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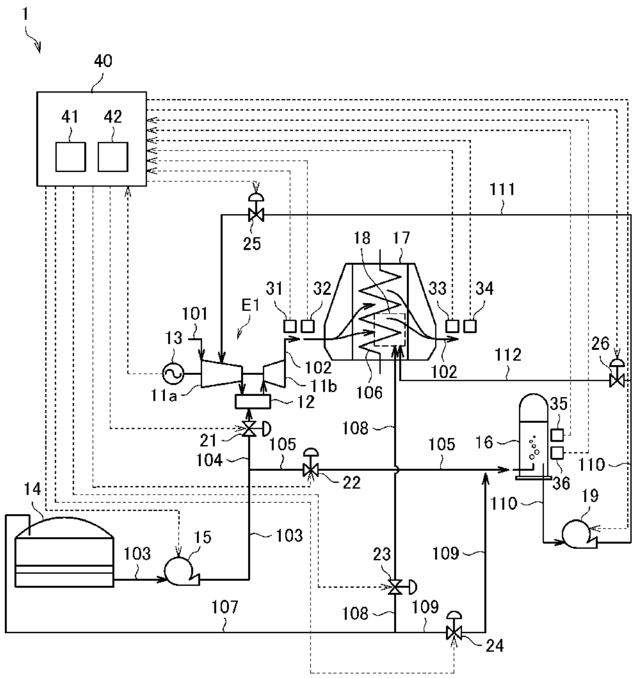
(54) **Title:** COMBUSTION SYSTEM

(54) 発明の名称： 燃焼システム

［図1］



(57) **Abstract:** A combustion system 1 comprises an ammonia tank 14, a combustor 12 connected to the ammonia tank 14, an intake flow path 101 connected to the combustor 12, a compressor 11a provided in the intake flow path 101, an ammonia recovery tub 16 connected to the ammonia tank 14, and a first flow path (flow paths 110, 111) connecting the ammonia recovery tub 16 and the compressor 11a.

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— 国際調査報告（条約第21条(3)）

(57) 要約：燃焼システム１は、アンモニアタンク１４と、アンモニアタンク１４と接続される燃焼器１２と、燃焼器１２と接続される吸気流路１０１と、吸気流路１０１に設けられる圧縮機１１ａと、アンモニアタンク１４と接続されるアンモニア回収槽１６と、アンモニア回収槽１６と圧縮機１１ａとを接続する第１流路（流路１１０、１１１）と、を備える。

Description

Title: COMBUSTION SYSTEM

Technical Field

[0001] The present disclosure relates to a combustion system. This application claims the benefit of priority to Japanese Patent Application No. 2022-049706 filed on March 25, 2022, and contents thereof are incorporated herein.

Background Art

[0002] A combustion system such as a gas turbine system that combusts fuel to obtain power has been used. As the combustion system such as the gas turbine system, for example, there exists a combustion system that uses ammonia as fuel, as disclosed in Patent Literature 1. Emission of carbon dioxide is suppressed by using ammonia as fuel.

Citation List

Patent Literature

[0003] Patent Literature 1: JP 2016-191507 A

Summary

Technical Problem

[0004] In the combustion system, a purge operation for discharging fuel from a pipe is performed so that the fuel does not remain in the pipe when the system is stopped. Ammonia has a property of being less combustible than other hydrocarbon fuels and the like. Thus, in the combustion system using ammonia as fuel, for example, when ammonia is to be disposed of through the purge operation, a disposal method of dissolving ammonia in water stored in an ammonia collection tank and disposing of the dissolved ammonia as an industrial waste is employed. Simple disposal of ammonia, which can be used as fuel, may result in a waste of costs and energy. Thus, it is desired that the amount of disposal of ammonia be reduced.

[0005] An object of the present disclosure is to provide a combustion system that enables a reduction in the amount of disposal of ammonia.

Solution to Problem

[0006] In order to achieve the above-mentioned object, according to the present disclosure, there is provided a combustion system, including: an ammonia tank; a combustor connected to the ammonia tank; an intake flow passage connected to the combustor; a compressor provided in the intake flow passage; an ammonia collection tank connected to the ammonia tank; and a first flow passage that connects the ammonia collection tank and the compressor to each other.

[0007] The combustion system may further include: an engine including the combustor; and a first control unit configured to control a supply amount of ammonia sent from the ammonia tank to the combustor and a supply amount of ammonia water that is sent from the ammonia collection tank to the compressor via the first flow passage so that an output from the engine becomes equal to a set value.

[0008] The first control unit may be configured to limit the supply amount of the ammonia water that is sent from the ammonia collection tank to the compressor via the first flow passage to a first upper limit value or less.

[0009] The combustion system may further include: an exhaust flow passage connected to the combustor; a denitration device provided in the exhaust flow passage; and a second flow passage that connects the ammonia collection tank and the denitration device to each other.

[0010] The denitration device is connected to the ammonia tank, and the combustion system may further include a second control unit configured to control a supply amount of ammonia sent from the ammonia tank to the denitration device and a supply amount of ammonia water that is sent from the ammonia collection tank to the denitration device via the second flow passage based on a nitrogen-oxide concentration in an exhaust gas discharged from the denitration device.

[0011] The second control unit may be configured to limit the supply amount of the ammonia water that is sent from the ammonia collection tank to the denitration device via the second flow passage to a second upper limit value or less.

Advantageous Effects of Invention

[0012] According to the present disclosure, it is possible to reduce the amount of disposal of ammonia.

Brief Description of Drawings

[0013] FIG. 1 is a schematic view for illustrating a configuration of a combustion system according to an embodiment of the present disclosure.

FIG. 2 is a flowchart for illustrating one example of an overall flow of processing performed by a controller in the embodiment of the present disclosure.

FIG. 3 is a flowchart for illustrating one example of a flow of a water supply process to an ammonia collection tank, which is performed by the controller in the embodiment of the present disclosure.

FIG. 4 is a flowchart for illustrating one example of a flow of an ammonia-water supply process to a compressor, which is performed by the controller in the embodiment of the present disclosure.

FIG. 5 is a flowchart for illustrating one example of a flow of an ammonia-water supply process to a denitration device, which is performed by the controller in the embodiment of the present disclosure.

Description of Embodiments

[0014] Now, with reference to the attached drawings, an embodiment of the present disclosure is described. The dimensions, materials, and other specific numerical values represented in the embodiment are merely examples used for facilitating the understanding of the disclosure, and do not limit the present disclosure otherwise particularly noted. Elements having substantially the same functions and configurations herein and in the drawings are denoted by the same reference symbols to omit redundant description thereof. Further, illustration of elements with no direct relationship to the present disclosure is omitted.

[0015] FIG. 1 is a schematic view for illustrating a configuration of a combustion system 1 according to this embodiment. The combustion system 1 is a gas turbine system corresponding to one example of a combustion system that generates energy by combusting fuel. As illustrated in FIG. 1, the combustion system 1 includes a compressor 11a, a turbine 11b, a combustor 12, a power generator 13, an ammonia tank 14, a pump 15, an ammonia collection tank 16, a boiler 17, a denitration device 18, a pump 19, flow rate control valves 21, 22, 23, 24, 25, and 26, an ammonia concentration sensor 31, a nitrogen-oxide concentration sensor 32, an ammonia concentration sensor 33, a nitrogen-oxide concentration sensor 34, an ammonia concentration sensor 35, a water-level sensor 36, and a controller 40. Further, the combustion system 1 includes an engine E1 includes the compressor 11a, the turbine 11b, and the combustor 12. The engine E1 is a gas turbine engine.

[0016] The compressor 11a and the turbine 11b rotate integrally. The compressor 11a and the turbine 11b are coupled to each other through intermediation of a shaft.

[0017] The compressor 11a is provided in an intake flow passage 101 connected to the combustor 12. Air to be supplied to the combustor 12 flows through the intake flow passage 101. An intake port (not shown) is formed at an upstream-side end portion of the intake flow passage 101. The intake port allows air to be introduced from an outside. The air introduced through the intake port passes through the compressor 11a and is sent to the combustor 12. The compressor 11a compresses the air and discharges the compressed air to a downstream side.

