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Combustion device and gas turbine system for suppressing vaporization of ammonia

Abstract

A combustion device includes: a liner including an opening at an end, the liner inside of which is formed with a combustion chamber; an air flow path communicating with the opening of the liner; an ammonia supply pipe inserted through the opening of the liner; and a starting fuel supply pipe disposed between the ammonia supply pipe and the air flow path.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation application of International Application No. PCT/JP2022/009178, filed on Mar. 3, 2022, which claims priority to Japanese Patent Application No. 2021-054176, filed on Mar. 26, 2021, the entire contents of which are incorporated by reference herein.

BACKGROUND ART

Technical Field

(1) The present disclosure relates to a combustion device and a gas turbine system. The present application claims the benefit of priority based on Japanese Patent Application No. 2021-054176 filed on Mar. 26, 2021, the content of which is incorporated herein.

Related Art

(2) Gas turbine systems, with which power is obtained by combusting fuel in a combustor, are used. Some of the gas turbine systems use, for example, ammonia as fuel as disclosed in Patent Literature 1. By using ammonia as fuel, carbon dioxide emission is suppressed.

CITATION LIST

Patent Literature

(3) Patent Literature 1: JP 2016-191507 A

SUMMARY

Technical Problem

(4) Some of the gas turbine systems provide ammonia to a combustion chamber of a combustor after vaporizing ammonia by a vaporizer. Using a vaporizer contributes to an increase in the equipment cost and starting time in the gas turbine system. It is conceivable to supply liquid ammonia to a combustion chamber without using a vaporizer. In this case, liquid ammonia is sent to the combustion chamber through an ammonia supply pipe. There is a possibility that the ammonia supply pipe is heated by the high-temperature air supplied to the combustion chamber and that vaporization of ammonia occurs. When ammonia is vaporized in the ammonia supply pipe, an injection amount of ammonia becomes unstable.

(5) An object of the present disclosure is to provide a combustion device and a gas turbine system capable of suppressing vaporization of liquid ammonia used as fuel.

Solution to Problem

(6) In order to solve the above problems, a combustion device according to the present disclosure includes: a liner including an opening at an end, the liner inside of which is formed with a combustion chamber; an air flow path communicating with the opening of the liner; an ammonia supply pipe inserted through the opening of the liner; and a starting fuel supply pipe disposed between the ammonia supply pipe and the air flow path.

(7) A heat shielding pipe disposed between the starting fuel supply pipe and the air flow path may be included.

(8) The ammonia supply pipe may have a double pipe structure including an inner pipe and an outer pipe, the air flow path may include a first air flow path disposed on a radially inner side with respect to the inner pipe and a second air flow path disposed on a radially outer side with respect to the outer pipe, and the starting fuel supply pipe may include a first starting fuel supply pipe disposed between the inner pipe and the first air flow path and a second starting fuel supply pipe disposed between the outer pipe and the second air flow path.

(9) A first heat shielding pipe disposed between the first starting fuel supply pipe and the first air flow path and a second heat shielding pipe disposed between the second starting fuel supply pipe and the second air flow path may be included.

(10) In order to solve the above disadvantage, a gas turbine system of the present disclosure includes the combustion device described above.

Effects of Disclosure

(11) According to the present disclosure, it is possible to suppress vaporization of liquid ammonia used as fuel.

Description

BRIEF DESCRIPTION OF DRAWINGS

- (1) FIG. 1 is a schematic diagram illustrating a configuration of a gas turbine system according to an embodiment of the present disclosure.
- (2) FIG. 2 is an enlarged cross-sectional view illustrating a burner according to a first modification.
- (3) FIG. 3 is an enlarged cross-sectional view illustrating a burner according to a second modification.
- (4) FIG. 4 is an enlarged cross-sectional view illustrating a burner according to a third modification.

DESCRIPTION OF EMBODIMENTS

(5) Embodiments of the present disclosure will be described below by referring to the accompanying drawings. Dimensions, materials, other specific numerical values, and the like illustrated in the embodiments are merely an example for facilitating understanding, and the present disclosure is not limited thereto unless otherwise specified. Note that, in the present specification and the drawings, components having substantially the same function and structure are denoted by the same symbol, and redundant explanations are omitted. Illustration of components not directly related to the present disclosure is omitted.

