the high-purity carbon dioxide generation system 40' is a system that generates high-purity carbon dioxide F7 and F19 without going through

a particular concentration step. Although the high-purity carbon dioxide generation system 40 includes at least the methane fermentation device 42 as an example, the high-purity carbon dioxide generation system 40' includes at least the alcohol fermentation device 66 as an example.

Although the high-purity carbon dioxide generation system 40' of FIG. 4 produces high-purity carbon dioxide F7 and F19 from both the alcohol fermentation device 66 and the methane fermentation device 42, the methane fermentation device 42 is not necessarily provided.

[0049]

The high-purity carbon dioxide generation system 40' of FIG. 4 is a system in which an alcohol fermentation system 65 is interposed between the pretreatment device 41 and the methane fermentation device 42 in the high-purity carbon dioxide generation system 40. The alcohol fermentation system 65 includes the alcohol fermentation device 66 and a solid-liquid separation device 67 that performs solid-liquid separation on a fermentation mash F20 produced in the alcohol fermentation device 66 and separates the fermentation mash into alcohol F21 and a residue F22. The solid-liquid separation device 67 is, for example, a screw press, a belt press, or the like.

First, biomass such as waste wood or bagasse (the pomace of sugar cane) is introduced into the pretreatment device 41. The biomass is hydrolyzed and saccharified in the pretreatment device 41 to produce glucose.

Next, the glucose produced in the pretreatment device 41 is introduced into the alcohol fermentation device 66 of the alcohol fermentation system 65. Then, yeast is supplied to the alcohol fermentation device 66, and alcohol fermentation is performed.

The chemical reaction formula for generation of the alcohol F21 ($\text{C}_2\text{H}_5\text{OH}$) and carbon dioxide F19 using glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) is exemplified as below.

Alcoholic fermentation: $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$

5 [0050]

The fermentation mash F20 produced in the alcohol fermentation in the alcohol fermentation device 66 is separated into the alcohol F21 and the residue F22 by the solid-liquid separation device 67, and the residue
10 F22 becomes a raw material for the methane fermentation device 42. That is, the methane fermentation device 42 performs methane fermentation using the residue F22.

The alcohol F21 is concentrated by using a
15 distillation device or a dehydration device, which are not illustrated, and can be sold as an alcoholic beverage or the like which is a valuable substance.
[0051]

The carbon dioxide F19 discharged from the
20 alcohol fermentation device 66 does not contain nitrogen oxides and particulate matter unlike exhaust gases coming from combustion furnaces and internal combustion engines, through alcoholic fermentation, but is high-purity carbon dioxide F19 containing no
25 impurities, in other words, extremely clean carbon dioxide F19. Thus, the carbon dioxide F19 can be used directly as a raw material for the methanation device 46 of the methanation system 72 or as a raw material for photosynthesis of plants in the plant-growing
30 facility 48 without purification treatment or filtering treatment. The carbon dioxide F19 may be stored in the carbon dioxide storage tank 49.

In the second modification, the carbon dioxide F19 generated from alcohol fermentation in the alcohol
35 fermentation device 66 may be stored in the carbon dioxide storage tank 49 or used as a raw material for the methanation device 46 or the plant-growing facility 48, and thus the amount of carbon dioxide F19

discharged to the outside of the combustion furnace-equipped plant can be significantly reduced.

Further, although most of the gas discharged from the alcohol fermentation device 66 is the carbon dioxide F19, the gas may contain a trace amount of impurities such as sulfur depending on the type of biomass. Therefore, in this case, the impurities may be removed by using an impurity gas removal device such as a desulfurization device, which is not illustrated.

[0052]

[B. Third Modification]

A hydrogen production system 1 according to the third modification will be described with reference to FIG. 5. The hydrogen production system 1 of the third modification differs from the hydrogen production system 1 of the example or the first modification in terms of the boiler-equipped combustion system 10' and the high-purity carbon dioxide generation system 40''.

Like the boiler-equipped combustion system 10, the boiler-equipped combustion system 10' is a system including at least a combustion furnace 68 and a boiler 20 that generates steam with heat from combustion in the combustion furnace 68. Although the boiler-equipped combustion system 10 includes the refuse incinerator 13 as an example of the combustion furnace 68, the combustion furnace 68 of the boiler-equipped combustion system 10' may not be the refuse incinerator 13. In a case that the gasification furnace 69 and the combustion furnace 68 are formed as a pair as will be described below, a fluidized bed furnace is generally used as the combustion furnace 68.