[0018] The turbine 11b is provided in an exhaust flow passage 102 connected to the combustor 12. An exhaust gas discharged from the combustor 12 flows through the exhaust flow passage 102. The exhaust gas discharged from the combustor 12 passes through the turbine 11b and is sent to a downstream side of the exhaust flow passage 102 from the turbine 11b. When the turbine 11b is rotated by the exhaust gas, rotational power is generated.

[0019] The power generator 13 is connected to the compressor 11a. The rotational power that has been transmitted from the turbine 11b to the compressor 11a is used by the power generator 13 for power generation.

[0020] The air, which has been compressed by the compressor 11a, is supplied to the combustor 12 through the intake flow passage 101, while ammonia is supplied in a liquid state as fuel from the ammonia tank 14 to the combustor 12. However, ammonia may be supplied in a gaseous state from the ammonia tank 14 to the combustor 12 as described later. Combustion is performed in the combustor 12 with use of ammonia as fuel. The exhaust gas generated in the combustor 12 is discharged to the exhaust flow passage 102.

[0021] Ammonia is stored in a liquid state in the ammonia tank 14. In the ammonia tank 14, ammonia is maintained in a liquid state at, for example, an atmospheric pressure and -33°C. The storage of ammonia in a low-temperature liquid state in the ammonia tank 14 suppresses an increase in vapor pressure in the ammonia tank 14. Thus, the occurrence of problems in tank strength and in structure is suppressed.

[0022] The ammonia tank 14 is connected to a flow passage 103. More specifically, the flow passage 103 communicates with an area inside the ammonia tank 14, in which liquid ammonia is stored. Liquid ammonia flows through the flow passage 103. The pump 15 is provided in the flow passage 103. The pump 15 pressurizes the liquid ammonia supplied from the ammonia tank 14 and feeds the pressurized liquid ammonia to a downstream side. The flow passage 103 branches into a flow passage 104 and a flow passage 105 at a position on a downstream side of the pump 15.

[0023] The flow passage 104 is connected to the combustor 12. In this manner, the ammonia tank 14 is connected to the combustor 12 through intermediation of the flow passage 103 and the flow passage 104. Thus, ammonia can be supplied from the ammonia tank 14 to the combustor 12 via the flow passage 103 and the flow passage 104. The flow rate control valve 21 is provided in the flow passage 104. The flow rate control valve 21 adjusts a flow rate of ammonia that is sent to the combustor 12 through the flow passage 104. More specifically, when an opening degree of the flow rate control valve 21 is adjusted, a supply amount of ammonia to the combustor 12 is adjusted.

[0024] The flow passage 105 is connected to the ammonia collection tank 16. In this manner, the ammonia tank 14 is connected to the ammonia collection tank 16 through intermediation of the flow passage 103 and the flow passage 105. Thus, ammonia can be supplied from the ammonia tank 14 to the ammonia collection tank 16 via the flow passage 103 and the flow passage 105. The flow rate control valve 22 is provided in the flow passage 105. The flow passage control valve 22 adjusts a flow rate of ammonia that is sent to the ammonia collection tank 16 through the flow passage 105. More specifically, when an opening degree of the flow rate control valve 22 is adjusted, a supply amount of ammonia to the ammonia collection tank 16 is adjusted.

[0025] Water is supplied to the ammonia collection tank 16. The ammonia that has been sent to the ammonia collection tank 16 is dissolved in the water in the ammonia collection tank 16. Thus, ammonia water is stored in the ammonia collection tank 16. A purge operation of opening the flow rate control valve 22 is performed, for example, when the combustion system 1 is stopped. As a result of the purge operation, ammonia remaining in the flow passages 103, 104, and 105 is sent to the ammonia collection tank 16. Thus, residual ammonia remaining in the flow passages 103, 104, and 105 is suppressed.

[0026] The boiler 17 is provided on a downstream side of the turbine 11b in the exhaust flow passage 102. The boiler 17 includes a flow passage 106 through which water flows. The water flowing through the flow passage 106 is heated with the exhaust gas flowing through the exhaust flow passage 102 and is thereby vaporized into gas (that is, steam). The flow passage 106 of the boiler 17 is connected to a steam turbine (not shown). The steam generated in the boiler 17 is sent to the steam turbine. Then, the steam turbine is rotated by the steam to thereby generate rotational power. The rotational power generated by the stream turbine is used for power generation.

[0027] The denitration device 18 is provided in the exhaust flow passage 102 and located inside the boiler 17. In FIG. 1, the denitration device 18 is schematically represented by a rectangle in broken line. However, the rectangle does not represent a precise arrangement of the denitration device 18 inside the boiler 17. The arrangement of the denitration device 18 inside the boiler 17 may be suitably determined. However, the denitration device 18 is only required to be provided in the exhaust flow passage 102, and may be provided outside the boiler 17. Ammonia is supplied to the denitration device 18 as described later. The denitration device 18 causes nitrogen oxides (NOx) contained in the exhaust gas flowing through the exhaust flow passage 102 to react with ammonia and decomposes the nitrogen oxides into nitrogen and water. This reaction is also referred to as "denitration reaction".

[0028] The ammonia tank 14 is connected to a flow passage 107. More specifically, the flow passage 107 communicates with an area inside the ammonia tank 14, in which vaporized gaseous ammonia is stored. The gaseous ammonia flows through the flow passage 107. The flow passage 107 branches into a flow passage 108 and a flow passage 109.

[0029] The flow passage 108 is connected to the denitration device 18. In this manner, the ammonia tank 14 is connected to the denitration device 18 through intermediation of the flow passage 107 and the flow passage 108. Thus, an ammonia gas, which is gaseous ammonia, can be supplied from the ammonia tank 14 to the denitration device 18 via the flow passage 107 and the flow passage 108. The flow rate control valve 23 is provided in the flow passage 108. The flow rate control valve 23 adjusts a flow rate of ammonia that is sent to the denitration device 18 through the flow passage 108. More specifically, when an opening degree of the flow rate control valve 23 is adjusted, a supply amount of ammonia to the denitration device 18 is adjusted.

[0030] The flow passage 109 is connected to the flow passage 105. Specifically, the ammonia tank 14 is connected to the ammonia collection tank 16 through intermediation of the flow passage 107, the flow passage 109, and the flow passage 105. Thus, ammonia can be supplied from the ammonia tank 14 to the ammonia collection tank 16 via the flow passage 107, the flow passage 109, and the flow passage 105. The flow rate control valve 24 is provided in the flow passage 109. The flow rate control valve 24 adjusts a flow rate of ammonia that is sent to the ammonia collection tank 16 through the flow passage 109. More specifically, when an opening degree of the flow rate control valve 24 is adjusted, a supply amount of ammonia to the ammonia collection tank 16 is adjusted.

[0031] A purge operation of opening the flow rate control valve 24 is performed, for example, when the combustion system 1 is stopped. As a result of the purge operation, ammonia remaining in the flow passages 107, 108, and 109 is sent to the ammonia collection tank 16. Thus, residual ammonia remaining in the flow passages 107, 108, and 109 is suppressed.

[0032] In the combustion system 1, the ammonia collection tank 16 is connected to a flow passage 110. More specifically, the flow passage 110 communicates with an area inside the ammonia collection tank 16, in which ammonia water is stored. The ammonia water flows through the flow passage 110. The pump 19 is provided in the flow passage 110. The pump 19 pressurizes the ammonia water supplied from the ammonia collection tank 16 and feeds the pressurized ammonia water to a downstream side. The flow passage 110 branches into a flow passage 111 and a flow passage 112 at a position on the downstream side of the pump 19.