(6) FIG. 1 is a schematic diagram illustrating a configuration of a gas turbine system **1** according to the present embodiment. As illustrated in FIG. 1, the gas turbine system **1** includes a turbocharger **11**, a generator **12**, a combustor **13**, a burner **14**, an ammonia tank **15**, a first flow rate control valve **16**, a starting fuel tank **17**, and a second flow rate control valve **18**.

(7) In the gas turbine system **1**, the combustor **13**, the burner **14**, the ammonia tank **15**, the first flow rate control valve **16**, the starting fuel tank **17**, and the second flow rate control valve **18** are included in a combustion device **10**.

(8) The turbocharger **11** includes a compressor **11a** and a turbine **11b**. The compressor **11a** and the turbine **11b** rotate in an integrated manner. The compressor **11a** and the turbine **11b** are connected by a shaft.

(9) The compressor **11a** is provided in an intake flow path **21** connected with the combustor **13**. The air supplied to the combustor **13** flows through the intake flow path **21**. An intake port (not illustrated) through which the air is taken in from the outside is provided at an upstream end of the intake flow path **21**. The air taken in from the intake port passes through the compressor **11a** and is sent to the combustor **13**. The compressor **11a** compresses the air and discharges the air to the downstream side.

(10) The turbine **11b** is provided in an exhaust flow path **22** connected with the combustor **13**. Exhaust gas discharged from the combustor **13** flows through the exhaust flow path **22**. An exhaust port (not illustrated) through which the exhaust gas is discharged to the outside is provided at a downstream end of the exhaust flow path **22**. The exhaust gas discharged from the combustor **13** passes through the turbine **11b** and is sent to the exhaust port. The turbine **11b** generates rotational power by being turned by the exhaust gas.

(11) The generator **12** is connected with the turbocharger **11**. The generator **12** generates electric power using the rotational power generated by the turbocharger **11**.

(12) The combustor **13** includes a casing **13a**, a liner **13b**, and a combustion chamber **13c**. The casing **13a** has a substantially cylindrical shape. The liner **13b** is included inside the casing **13a**. The liner **13b** has a substantially cylindrical shape. The liner **13b** is disposed coaxially with the casing **13a**. The combustion chamber **13c** is formed inside the liner **13b**. That is, the internal space of the liner **13b** corresponds to the combustion chamber **13c**. The combustion chamber **13c** is a substantially cylindrical space. The exhaust flow path **22** is connected to the combustion chamber **13c**.

(13) As described later, fuel and air are supplied to the combustion chamber **13c**. In the combustion chamber **13c**, ammonia is mainly used as fuel, whereby combustion is performed. Note that, as

described later, a starting fuel (such as natural gas or hydrogen) is also used as the fuel supplied to the combustion chamber **13c** in addition to ammonia. The starting fuel is a fuel used for starting the gas turbine system **1**. The exhaust gas generated by the combustion in the combustion chamber **13c** is discharged to the exhaust flow path **22**.

(14) The liner **13b** has a main body **13d**. The main body **13d** has a cylindrical shape. The combustion chamber **13c** is formed inside the main body **13d**. A communication portion **13e** is provided at an end of the main body **13d**. The communication portion **13e** communicates the outside of the liner **13b** (specifically, an air flow path **23** described later) with the combustion chamber **13c**. The communication portion **13e** has a cylindrical shape and is disposed coaxially with the main body **13d**. The outer diameter of the communication portion **13e** is smaller than the outer diameter of the main body **13d**. The inner diameter of the communication portion **13e** is smaller than the inner diameter of the main body **13d**. Note that the inner diameter of the communication portion **13e** may decrease as it is closer to the main body **13d**. Various members such as swirling blades for forming a swirl flow of air may be provided in the communication portion **13e**. An opening **13f** is included at an end of the communication portion **13e** on the side opposite to the main body **13d** side. In this manner, the opening **13f** is included at the end of the liner **13b**.

(15) The air flow path **23** is formed between the inner surface of the casing **13a** and the outer surface of the liner **13b**. An intake flow path **21** is connected to the air flow path **23**. Air is sent from a compressor **11a** to the air flow path **23** via the intake flow path **21**. The air flow path **23** communicates with the opening **13f** of the liner **13b**. The burner **14** is inserted through the opening **13f** of the liner **13b**. As indicated by arrows **F1**, the air sent to the air flow path **23** passes through the air flow path **23** and then is injected into the combustion chamber **13c** through the opening **13f** of the liner **13b**. Specifically, the air sent to the air flow path **23** passes between the inner curved surface of the communication portion **13e** and the outer curved surface of the burner **14** (specifically, the outer curved surface of a starting fuel supply pipe **32** described later) and is injected into the combustion chamber **13c**.