Similar to the high-purity carbon dioxide generation systems 40 and 40', the high-purity carbon dioxide generation system 40'' is a system that generates high-purity carbon dioxide without going through a particular concentration step. Although the

high-purity carbon dioxide generation systems 40 and 40' include the methane fermentation device 42 and the alcohol fermentation device 66 as an example, the high-purity carbon dioxide generation system 40'' includes at least the gasification furnace 69 that gasifies wood biomass as an example.

[0053]

The high-purity carbon dioxide generation system 40'' of FIG. 5 is configured in view of the fact that the gas gasified in the gasification furnace 69 (gasified gas) contains not only high-purity carbon dioxide but also a large amount of compositions that can be used as raw materials for methanation in the methanation device 46. Specifically, in a case that wood biomass is gasified in the gasification furnace 69, the components contained in the gasified gas include about 15% of CO₂, about 35% of H₂, about 40% of CO, and about 4% of CH₄. The remaining components include a trace amount of sulfur, or the like.

[0054]

First, woody biomass, for example, waste wood is introduced into the pretreatment device 41 and pulverized. Next, the waste wood pulverized in the pretreatment device 41 is introduced into the gasification furnace 69 and gasified in the gasification furnace 69. Since the gasified gas generated in the gasification furnace 69 contains tar, the gasified gas is supplied to a tar reforming device 70 to reform or remove the tar.

Then, the gasified gas from which the tar has been reformed or removed in the tar reforming device 70 is introduced into a desulfurization device 71. At this time, although not illustrated, other impurities may be removed by using an impurity gas removing device.

The gasified gas from which a trace amount of sulfur and impurities have been removed in the desulfurization device 71 or the like is supplied to

the methanation device 46 of the methanation system 72 as a raw material for methanation.

Further, the pyrolysis residue generated from the waste wood after the gasification gas is released in the gasification furnace 69 is burned in the combustion furnace 68 of the boiler-equipped combustion system 10'. In addition, the heat generated from the burning in the combustion furnace 68 heats the gasification furnace 69 to promote gasification in the gasification furnace 69.

In the third modification, since the gasified gas generated in the gasification furnace 69 is used as a raw material in the methanation device 46, the amount of carbon dioxide discharged from the gasification furnace 69 to the outside of the combustion furnace-equipped plant can be significantly reduced.

[0055]

The example, and the first, second, and third modifications of the present invention have been described above. The boiler-equipped combustion systems 10 and 10', the electrolysis systems 50 and 50', and the high-purity carbon dioxide generation systems 40, 40', and 40'' in the hydrogen production system 1 according to the example and each modification may be appropriately replaced or connected in parallel.

Reference Signs List

[0056]

- 1 Hydrogen production system
- 10, 10' Boiler-equipped combustion system
- 11 Platform
- 12 Refuse pit
- 13 Refuse incinerator
- 14 Ash extruder
- 15 Flue
- 16 Quench tower

- 17 Dust removal device (bag filter, electric dust collector, etc.)
- 18 Fly ash cleaning device
- 19 Stack
- 5 20 Boiler
- 21 Steam drum
- 22 Waste heat recovery unit (heat transfer tube, superheater tube, etc.)
- 23 Steam turbine
- 10 24 Power generator
- 25 Condenser
- 26 Deaerator
- 27 Water purifying device
- 28 Chemical adding device
- 15 29 Blow pipe
- 30 Wastewater treatment system
- 31 Organic wastewater treatment facility (biological treatment facility, etc.)
- 32 Inorganic wastewater treatment facility
- 20 40, 40', 40'' High-purity carbon dioxide generation system
- 41 Pretreatment device
- 42 Methane fermentation device
- 43 Dehydrator (trommel, etc.)
- 25 44 Conveyor
- 45 Carbon dioxide separation membrane
- 46 Methanation device
- 47 Methane gas utilization facility
- 48 Plant-growing facility
- 30 49 Carbon dioxide storage tank
- 50, 50' Electrolysis system
- 51 Water treatment device (biological treatment device)
- 52 Ion removal device
- 35 53 Water electrolysis device
- 54 Electrolysis device
- 60 Carbon dioxide separation device
- 61 Absorber

- 62 Heat exchanger
- 63 Desorber
- 64 Reheater
- 65 Alcohol fermentation system
- 5 66 Alcohol fermentation device
- 67 Solid-liquid separation device (screw press, belt press, etc.)
- 68 Combustion furnace
- 69 Gasification furnace
- 10 70 Tar reforming device
- 71 Desulfurization device
- 72 Methanation system
- F1 Boiler blowdown water
- F2 Separated water
- 15 F3 Concentrated water
- F4 Hydrogen
- F5 Oxygen
- F6 Methane (second methane, which is generated in the methane fermentation device 42 and separated in the carbon dioxide separation membrane 45)
- 20 F7 Carbon dioxide (generated in the methane fermentation device 42 and separated in the carbon dioxide separation membrane 45)
- F8 Biogas
- 25 F9 Fermentation residue
- F10 Filtrate (dehydrated in the dehydrator 43)
- F11 Filtrate (biologically treated in the water treatment device 51)
- F12 Methane (first methane, which is generated in the methanation device 46)
- 30 F13 Pure water (generated in the methanation device 46)
- F14 Recycled water
- F15 Pure water (generated in the water purifying device 27)
- 35 F16 Sodium hypochlorite solution (generated in the electrolysis device 54)