[0033] The flow passage 111 is connected to the compressor 11a. In this manner, the ammonia collection tank 16 is connected to the compressor 11a through intermediation of the flow passage 110 and the flow passage 111. Thus, the ammonia water can be supplied from the ammonia collection tank 16 to the compressor 11a via the flow passage 110 and the flow passage 111. The compressor 11a is, for example, a multi-stage compressor. The flow passage 111 is connected to an intermediate stage of the compressor 11a. Thus, the ammonia water is supplied from the flow passage 111 to the intermediate stage of the compressor 11a. The flow passage 110 and the flow passage 111 correspond to one example of a first flow passage through which ammonia water flows. The flow rate control valve 25 is provided in the flow passage 111. The flow rate control valve 25 adjusts a flow rate of ammonia water that is sent to the compressor 11a through the flow passage 111. More specifically, when an opening degree of the flow rate control valve 25 is adjusted, a supply amount of ammonia water to the compressor 11a is adjusted.

[0034] The flow passage 112 is connected to the denitration device 18. In this manner, the ammonia collection tank 16 is connected to the denitration device 18 through intermediation of the flow passage 110 and the flow passage 112. Thus, the ammonia water can be supplied from the ammonia collection tank 16 to the denitration device 18 via the flow passage 110 and the flow passage 112. The flow passage 110 and the flow passage 112 correspond to one example of a second flow passage through which ammonia water flows. The flow rate control valve 26 is provided in the flow passage 112. The flow rate control valve 26 adjusts a flow rate of ammonia water that is sent to the denitration device 18 through the flow passage 112. More specifically, when an opening degree of the flow rate control valve 26 is adjusted, a supply amount of ammonia water to the denitration device 18 is adjusted.

[0035] The ammonia concentration sensor 31, the nitrogen-oxide concentration sensor 32, the ammonia concentration sensor 33, and the nitrogen-oxide concentration sensor 34 are provided in the exhaust flow passage 102. The ammonia concentration sensor 31 and the nitrogen-oxide concentration sensor 32 are provided on a downstream side of the turbine 11b and an upstream side of the denitration device 18 in the exhaust flow passage 102. The ammonia concentration sensor 31 detects an ammonia concentration in the exhaust gas flowing into the denitration device 18. The nitrogen-oxide concentration sensor 32 detects a nitrogen-oxide concentration in the exhaust gas flowing into the denitration device 18. The ammonia concentration sensor 33 and the nitrogen-oxide concentration sensor 34 are arranged on a downstream side of the denitration device 18 in the exhaust flow passage 102. The ammonia concentration sensor

33 detects an ammonia concentration in the exhaust gas discharged from the denitration device 18. The nitrogen-oxide concentration sensor 34 detects a nitrogen-oxide concentration in the exhaust gas discharged from the denitration device 18.

[0036] The ammonia concentration sensor 35 and the water-level sensor 36 are provided to the ammonia collection tank 16. The ammonia concentration sensor 35 detects an ammonia concentration of the ammonia water in the ammonia collection tank 16. The water-level sensor 36 detects a water level of the ammonia water in the ammonia collection tank 16.

[0037] The controller 40 includes, for example, a central processing unit (CPU), a ROM stores, for example, a program, and a RAM serves as a work area. The controller 40 controls operations of the devices in the combustion system 1. For example, the controller 40 controls operations of the flow rate control valves 21, 22, 23, 24, 25, and 26. Further, the controller 40 controls operations of the pumps 15 and 19. Further, the controller 40 acquires information from the power generator 13, the ammonia concentration sensor 31, the nitrogen-oxide concentration sensor 32, the ammonia concentration sensor 33, the nitrogen-oxide concentration sensor 34, the ammonia concentration sensor 35, and the water-level sensor 36.

[0038] The controller 40 includes a first control unit 41 and a second control unit 42. Functions of the first control unit 41 and the second control unit 42 are achieved by, for example, the central processing unit and the ROM.

[0039] The first control unit 41 controls a supply amount of ammonia sent from the ammonia tank 14 to the combustor 12 and a supply amount of ammonia water sent from the ammonia collection tank 16 to the compressor 11a via the flow passages 110 and 111 corresponding to the first flow passage. More specifically, the first control unit 41 controls each of the above-mentioned two supply amounts by controlling each of the operations of the flow rate control valve 21 and the flow rate control valve 25.

[0040] The second control unit 42 controls a supply amount of ammonia sent from the ammonia tank 14 to the denitration device 18 and a supply amount of ammonia water sent from the ammonia collection tank 16 to the denitration device 18 via the flow passages 110 and 112 corresponding to the second flow passage. More specifically, the second control unit 42 controls each of the above-mentioned two supply amounts by controlling each of the operations of the flow rate control valve 23 and the flow rate control valve 26.

[0041] The controller 40 may be one device or may be a plurality of separate devices. Specifically, functions of the controller 40 may be achieved by one device or by a plurality of separate devices. Details of processing performed by the controller 40 are described later.

[0042] As described above, in the combustion system 1, the ammonia collection tank 16 and the compressor 11a are connected to each other by the flow passages 110 and 111, which correspond to the first flow passage. In this manner, the ammonia water stored in the ammonia collection tank 16 can be sent to the compressor 11a. Air passing through the compressor 11a is cooled with the ammonia water that has been sent to the compressor 11a. Then, ammonia contained in the ammonia water that has been sent to the compressor 11a is supplied to the combustor 12 as fuel. As a result, the amount of ammonia water stored in the ammonia collection tank 16, which is to be disposed of as an industrial waste, is reduced. Further, the ammonia water stored in the ammonia collection tank 16 is effectively used as fuel for the combustor 12 without being disposed of. Thus, efficiency of the combustion system 1 is also improved.

[0043] Further, as described above, in the combustion system 1, the air passing through the compressor 11a is cooled with the ammonia water that has been sent to the compressor 11a. As a result, a temperature of compressed air in the compressor 11a is decreased to reduce power for driving the compressor 11a, resulting in an increased output from the compressor 11a. Thus, the efficiency of the combustion system 1 is effectively improved.

[0044] The intake flow passage 101 and the exhaust flow passage 102 may be connected by a bypass flow passage that bypasses the combustor 12 in some cases. In this case, a part of air containing ammonia fed from the compressor 11a is sent to the turbine 11b via the bypass flow passage so as to be used to cool the turbine 11b. In this case, the ammonia contained in the air that bypasses the combustor 12 is sent to the denitration device 18 and is used for a denitration reaction in the denitration device 18. Thus, the ammonia is not released into the atmosphere.

[0045] Further, in the combustion system 1, the ammonia collection tank 16 and the denitration device 18 are connected to each other through intermediation of the flow passages 110 and 112, which correspond to the second flow passage. In this manner, the ammonia water stored in the ammonia collection tank 16 can be sent to the denitration device 18. The ammonia contained in the ammonia water that has been sent to the denitration device 18 is used for a denitration reaction in the denitration device 18. As a result, disposal of the ammonia water stored in the ammonia collection tank 16 as an industrial waste is further suppressed to thereby further reduce the amount of disposal of ammonia. Further, the ammonia water stored in the ammonia collection tank 16 is effectively used for a denitration reaction in the denitration device 18 without being disposed of. Thus, the efficiency of the combustion system 1 is also improved. However, the second flow passage may be omitted from the combustion system 1.

[0046] Now, an operation of the combustion system 1 according to this embodiment is described with reference to FIG. 2 to FIG. 5.

[0047] FIG. 2 is a flowchart for illustrating one example of an overall flow of processing performed by the controller 40. After a processing flow illustrated in FIG. 2 is started, the controller 40 determines, in Step S101, whether or not a water level in the ammonia collection tank 16 is equal to or lower than a lower limit value. The lower limit value used in Step S101 is an index for determining whether or not a water quantity in the ammonia collection tank 16 is less than a quantity that is required for recovery of ammonia. When the water level in the ammonia collection tank 16 is equal to or lower than the lower limit value, the water quantity in the ammonia collection tank 16 is less than the quantity that is required for recovery of ammonia.