(16) The burner **14** includes an ammonia supply pipe **31** and the starting fuel supply pipe **32**. The ammonia supply pipe **31** is a pipe for supplying ammonia to the combustion chamber **13c**. Ammonia flows through the space defined by the ammonia supply pipe **31**. The starting fuel supply pipe **32** is a pipe for supplying the starting fuel to the combustion chamber **13c**. The starting fuel flows through a space defined by the starting fuel supply pipe **32**.

(17) The ammonia supply pipe **31** and the starting fuel supply pipe **32** have a cylindrical shape. The starting fuel supply pipe **32** is disposed coaxially with the ammonia supply pipe **31** and on a radially outer side with respect to the ammonia supply pipe **31**. The starting fuel supply pipe **32** covers the outer curved surface of the ammonia supply pipe **31**. That is, the ammonia supply pipe **31** is inserted in the starting fuel supply pipe **32**, and the starting fuel supply pipe **32** faces the outer curved surface of the ammonia supply pipe **31**. However, the central axis of the starting fuel supply pipe **32** and the central axis of the ammonia supply pipe **31** may not coincide with each other. The starting fuel supply pipe **32** is disposed between the ammonia supply pipe **31** and the air flow path **23**.

(18) The ammonia supply pipe **31** and the starting fuel supply pipe **32** are inserted through the opening **13f** of the liner **13b**. Distal ends of the ammonia supply pipe **31** and the starting fuel supply pipe **32** are positioned, for example, in the vicinity of a step portion between the main body **13d** of the liner **13b** and the communication portion **13e** in the axial direction. The ammonia supply pipe **31** and the starting fuel supply pipe **32** penetrate through the casing **13a** and extend to the outside of the casing **13a**.

(19) Hereinafter, the radial direction of the burner **14**, the axial direction of the burner **14**, and the circumferential direction of the burner **14** are also simply referred to as the radial direction, the axial direction, and the circumferential direction, respectively. The combustion chamber **13c** side

(right side in FIG. 1) of the burner **14** is referred to as a distal end side, and the opposite side (left side in FIG. 1) of the burner **14** to the combustion chamber **13c** side is referred to as a rear end side. (20) The ammonia tank **15** is connected to a portion of the ammonia supply pipe **31** that is outside the casing **13a**. Liquid ammonia is stored in the ammonia tank **15**. A first flow rate control valve **16** is provided in a flow path connecting the ammonia tank **15** and the ammonia supply pipe **31**. The ammonia stored in the ammonia tank **15** is supplied to the ammonia supply pipe **31**. The first flow rate control valve **16** controls (namely, adjusts) the flow rate of ammonia supplied from the ammonia tank **15** to the ammonia supply pipe **31**.

(21) An injection valve **33** is provided at the distal end of the ammonia supply pipe **31**. As indicated by an arrow **F2**, the ammonia supplied to the ammonia supply pipe **31** flows through the internal space of the ammonia supply pipe **31**. The ammonia that has passed through the ammonia supply pipe **31** is injected (specifically, sprayed) from the injection valve **33** into the combustion chamber **13c**. The injection valve **33** is, for example, a pressure injection valve (namely, a valve that atomizes liquid using a pressure difference between the inside and the outside of the injection valve) or an air flow injection valve (namely, a valve that generates a film of liquid to be injected and atomizes the liquid using a shear force between the film and air).

(22) A starting fuel tank **17** is connected to a portion of the starting fuel supply pipe **32** that is outside the casing **13a**. The starting fuel tank **17** stores starting fuel such as natural gas or hydrogen. The second flow rate control valve **18** is provided in a flow path connecting the starting fuel tank **17** and the starting fuel supply pipe **32**. The starting fuel stored in the starting fuel tank **17** is supplied to the starting fuel supply pipe **32**. The second flow rate control valve **18** controls (namely, adjusts) the flow rate of the starting fuel supplied from the starting fuel tank **17** to the starting fuel supply pipe **32**.