F17 Sodium hypochlorite solution (generated in the water electrolysis device 53)

F18 Carbon dioxide (separated in the carbon dioxide separation device 60)

5 F19 Carbon dioxide (separated in the alcohol fermentation device 66)

F20 Fermentation mash (generated in the alcohol fermentation device 66)

10 F21 Alcohol (separated in the solid-liquid separation device 67)

F22 Residue (separated in the solid-liquid separation device 67)

Claims

[Claim 1]

A hydrogen production system applicable to a combustion furnace-equipped plant, the hydrogen production system comprising:

- a boiler-equipped combustion system including at least

- a combustion furnace, and

- a boiler configured to generate steam by utilizing heat from combustion in the combustion furnace;

- an electrolysis system including at least

- an ion removal device into which at least a part of boiler blowdown water discharged from the boiler is introduced, the ion removal device being configured to generate separated water in which unnecessary ions are removed and concentrated water containing the unnecessary ions, and

- a water electrolysis device configured to electrolyze the separated water to generate hydrogen; and

- a wastewater treatment system including at least an inorganic wastewater treatment facility configured to perform inorganic water treatment of plant wastewater generated in the combustion furnace-equipped plant, the plant wastewater containing remaining boiler blowdown water.

[Claim 2]

The hydrogen production system according to claim 1, further comprising:

- a high-purity carbon dioxide generation system configured to generate carbon dioxide with high purity through methane fermentation, alcohol fermentation, or gasification of wood biomass; and

- a methanation system configured to generate first methane and pure water through methanation by using the carbon dioxide and the hydrogen.

[Claim 3]

The hydrogen production system according to claim 2, wherein the hydrogen production system

supplies the first methane to a gas pipe introduction facility, a home, a business, or a factory that use methane as a city gas, or a gas engine that generates electric power by burning methane, or

supplies the carbon dioxide to a plant-growing facility in which plants grow with photosynthesis, or stores the carbon dioxide in a carbon dioxide storage tank.

[Claim 4]

The hydrogen production system according to claim 3, wherein

the high-purity carbon dioxide generation system includes

a methane fermentation device configured to generate a biogas including at least two kinds of the carbon dioxide and second methane and a fermentation residue through methane fermentation,

a carbon dioxide separation membrane configured to separate the carbon dioxide and the second methane in the biogas from each other, and

a dehydrator configured to dehydrate the fermentation residue to produce a filtrate,

the electrolysis system further includes a water treatment device configured to perform biological treatment of the filtrate,

the electrolysis system performs electrolysis by using the filtrate subjected to the biological treatment in the water electrolysis device or a different electrolysis device from the water electrolysis device to generate a sodium hypochlorite solution by using sodium ions and chloride ions included in the filtrate, and

the second methane is supplied to the gas pipe introduction facility, the home, the business, the factory, or the gas engine.

[Claim 5]

The hydrogen production system according to claim 4, wherein

the boiler-equipped combustion system further includes

a quench tower configured to cool down an exhaust gas generated in the combustion furnace,

a dust removal device configured to remove dust from the exhaust gas cooled in the quench tower, and

a carbon dioxide separation device configured to separate carbon dioxide contained in the exhaust gas whose dust has been removed by the dust removal device from the exhaust gas and to store the carbon dioxide in the carbon dioxide storage tank, and

the carbon dioxide separation device absorbs and desorbs the carbon dioxide included in the exhaust gas using an amine solution.

[Claim 6]

The hydrogen production system according to claim 5, wherein

the boiler-equipped combustion system further includes

a steam drum configured to store the steam,

a steam turbine configured so that its impeller rotates by the steam stored in the steam drum, and

a power generator configured to generate electric power by the rotation, and

the generated electric power is supplied to the water electrolysis device, the different electrolysis device, or the methanation system, or

waste steam generated after rotating the impeller is supplied to the methanation system or the carbon dioxide separation device, or

the pure water is supplied to the steam drum.

[Claim 7]

The hydrogen production system according to any one of claims 1 to 6, wherein

the combustion furnace-equipped plant is any one of a refuse incineration plant, a thermal power plant, or a chemical plant.