[0048] When it is determined that the water level in the ammonia collection tank 16 is equal to or lower than the lower limit value (Step S101/YES), the processing proceeds to Step S102. After the controller 40 executes a water supply process to the ammonia collection tank 16 in Step S102, the processing returns to Step S101. The water supply process to the ammonia collection tank 16 is a process of supplying water to the ammonia collection tank 16. Details of the water supply process to the ammonia collection tank 16 are described with reference to FIG. 3. Meanwhile, when it is determined that the water level in the ammonia collection tank 16 is higher than the lower limit value (Step S101/NO), the processing proceeds to Step S103.

[0049] In Step S103, the controller 40 determines whether or not an ammonia concentration in the ammonia collection tank 16 (more specifically, an ammonia concentration in the ammonia water) is equal to or lower than a threshold value. The threshold value used in Step S103 is an index for determining whether or not the ammonia water in the ammonia collection tank 16 has such an ammonia concentration that allows the ammonia water to be used for combustion in the combustor 12 or for a denitration reaction in the denitration device 18. When the ammonia concentration in the ammonia collection tank 16 is equal to or lower than the threshold value, the ammonia water in the ammonia collection tank 16 does not have such an ammonia concentration that allows the ammonia water to be used for combustion in the combustor 12 or for a denitration reaction in the denitration device 18.

[0050] When it is determined that the ammonia concentration in the ammonia collection tank 16 is equal to or lower than the threshold value (Step S103/YES), the processing proceeds to Step S106 described later. Meanwhile, when it is determined that the ammonia concentration in the ammonia collection tank 16 is higher than the threshold value (Step S103/NO), the processing proceeds to Step S104.

[0051] In Step S104, the controller 40 determines whether or not an inhibiting condition for inhibiting the supply of ammonia water to the compressor 11a is satisfied. Examples of the inhibiting condition in Step S104 include an extremely low rpm of the compressor 11a. With the use of the inhibiting condition described above, unstable combustion, which may be caused by the supply of ammonia water to the compressor 12 under a state in which the combustion in the combustor 12 is not stable, is suppressed. Further, examples of the inhibiting condition in Step S104 include the ammonia concentration detected by the ammonia concentration sensor 31 being higher than the nitrogen-oxide concentration detected by the nitrogen-oxide concentration sensor 32 (specifically, a higher ammonia concentration in the exhaust gas that has been discharged from the combustor 12 and flows into the denitration device 18 than the nitrogen-oxide concentration). With use of the inhibiting condition described above, an increase in unburned ammonia is suppressed.

[0052] When it is determined that the inhibiting condition for inhibiting the supply of ammonia water to the compressor 11a is satisfied (Step S104/YES), the processing proceeds to Step S106 described later. Meanwhile, when it is determined that the inhibiting condition for inhibiting the supply of ammonia water to the compressor 11a is not satisfied (Step S104/NO), the processing proceeds to Step S105.

[0053] In Step S105, the first control unit 41 of the controller 40 executes an ammonia-water supply process to the compressor 11a. The ammonia-water supply process to the compressor 11a is a process of supplying ammonia water from the ammonia collection tank 16 to the compressor 11a. Details of the ammonia-water supply process to the compressor

11a are described later with reference to FIG. 4.

[0054] Subsequently to Step S105, in Step S106, the controller 40 determines whether or not an inhibiting condition for inhibiting the supply of ammonia water to the denitration device 18 is satisfied. Examples of the inhibiting condition in Step S106 include the ammonia concentration detected by the ammonia concentration sensor 33 being higher than a nitrogen-oxide concentration detected by the nitrogen-oxide concentration sensor 34 (specifically, a higher ammonia concentration in the exhaust gas discharged from the denitration device 18 than the nitrogen-oxide concentration). With use of the inhibiting condition described above, an increase in unburned ammonia is suppressed.

[0055] When it is determined that the inhibiting condition for inhibiting the supply of ammonia water to the denitration device 18 is satisfied (Step S106/YES), the processing returns to Step S101. Meanwhile, when it is determined that the inhibiting condition for inhibiting the supply of ammonia water to the denitration device 18 is not satisfied (Step S106/NO), the processing proceeds to Step S107.

[0056] In Step S107, the controller 40 determines whether or not a NOx discharge concentration is equal to or higher than an upper limit value. The NOx discharge concentration is a concentration of nitrogen oxides discharged from the combustion system 1. Specifically, the nitrogen-oxide concentration detected by the nitrogen-oxide concentration sensor 34 corresponds to the NOx discharge concentration. The upper limit value used in Step S107 is an index for determining whether or not a discharge amount of nitrogen oxides from the combustion system 1 is excessively large in terms of environmental deterioration. When the NOx discharge concentration is equal to or higher than the upper limit value, the discharge amount of nitrogen oxides from the combustion system 1 is excessively large in terms of environmental deterioration.

[0057] When it is determined that the NOx discharge concentration is lower than the upper limit value (Step S107/NO), the processing returns to Step S101. Meanwhile, when it is determined that the NOx discharge concentration is equal or higher than the upper limit value (Step S107/YES), the processing proceeds to Step S108. After the second control unit 42 of the controller 40 executes the ammonia-water supply process to the denitration device 18 in Step S108, the processing returns to Step S101. The ammonia-water supply process to the denitration device 18 is a process of supplying ammonia water from the ammonia collection tank 16 to the denitration device 18. Details of the ammonia-water supply process to the denitration device 18 are described later with reference to FIG. 5.

[0058] FIG. 3 is a flowchart for illustrating one example of a flow of the water supply process to the ammonia collection tank 16, which is performed by the controller 40.

A processing flow illustrated in FIG. 3 is executed in Step S102 in the flowchart of FIG. 2.

[0059] After the processing flow illustrated in FIG. 3 is started, the controller 40 starts water supply to the ammonia collection tank 16 in Step S201.

[0060] Subsequently to Step S201, in Step S202, the controller 40 determines whether or not the water level in the ammonia collection tank 16 is equal to or higher than an upper limit value. The upper limit value used in Step S202 can be suitably set in accordance with, for example, a volume of the ammonia collection tank 16.

[0061] When it is determined that the water level in the ammonia collection tank 16 is lower than the upper limit value (Step S202/NO), Step S202 is repeated. Meanwhile, when it is determined that the water level in the ammonia collection tank 16 is equal to or higher than the upper limit value (Step S202/YES), the processing proceeds to Step S203. In Step S203, the controller 40 stops the water supply to the ammonia collection tank 16. Then, the processing flow illustrated in FIG. 3 ends. In general, a lower-limit switch and an upper-limit switch are used. The lower-limit switch and the upper-limit switch detect that the water level in the ammonia collection tank 16 has reached the lower limit value and the upper limit value, respectively. With use of those switches, a make-up tank for supplying water to the ammonia collection tank 16 controls the water level in the ammonia collection tank 16 so that the water level falls within a range between the lower limit value and the upper limit value.

[0062] FIG. 4 is a flowchart for illustrating one example of a flow of the ammonia-water supply process to the compressor 11a, which is performed by the controller 40 (specifically, by the first control unit 41). A processing flow illustrated in FIG. 4 is executed in Step S105 in the flowchart of FIG. 2.

[0063] After the processing flow illustrated in FIG. 4 is started, the first control unit 41 determines, in Step S301, whether or not the supply amount of ammonia water to the compressor 11a is less than an upper limit value. The upper limit value used in Step S301 is an index for determining whether or not the supply amount of ammonia water to the compressor 11a is so large that a misfire may be caused in the combustor 12. When the supply amount of ammonia water to the compressor 11a is larger than the upper limit value, the supply amount of ammonia water to the compressor 11a is so large that a misfire may be caused in the combustor 12.