(23) As indicated by arrows **F3**, the starting fuel supplied to the starting fuel supply pipe **32** flows in the space between the inner curved portion of the starting fuel supply pipe **32** and the outer curved portion of the ammonia supply pipe **31**. The starting fuel that has passed through the space is injected into the combustion chamber **13c** from an annular opening between the distal end of the starting fuel supply pipe **32** and the distal end of the ammonia supply pipe **31**. As described above, the starting fuel supply pipe **32** is separated from the ammonia supply pipe **31** in the radial direction. That is, the inner diameter of the starting fuel supply pipe **32** is larger than the outer diameter of the ammonia supply pipe **31**.

(24) Ammonia has a property of being less likely to burn than other fuels (namely, flame retardancy). Therefore, at the time of starting of the gas turbine system **1** (namely, when the combustion device **10** is started), ignition is performed using the starting fuel in the combustion chamber **13c**. Specifically, ignition is performed by an ignition device (not illustrated) in a state where the starting fuel is supplied from the starting fuel supply pipe **32** to the combustion chamber **13c**. That is, the starting fuel is used as fuel for ignition.

(25) Thereafter, the supply amount of the starting fuel to the combustion chamber **13c** gradually increases, and even if supply of ammonia to the combustion chamber **13c** is started, the combustibility in the combustion chamber **13c** is maintained at a predetermined level or more. In this state, supply of ammonia from the ammonia supply pipe **31** to the combustion chamber **13c** is started. As described above, the starting fuel is also used as fuel for combustion assist (namely, fuel for assisting combustion). Note that, after the supply of ammonia to the combustion chamber **13c** is started, the supply of the starting fuel to the combustion chamber **13c** may be continued or stopped.

(26) In a case where the starting fuel supply pipe **32** is not disposed between the ammonia supply pipe **31** and the air flow path **23** unlike in the present embodiment, the ammonia supply pipe **31** is exposed to high-temperature (for example, about 350° C.) air passing through the air flow path **23**. Therefore, there is a risk that the ammonia supply pipe **31** is directly heated by the air passing through the air flow path **23**, and vaporization of ammonia in the ammonia supply pipe **31** occurs. When ammonia is vaporized in the ammonia supply pipe **31**, an injection amount of ammonia to

the combustion chamber **13c** becomes unstable. Further, the ammonia vaporized in the ammonia supply pipe **31** is liquefied again as the pressure in the injection valve **33** decreases. Therefore, vaporization and liquefaction of ammonia are repeated in the ammonia supply pipe **31** and the injection valve **33**. Such a phenomenon also contributes to instability of the injection amount of ammonia into the combustion chamber **13c**.

(27) As described above, after ignition using the starting fuel is performed, supply of ammonia to the combustion chamber **13c** is started. Therefore, in a case where the outer curved surface of the ammonia supply pipe **31** is not covered with the starting fuel supply pipe **32**, the ammonia supply pipe **31** continues to be directly heated by the air passing through the air flow path **23** during a period before the supply of ammonia to the combustion chamber **13c** is started.

(28) Therefore, in particular, at the time when the supply of ammonia to the combustion chamber **13c** is started, vaporization of ammonia in the ammonia supply pipe **31** is likely to occur.

(29) As described above, in the combustion device **10** of the gas turbine system **1** according to the present embodiment, the starting fuel supply pipe **32** covers the curved surface (specifically, the outer curved surface) of the ammonia supply pipe **31** and is disposed between the ammonia supply pipe **31** and the air flow path **23**. That is, in the radial direction, the flow path of the starting fuel is interposed between the flow path of ammonia and the air flow path **23**. This makes it possible to prevent the ammonia supply pipe **31** from being directly heated by the air passing through the air flow path **23**. The ammonia supply pipe **31** is cooled by the starting fuel passing between the starting fuel supply pipe **32** and the ammonia supply pipe **31**.

(30) During the period before supply of ammonia to the combustion chamber **13c** is started, the ammonia supply pipe **31** is cooled by the starting fuel passing between the starting fuel supply pipe **32** and the ammonia supply pipe **31**, and heat transfer from the air flow path **23** to the ammonia supply pipe **31** is suppressed. After the supply of ammonia to the combustion chamber **13c** is started, the supply of the starting fuel to the combustion chamber **13c** is stopped, or the supply amount of the starting fuel to the combustion chamber **13c** is reduced, however, vaporization of ammonia is suppressed by the heat capacity of ammonia itself passing through the ammonia supply pipe **31**.