[0064] When it is determined that the supply amount of ammonia water to the compressor 11a is less than the upper limit value (Step S301/YES), the processing proceeds to Step S302. After the first control unit 41 increases the supply amount of ammonia water from the ammonia collection tank 16 to the compressor 11a in Step S302, the processing proceeds to Step S304. Meanwhile, when it is determined that the supply amount of ammonia water to the compressor 11a is equal to or larger than the upper limit value (Step S301/NO), the processing proceeds to Step S303. After the first control unit 41 decreases the supply amount of ammonia water from the ammonia collection tank 16 to the compressor 11a in Step S303, the processing proceeds to Step S304.

[0065] In Step S304, the first control unit 41 determines whether or not an output from the engine E1 is lower than a set value. The set value used in Step S304 is determined in accordance with, for example, a request value for an amount of power to be generated by the power generator 13.

[0066] When it is determined that the output from the engine E1 is lower than the set value (Step S304/YES), the processing proceeds to Step S305. After the first control unit 41 increases the supply amount of ammonia from the ammonia tank 14 to the combustor 12 in Step S305, the processing flow illustrated in FIG. 4 ends. Meanwhile, when it is determined that the output from the engine E1 is equal to or higher than the set value (Step S304/NO), the processing proceeds to Step S306.

[0067] In Step S306, the first control unit 41 determines whether or not an output from the engine E1 is higher than a set value. The set value used in Step S306 is the same as the set value used in Step S304.

[0068] When it is determined that the output from the engine E1 is higher than the set value (Step S306/YES), the processing proceeds to Step S307. After the first control unit 41 decreases the supply amount of ammonia from the ammonia tank 14 to the combustor 12 in Step S307, the processing flow illustrated in FIG. 4 ends. Meanwhile, when it is determined that the output from the engine E1 is equal to or lower than the set value (Step S306/NO), the processing flow illustrated in FIG. 4 ends.

[0069] Under a condition in which the processing flow illustrated in FIG. 4 is repeated, after the supply of ammonia water from the ammonia collection tank 16 to the compressor 11a is started, the supply amount of ammonia water from the ammonia collection tank 16 to the compressor 11a is increased or decreased so as to be maintained in the vicinity of the upper limit value (Step S302, S303). Then, the supply amount of ammonia from the ammonia tank 14 to the combustor 12 is increased or decreased in accordance with the output from the engine E1 (Step S305, S307). In this manner, the output from the engine E1 is controlled to be equal to the set value.

[0070] As described above, in the combustion system 1, the first control unit 41 controls the supply amount of ammonia sent from the ammonia tank 14 to the combustor 12 and the supply amount of ammonia water sent from the ammonia collection tank 16 to the compressor 11a via the first flow passage (the flow passages 110 and 111 in the example described above) so that the output from the engine E1 becomes equal to the set value. In this manner, the ammonia sent from the ammonia tank 14 to the combustor 12 is used as fuel, while the ammonia water stored in the ammonia collection tank 16 is effectively used as fuel for the combustor 12. As a result, the output from the engine E1 can be controlled to be equal to the set value. Thus, the output from the engine E1 can be appropriately controlled, while the amount of disposal of ammonia is reduced.

[0071] Further, in the combustion system 1, the first control unit 41 limits the supply amount of ammonia water that is sent from the ammonia collection tank 16 to the compressor 11a via the first flow passage (the flow passages 110 and 111 in the example described above) to a first upper limit value (the upper limit value used in Step S301 in the example described above) or lower. As a result, such an increase in the supply amount of ammonia water to the compressor 11a that may cause a misfire in the combustor 12 is suppressed. Thus, occurrence of a misfire in the combustor 12 is suppressed. The first upper limit value may be a fixed value or may be a value varying in accordance with various kinds of parameters. Examples of the above-mentioned parameters include an ammonia concentration of the ammonia water stored in the ammonia collection tank 16.

[0072] FIG. 5 is a flowchart for illustrating one example of a flow of the ammonia-water supply process to the denitration device 18, which is performed by the controller 40 (specifically, by the first control unit 41). A processing flow illustrated in FIG. 5 is executed in Step

S108 in the flowchart of FIG. 2.

[0073] After the processing flow illustrated in FIG. 5 is started, the second control unit 42 determines, in Step S401, whether or not the supply amount of ammonia water to the denitration device 18 is less than an upper limit value. The upper limit value used in Step S401 is an index for determining whether or not the supply amount of ammonia water to denitration device 18 is so large that a denitration reaction in the denitration device 18 is prevented from proceeding smoothly. When the supply amount of ammonia water to the denitration device 18 is larger than the upper limit value, the supply amount of ammonia water to the denitration device 18 is so large that prevents a denitration reaction in the denitration device 18 is prevented from proceeding smoothly.

[0074] When it is determined that the supply amount of ammonia water to the denitration device 18 is less than the upper limit value (Step S401/YES), the processing proceeds to Step S402. After the second control unit 42 increases the supply amount of ammonia water from the ammonia collection tank 16 to the denitration device 18 in Step S402, the processing flow illustrated in FIG. 5 ends. Meanwhile, when it is determined that the supply amount of ammonia water to the denitration device 18 is equal to or larger than the upper limit value (Step S401/NO), the processing proceeds to Step S403. After the second control unit 42 decreases the supply amount of ammonia water from the ammonia collection tank 16 to the denitration device 18 in Step S403, the processing proceeds to Step S404. After the second control unit 42 increases the supply amount of ammonia gas from the ammonia tank 14 to the denitration device 18 in Step S404, the processing flow illustrated in FIG. 5 ends.

[0075] The processing flow illustrated in FIG. 5 is repeated as long as it is determined, based on the nitrogen-oxide concentration in the exhaust gas discharged from the denitration device 18, that it is required that a discharge amount of nitrogen oxides from the combustion system 1 be reduced. More specifically, the processing flow illustrated in FIG. 5 is repeated while the NOx discharge concentration is being equal to or larger than the upper limit value. Under a condition in which the processing flow illustrated in FIG. 5 is repeated, after the supply of ammonia water from the ammonia collection tank 16 to the denitration device 18 is started, the supply amount of ammonia water from the ammonia collection tank 16 to the denitration device 18 is increased or decreased so as to be maintained in the vicinity of the upper limit value (Step S402, S403). Then, when the supply amount of ammonia water to the denitration device 18 is equal to or larger than the upper limit value, the supply amount of ammonia gas from the ammonia tank 14 to the denitration device 18 is increased (Step S404). As a result, the NOx discharge concentration becomes smaller than the upper limit value, and thus the discharge amount of nitrogen oxides from the combustion system 1 is appropriately suppressed.

[0076] As described above, in the combustion system 1, the second control unit 42 controls the supply amount of ammonia that is sent from the ammonia tank 14 to the denitration device 18 and the supply amount of ammonia water that is sent from the ammonia collection tank 16 to the denitration device 18 via the second flow passage (the flow passages 110 and 112 in the example described above) based on the nitrogen-oxide concentration in the exhaust gas discharged from the denitration device 18. As a result, the ammonia gas sent from the ammonia tank 14 to the denitration device 18 is used for a denitration reaction in the denitration device 18, while the ammonia water stored in the ammonia collection tank 16 is effectively used for the denitration reaction. As a result, the discharge amount of nitrogen oxides from the combustion system 1 can be appropriately reduced. Thus, the discharge amount of nitrogen oxides from the combustion system 1 can be appropriately reduced, while the amount of disposal of ammonia is reduced.

[0077] Further, in the combustion system 1, the second control unit 42 limits the supply amount of ammonia water that is sent from the ammonia collection tank 16 to the denitration device 18 via the second flow passage (the flow passages 110 and 112 in the example described above) to a second upper limit value (the upper limit value used in Step S401 in the example described above) or less. In this manner, such an increase in the supply amount of ammonia water to the denitration device 18 that prevents a denitration reaction in the denitration device 18 from proceeding smoothly is suppressed. Thus, the prevention of smooth proceeding of a denitration reaction in the denitration device 18 is suppressed. The second upper limit value may be a fixed value or may be a value varying in accordance with various kinds of parameters. Examples of the above-mentioned parameters include the ammonia concentration of the ammonia water stored in the ammonia collection tank 16 and exhaust-gas temperature data that is necessary to cause a denitration reaction.

[0078] The embodiment of the present disclosure has been described above with reference to the attached drawings, but, needless to say, the present disclosure is not limited to the above-mentioned embodiment. It is apparent that those skilled in the art may arrive at various alternations and modifications within the scope of claims, and those examples are construed as naturally falling within the technical scope of the present disclosure.

[0079] An example of the processing performed by the controller 40 has been described with reference to FIG. 2 to FIG. 5. However, the processing performed by the controller 40 is not limited to the example described above. For example, the processing described above with reference to the flowcharts is not always required to be executed in the order illustrated in the flowcharts. Some of the processing steps may be executed in parallel. Further, an additional processing step may be used, or a part of the processing steps may be omitted.

[0080] There has been described above an example in which the engine E1 including the combustor 12 is a gas turbine engine. However, the engine E1 including the combustor 12 is not limited to a gas turbine engine. For example, the engine E1 including the combustor 12 may be a reciprocating engine with a turbocharger. In this case, a compressor of the turbocharger and the ammonia collection tank 16 are connected to each other through intermediation of the first flow passage, and the same effects as those of the example described above are obtained.

[0081] There has been described above an example in which the rotational power transmitted from the turbine 11b to the compressor 11a is used as energy for driving the power generator 13 in the combustion system 1. However, the rotational power transmitted from the turbine 11b to the compressor 11a in the combustion system 1 may be used for other purposes of use, for example, in order to drive a movable object such as a ship.

[0082] There have been described above examples in which ammonia is supplied in a liquid state from the ammonia tank 14 to the combustor 12. However, ammonia may be supplied in a gaseous state from the ammonia tank 14 to the combustor 12. In this case, a vaporizer is provided in the flow passage 103 or the flow passage 104, and ammonia is vaporized by the vaporizer.

[0083] There has been described above an example in which ammonia is sent in a gaseous state from the ammonia tank 14 to the flow passage 107. However, ammonia may be sent in a liquid state from the ammonia tank 14 to the flow passage 107, and the ammonia may be vaporized in the flow passage 107, the flow passage 108, or the flow passage 109.

[0084] The present disclosure contributes to the improvement of efficiency of the gas turbine system or the like. Thus, the present disclosure can contribute to, for example, achievement of Goal 7 "ensure access to affordable, reliable, sustainable and modern energy" of the sustainable development goals (SGDs).

Reference Signs List

[0085] 1: combustion system, 11a: compressor, 12: combustor, 14: ammonia tank, 16: ammonia collection tank, 18: denitration device, 41: first control unit, 42: second control unit, 101: intake flow passage, 102: exhaust flow passage, 110: flow passage (first flow passage, second flow passage) , 111: flow passage (first flow passage) , 112: flow passage (second flow passage) , E1: engine

Claims

1. A combustion system, comprising:

an ammonia tank;

a combustor connected to the ammonia tank;

an intake flow passage connected to the combustor;

a compressor provided in the intake flow passage;

an ammonia collection tank connected to the ammonia tank; and

a first flow passage that connects the ammonia collection tank and the compressor to each other.

2. The combustion system according to claim 1, further comprising:

an engine including the combustor; and

a first control unit configured to control a supply amount of ammonia sent from the ammonia tank to the combustor and a supply amount of ammonia water that is sent from the ammonia collection tank to the compressor via the first flow passage so that an output from the engine becomes equal to a set value.

3. The combustion system according to claim 2, wherein the first control unit is configured to limit the supply amount of the ammonia water that is sent from the ammonia collection tank to the compressor via the first flow passage to a first upper limit value or less.

4. The combustion system according to any one of claims 1 to 3, further comprising:

an exhaust flow passage connected to the combustor;

a denitration device provided in the exhaust flow passage; and

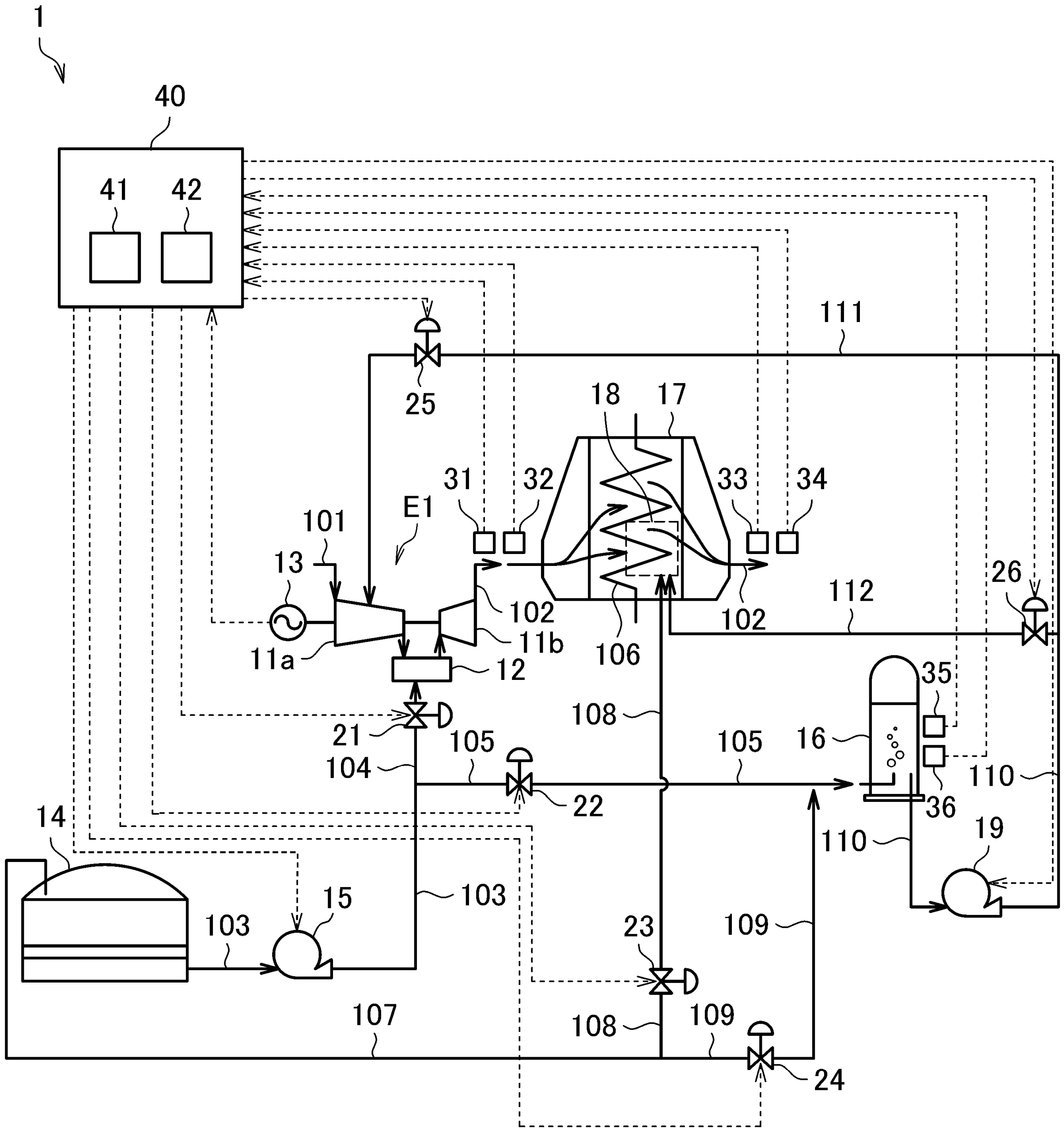
a second flow passage that connects the ammonia collection tank and the denitration device to each other.

5. The combustion system according to claim 4,

wherein the denitration device is connected to the ammonia tank, and

wherein the combustion system further comprises a second control unit configured to control a supply amount of ammonia sent from the ammonia tank to the denitration device and a supply amount of ammonia water that is sent from the ammonia collection tank to the denitration device via the second flow passage based on a nitrogen-oxide concentration in an exhaust gas discharged from the denitration device.