(31) As described above, according to the combustion device **10** of the gas turbine system **1** of the present embodiment, it is possible to suppress vaporization of liquid ammonia used as fuel.

(32) Hereinafter, gas turbine systems according to individual modifications will be described with reference to FIGS. **2** to **4**. Note that, in the gas turbine systems according to individual modifications described below, the configuration other than that of a burner is similar to that of the gas turbine system **1** described above, and thus description thereof is omitted.

(33) FIG. **2** is an enlarged cross-sectional view illustrating a burner **14A** according to a first modification. As illustrated in FIG. **2**, a combustion device **10A** of a gas turbine system **1A** according to the first modification includes the burner **14A**.

(34) The burner **14A** is different from the burner **14** described above in that a heat shielding pipe **41** is further included. The burner **14A** includes an ammonia supply pipe **31**, a starting fuel supply pipe **32**, and the heat shielding pipe **41**.

(35) The heat shielding pipe **41** has a cylindrical shape. The heat shielding pipe **41** is disposed coaxially with the starting fuel supply pipe **32** and on a radially outer side with respect to the starting fuel supply pipe **32**. The heat shielding pipe **41** covers the outer curved surface of the starting fuel supply pipe **32**. That is, the starting fuel supply pipe **32** is inserted into the heat shielding pipe **41**, and the heat shielding pipe **41** faces the outer curved surface of the starting fuel supply pipe **32**. The heat shielding pipe **41** is separated from the starting fuel supply pipe **32** in the radial direction. That is, the inner diameter of the heat shielding pipe **41** is larger than the outer diameter of the starting fuel supply pipe **32**. However, the central axis of the heat shielding pipe **41** and the central axis of the starting fuel supply pipe **32** may not coincide with each other. The heat shielding pipe **41** is disposed between the starting fuel supply pipe **32** and an air flow path **23**.

(36) The rear end of the heat shielding pipe **41** is attached to the inner surface of a casing **13a**. However, the heat shielding pipe **41** may be attached to the starting fuel supply pipe **32**. The heat shielding pipe **41** is inserted through an opening **13f** of a liner **13b**. The distal end of the heat shielding pipe **41** is positioned, for example, behind (left side in FIG. 2) the distal end of the starting fuel supply pipe **32** in the axial direction. As described above, since the heat shielding pipe **41** does not extend into the combustion chamber **13c**, heat is less likely to be transferred from the combustion chamber **13c** to the heat shielding pipe **41**. However, the heat shielding pipe **41** may not be inserted through the opening **13f** of the liner **13b**. In this case, the distal end of the heat shielding pipe **41** is positioned behind the opening **13f** of the liner **13b**.

(37) As described above, in the combustion device **10A** of the gas turbine system **1A** according to the first modification, the heat shielding pipe **41** covers the curved surface (specifically, the outer curved surface) of the starting fuel supply pipe **32** and is disposed between the starting fuel supply pipe **32** and the air flow path **23**. As a result, it is possible to prevent the starting fuel supply pipe **32** from being directly heated by the air passing through the air flow path **23**. Therefore, heat transfer from the air flow path **23** to the ammonia supply pipe **31** is more effectively suppressed. Therefore, vaporization of liquid ammonia used as fuel can be more effectively suppressed.

(38) From the viewpoint of effectively suppressing heat transfer from the air flow path **23** to the ammonia supply pipe **31**, the heat shielding pipe **41** is preferably formed of a material having low thermal conductivity. However, the material of the heat shielding pipe **41** is selected in consideration of various properties such as strength and heat resistance.

(39) FIG. 3 is an enlarged cross-sectional view illustrating a burner **14B** according to a second modification. As illustrated in FIG. 3, a combustion device **10B** of a gas turbine system **1B** according to a second modification includes the burner **14B**.

(40) The burner **14B** is different from the burner **14** described above in that an ammonia supply pipe **131** has a double cylinder structure. The burner **14B** has an ammonia supply pipe **131** (specifically, an inner pipe **131a** and an outer pipe **131b**) and a starting fuel supply pipe **132** (specifically, a first starting fuel supply pipe **132a** and a second starting fuel supply pipe **132b**).