6. The combustion system according to claim 5, wherein the second control unit is configured to limit the supply amount of the ammonia water that is sent from the ammonia collection tank to the denitration device via the second flow passage to a second upper limit value or less.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111
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18
17
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32
33
34
E1
101
13
102
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11b
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112
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FIG. 1

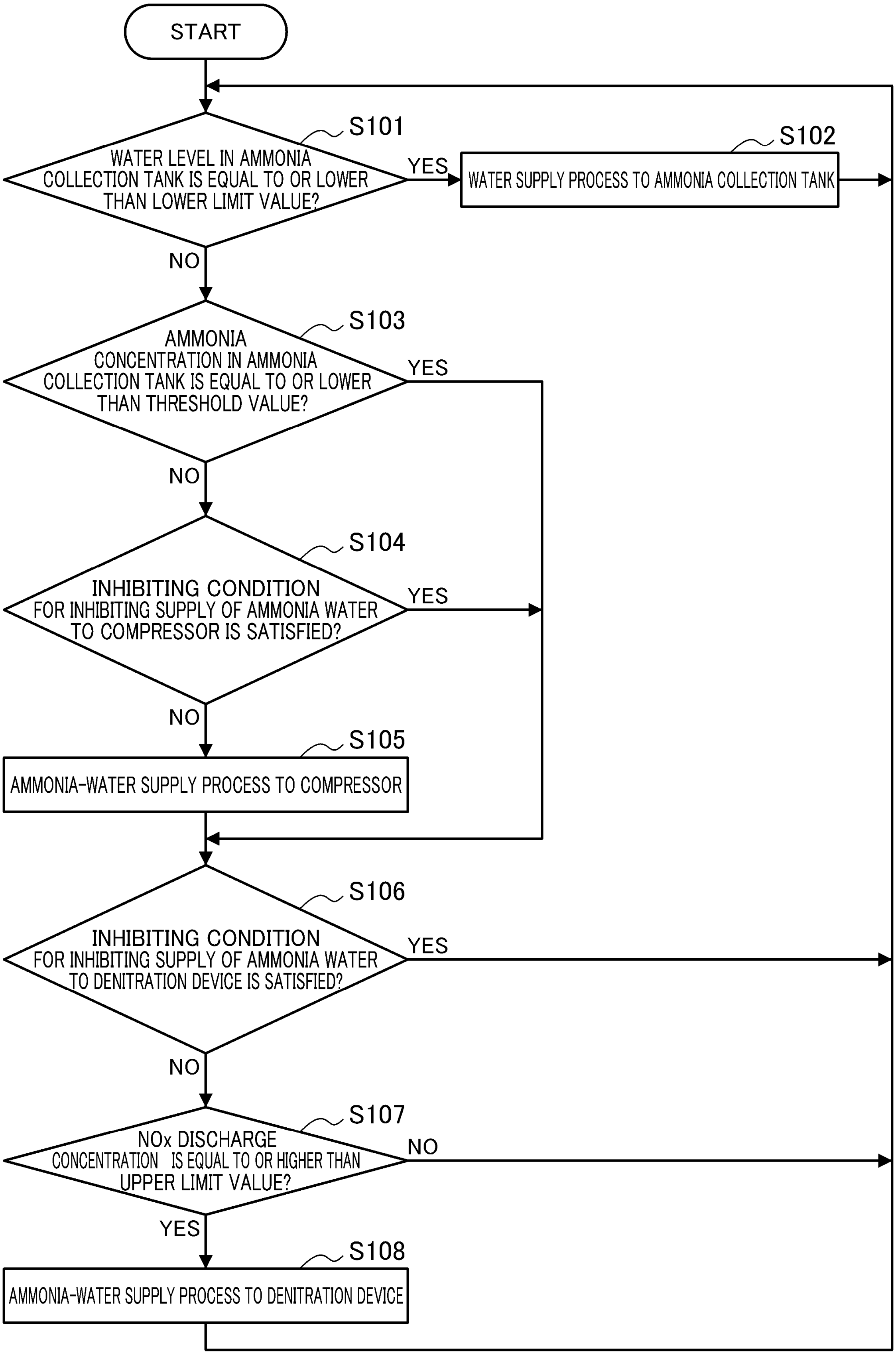
START
S101
WATER LEVEL IN AMMONIA COLLECTION TANK IS EQUAL TO OR LOWER THAN LOWER LIMIT VALUE?
YES
S102
WATER SUPPLY PROCESS TO AMMONIA COLLECTION TANK
NO
S103
AMMONIA CONCENTRATION IN AMMONIA COLLECTION TANK IS EQUAL TO OR LOWER THAN THRESHOLD VALUE?
YES
NO
S104
INHIBITING CONDITION FOR INHIBITING SUPPLY OF AMMONIA WATER TO COMPRESSOR IS SATISFIED?
YES
NO
S105
AMMONIA-WATER SUPPLY PROCESS TO COMPRESSOR
S106
INHIBITING CONDITION FOR INHIBITING SUPPLY OF AMMONIA WATER TO DENITRATION DEVICE IS SATISFIED?
YES
NO
S107
NOx DISCHARGE CONCENTRATION IS EQUAL TO OR HIGHER THAN UPPER LIMIT VALUE?
NO
YES
S108
AMMONIA-WATER SUPPLY PROCESS TO DENITRATION DEVICE

FIG. 2

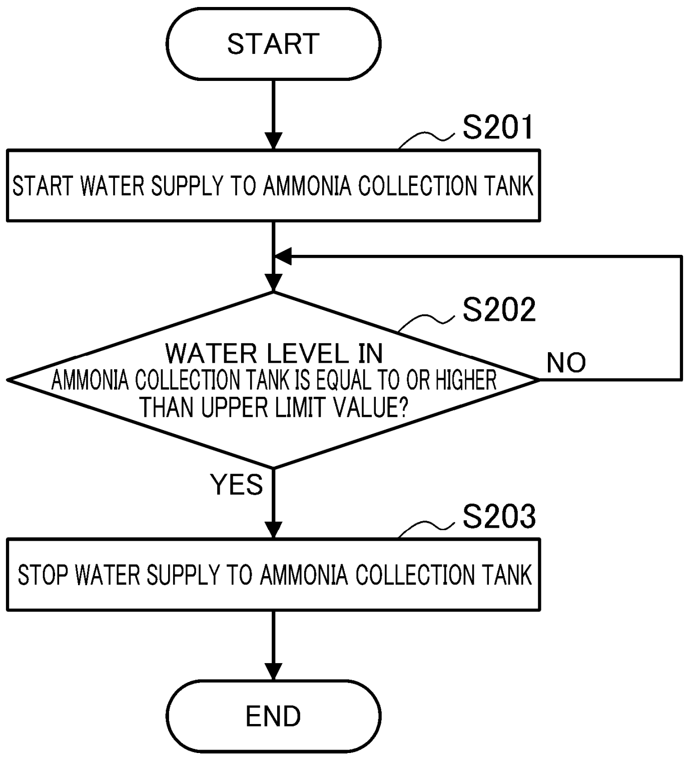
START
S201
START WATER SUPPLY TO AMMONIA COLLECTION TANK
S202
WATER LEVEL IN AMMONIA COLLECTION TANK IS EQUAL TO OR HIGHER THAN UPPER LIMIT VALUE?
NO
YES
S203
STOP WATER SUPPLY TO AMMONIA COLLECTION TANK
END

FIG. 3

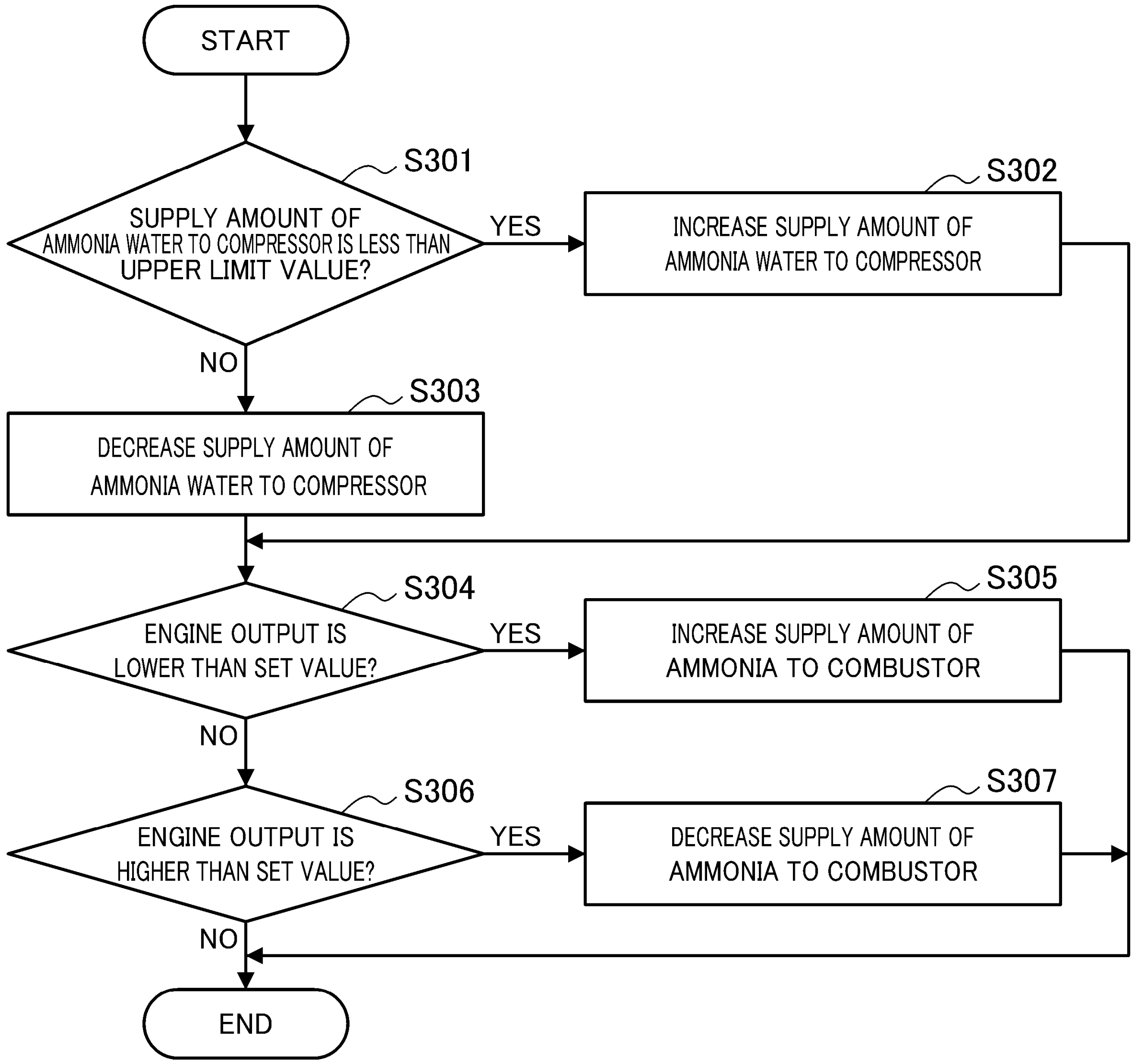
START
S301
SUPPLY AMOUNT OF AMMONIA WATER TO COMPRESSOR IS LESS THAN UPPER LIMIT VALUE?
YES
S302
INCREASE SUPPLY AMOUNT OF AMMONIA WATER TO COMPRESSOR
NO
S303
DECREASE SUPPLY AMOUNT OF AMMONIA WATER TO COMPRESSOR
S304
ENGINE OUTPUT IS LOWER THAN SET VALUE?
YES
S305
INCREASE SUPPLY AMOUNT OF AMMONIA TO COMBUSTOR
NO
S306
ENGINE OUTPUT IS HIGHER THAN SET VALUE?
YES
S307
DECREASE SUPPLY AMOUNT OF AMMONIA TO COMBUSTOR
NO
END

FIG. 4

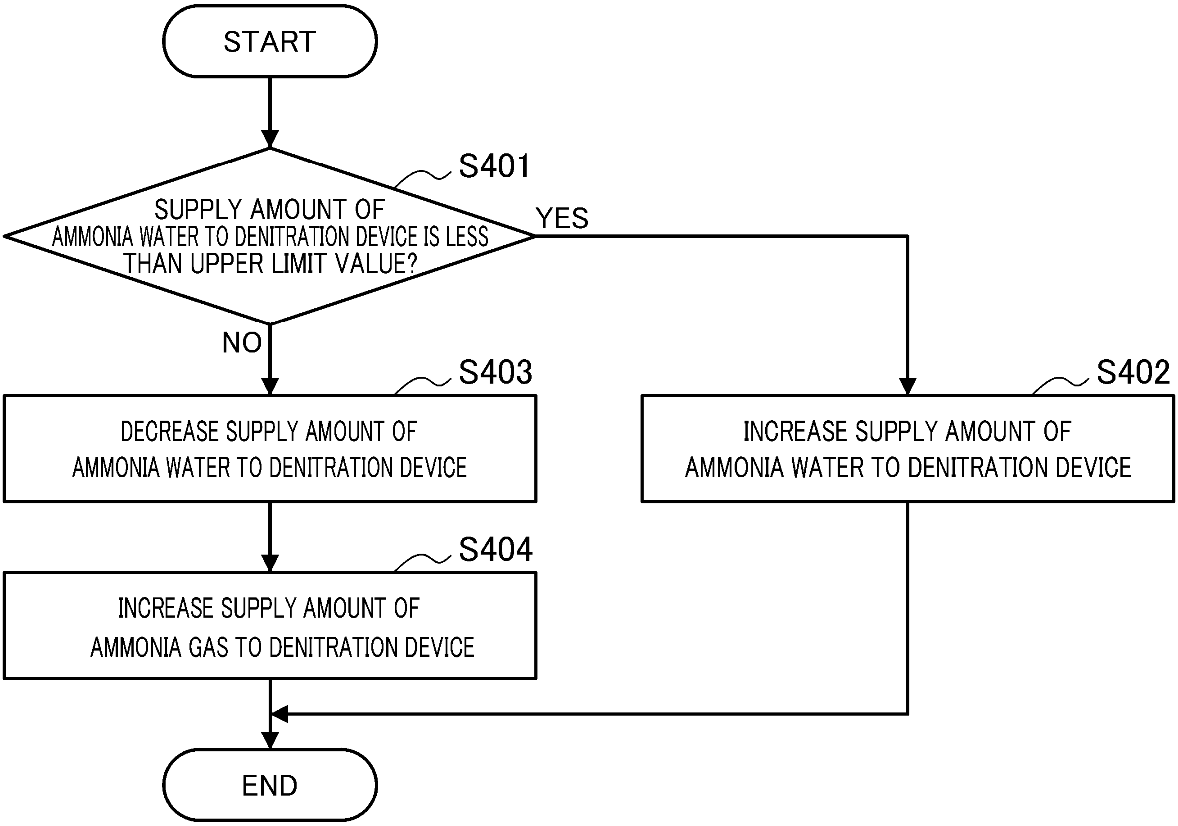
START
SUPPLY AMOUNT OF AMMONIA WATER TO DENITRATION DEVICE IS LESS THAN UPPER LIMIT VALUE?
S401
YES
NO
S403
DECREASE SUPPLY AMOUNT OF AMMONIA WATER TO DENITRATION DEVICE
S402
INCREASE SUPPLY AMOUNT OF AMMONIA WATER TO DENITRATION DEVICE
S404
INCREASE SUPPLY AMOUNT OF AMMONIA GAS TO DENITRATION DEVICE
END

FIG. 5