(41) The ammonia supply pipe **131** has a double pipe structure including the inner pipe **131a** and the outer pipe **131b**. The inner pipe **131a** and the outer pipe **131b** have a cylindrical shape. The outer pipe **131b** is disposed coaxially with the inner pipe **131a** and on a radially outer side with respect to the inner pipe **131a**. The outer pipe **131b** is separated from the inner pipe **131a** in the radial direction. That is, the inner diameter of the outer pipe **131b** is larger than the outer diameter of the inner pipe **131a**. The ammonia supply pipe **131** is supplied with ammonia from an ammonia tank **15**, similarly to the above-described ammonia supply pipe **31**.

(42) An injection valve **133** is provided at the distal end of the ammonia supply pipe **131**. The injection valve **133** has an annular shape. The injection valve **133** is provided in an annular opening between the distal end of the inner pipe **131a** and the distal end of the outer pipe **131b**. As indicated by arrows **F21**, the ammonia supplied to the ammonia supply pipe **131** flows in a space between the inner curved portion of the outer pipe **131b** and the outer curved portion of the inner pipe **131a**. The ammonia that has passed through the space is injected (specifically, sprayed) from the injection valve **133** into the combustion chamber **13c**. The injection valve **133** is, for example, similar to the injection valve **33** described above.

(43) The starting fuel supply pipe **132** includes a first starting fuel supply pipe **132a** and a second starting fuel supply pipe **132b**. The starting fuel is supplied from the starting fuel tank **17** to the first starting fuel supply pipe **132a** and the second starting fuel supply pipe **132b**, similarly to the starting fuel supply pipe **32** described above.

(44) The first starting fuel supply pipe **132a** is disposed coaxially with the ammonia supply pipe **131** on a radially inner side with respect to the inner pipe **131a** of the ammonia supply pipe **131**. The first starting fuel supply pipe **132a** covers the inner curved surface of the inner pipe **131a**. That is, the first starting fuel supply pipe **132a** is inserted in the inner pipe **131a**, and the first starting

fuel supply pipe **132a** faces the inner curved surface of the inner pipe **131a**. However, the central axis of the first starting fuel supply pipe **132a** and the central axis of the ammonia supply pipe **131** may not coincide with each other.

(45) As indicated by arrows **F31**, the starting fuel supplied to the first starting fuel supply pipe **132a** flows in the space between the outer curved portion of the first starting fuel supply pipe **132a** and the inner curved portion of the inner pipe **131a**. The starting fuel that has passed through the space is injected into the combustion chamber **13c** from an annular opening between the distal end of the first starting fuel supply pipe **132a** and the distal end of the inner pipe **131a**. As described above, the first starting fuel supply pipe **132a** is separated from the inner pipe **131a** in the radial direction. That is, the outer diameter of the first starting fuel supply pipe **132a** is smaller than the inner diameter of the inner pipe **131a**.

(46) The second starting fuel supply pipe **132b** is disposed coaxially with the ammonia supply pipe **131** and on a radially outer side with respect to the outer pipe **131b** of the ammonia supply pipe **131**. The second starting fuel supply pipe **132b** covers the outer curved surface of the outer pipe **131b**. That is, the outer pipe **131b** is inserted in the second starting fuel supply pipe **132b**, and the second starting fuel supply pipe **132b** faces the outer curved surface of the outer pipe **131b**. However, the central axis of the second starting fuel supply pipe **132b** and the central axis of the ammonia supply pipe **131** may not coincide with each other.

(47) As indicated by arrows **F32**, the starting fuel supplied to the second starting fuel supply pipe **132b** flows in the space between the inner curved portion of the second starting fuel supply pipe **132b** and the outer curved portion of the outer pipe **131b**. The starting fuel that has passed through the space is injected into the combustion chamber **13c** from an annular opening between the distal end of the second starting fuel supply pipe **132b** and the distal end of the outer pipe **131b**. As described above, the second starting fuel supply pipe **132b** is separated from the outer pipe **131b** in the radial direction. That is, the inner diameter of the second starting fuel supply pipe **132b** is larger than the outer diameter of the outer pipe **131b**.

(48) The air flow path **123** includes a first air flow path **123a** and a second air flow path **123b**. Similarly to the air flow path **23** described above, an intake flow path **21** is connected to each of the first air flow path **123a** and the second air flow path **123b**. The first air flow path **123a** and the second air flow path **123b** each communicate with an opening **13f** of a liner **13b**, similarly to the air flow path **23** described above.

(49) The first air flow path **123a** is partitioned by the inner curved surface of the first starting fuel supply pipe **132a**. The first air flow path **123a** extends on the central axis of the ammonia supply pipe **131**. The first air flow path **123a** is disposed on a radially inner side with respect to the inner pipe **131a**. The inner curved surface of the inner pipe **131a** is covered with the first starting fuel supply pipe **132a**. That is, the first starting fuel supply pipe **132a** is disposed between the inner pipe **131a** and the first air flow path **123a**. As indicated by an arrow **F11**, the air sent to the first air flow path **123a** passes through the first air flow path **123a** and then is injected from the distal end of the first starting fuel supply pipe **132a** into the combustion chamber **13c**.

(50) Similarly to the air flow path **23** described above, the second air flow path **123b** is formed between the inner surface of a casing **13a** and the outer surface of the liner **13b**. The second air flow path **123b** is disposed on a radially outer side with respect to the outer pipe **131b**. The outer curved surface of the outer pipe **131b** is covered with the second starting fuel supply pipe **132b**. That is, the second starting fuel supply pipe **132b** is disposed between the outer pipe **131b** and the second air flow path **123b**. As indicated by arrows **F12**, the air sent to the second air flow path **123b** passes through the second air flow path **123b** and then is injected into the combustion chamber **13c** through the opening **13f** of the liner **13b**. Specifically, the air sent to the second air flow path **123b** passes between the inner curved surface of a communication portion **13e** and the outer curved surface of the second starting fuel supply pipe **132b** and is injected into the combustion chamber **13c**.

(51) As described above, in the combustion device **10B** of the gas turbine system **1B** according to the second modification, the first starting fuel supply pipe **132a** covers the inner curved surface of the inner pipe **131a** and is disposed between the inner pipe **131a** and the first air flow path **123a**. That is, in the radial direction, a flow path of the starting fuel is interposed between the flow path of ammonia and the first air flow path **123a**. This makes it possible to prevent the inner pipe **131a** from being directly heated by the air passing through the first air flow path **123a**. The inner pipe **131a** is also cooled by the starting fuel passing between the first starting fuel supply pipe **132a** and the inner pipe **131a**. The second starting fuel supply pipe **132b** covers the outer curved surface of the outer pipe **131b** and is disposed between the outer pipe **131b** and the second air flow path **123b**. That is, in the radial direction, a flow path of the starting fuel is interposed between the flow path of ammonia and the second air flow path **123b**. This makes it possible to prevent the outer pipe **131b** from being directly heated by the air passing through the second air flow path **123b**. The outer pipe **131b** is also cooled by the starting fuel passing between the second starting fuel supply pipe **132b** and the outer pipe **131b**.

(52) As described above, according to the second modification, in the combustion device **10B** including the ammonia supply pipe **131** having the double pipe structure, heat transfer from the air flow path **123** to the ammonia supply pipe **131** is suppressed. Therefore, vaporization of liquid ammonia used as the fuel can be suppressed.

(53) The example in which the first starting fuel supply pipe **132a** and the second starting fuel supply pipe **132b** are provided as the starting fuel supply pipe **132** has been described above. However, only one of the first starting fuel supply pipe **132a** and the second starting fuel supply pipe **132b** may be provided as the starting fuel supply pipe **132**. Also in this case, heat transfer from the air flow path **123** to the ammonia supply pipe **131** is suppressed, and thus an effect of suppressing vaporization of ammonia can be achieved. However, from the viewpoint of effectively suppressing the heat transfer from the air flow path **123** to the ammonia supply pipe **131**, the first starting fuel supply pipe **132a** and the second starting fuel supply pipe **132b** are preferably provided as the starting fuel supply pipe **132**.

(54) FIG. **4** is an enlarged cross-sectional view illustrating a burner **14C** according to a third modification. As illustrated in FIG. **4**, a combustion device **10C** of a gas turbine system **1C** according to the third modification includes the burner **14C**.

(55) The burner **14C** is different from the burner **14B** described above in that a heat shielding pipe **141** is further included. The burner **14C** includes an ammonia supply pipe **131** (specifically, an inner pipe **131a** and an outer pipe **131b**), a starting fuel supply pipe **132** (specifically, a first starting fuel supply pipe **132a** and a second starting fuel supply pipe **132b**), and a heat shielding pipe **141** (specifically, a first heat shielding pipe **141a** and a second heat shielding pipe **141b**).

(56) The heat shielding pipe **141** includes the first heat shielding pipe **141a** and the second heat shielding pipe **141b**. The first heat shielding pipe **141a** and the second heat shielding pipe **141b** have a cylindrical shape.

(57) The first heat shielding pipe **141a** is disposed coaxially with the first starting fuel supply pipe **132a** and on a radially inner side with respect to the first starting fuel supply pipe **132a**. The first heat shielding pipe **141a** covers the inner curved surface of the first starting fuel supply pipe **132a**. That is, the first heat shielding pipe **141a** is inserted in the first starting fuel supply pipe **132a**, and the first heat shielding pipe **141a** faces the inner curved surface of the first starting fuel supply pipe **132a**. The first heat shielding pipe **141a** is separated from the first starting fuel supply pipe **132a** in the radial direction. That is, the outer diameter of the first heat shielding pipe **141a** is smaller than the inner diameter of the first starting fuel supply pipe **132a**. However, the central axis of the first heat shielding pipe **141a** and the central axis of the first starting fuel supply pipe **132a** may not coincide with each other. The first heat shielding pipe **141a** is disposed between the first starting fuel supply pipe **132a** and the first air flow path **123a**. That is, in the third modification, the first air flow path **123a** is partitioned by the inner curved surface of the first heat shielding pipe **141a**.

(58) The first heat shielding pipe **141a** is attached to, for example, the first starting fuel supply pipe **132a**. However, the first heat shielding pipe **141a** may be attached to a member of the burner **14C** other than the first starting fuel supply pipe **132a**. The first heat shielding pipe **141a** is inserted through an opening **13f** of a liner **13b**. The distal end of the first heat shielding pipe **141a** is positioned, for example, behind (left side in FIG. 4) the distal end of the first starting fuel supply pipe **132a** in the axial direction. However, the first heat shielding pipe **141a** may not be inserted through the opening **13f** of the liner **13b**. In this case, the distal end of the first heat shielding pipe **141a** is positioned behind the opening **13f** of the liner **13b**.

(59) The second heat shielding pipe **141b** is disposed coaxially with the second starting fuel supply pipe **132b** and on a radially outer side with respect to the second starting fuel supply pipe **132b**. The second heat shielding pipe **141b** covers the outer curved surface of the second starting fuel supply pipe **132b**. That is, the second starting fuel supply pipe **132b** is inserted in the second heat shielding pipe **141b**, and the second heat shielding pipe **141b** faces the outer curved surface of the second starting fuel supply pipe **132b**. The second heat shielding pipe **141b** is separated from the second starting fuel supply pipe **132b** in the radial direction. That is, the inner diameter of the second heat shielding pipe **141b** is larger than the outer diameter of the second starting fuel supply pipe **132b**. However, the central axis of the second heat shielding pipe **141b** and the central axis of the second starting fuel supply pipe **132b** may not coincide with each other. The second heat shielding pipe **141b** is disposed between the second starting fuel supply pipe **132b** and the second air flow path **123b**.

(60) The rear end of the second heat shielding pipe **141b** is attached to the inner surface of the casing **13a**. However, the second heat shielding pipe **141b** may be attached to the second starting fuel supply pipe **132b**. The second heat shielding pipe **141b** is inserted through the opening **13f** of the liner **13b**. The distal end of the second heat shielding pipe **141b** is positioned, for example, in the axial direction, behind (left side in FIG. 4) the distal end of the second starting fuel supply pipe **132b**. However, the second heat shielding pipe **141b** may not be inserted through the opening **13f** of the liner **13b**. In this case, the distal end of the second heat shielding pipe **141b** is positioned behind the opening **13f** of the liner **13b**.

(61) As described above, in the combustion device **10C** of the gas turbine system **1C** according to the third modification, the first heat shielding pipe **141a** covers the inner curved surface of the first starting fuel supply pipe **132a** and is disposed between the first starting fuel supply pipe **132a** and the first air flow path **123a**. This makes it possible to prevent the first starting fuel supply pipe **132a** from being directly heated by the air passing through the first air flow path **123a**. Therefore, heat transfer from the first air flow path **123a** to the inner pipe **131a** is more effectively suppressed. The second heat shielding pipe **141b** covers the outer curved surface of the second starting fuel supply pipe **132b** and is disposed between the second starting fuel supply pipe **132b** and the second air flow path **123b**. This makes it possible to prevent the second starting fuel supply pipe **132b** from being directly heated by the air passing through the second air flow path **123b**. Therefore, heat transfer from the second air flow path **123b** to the outer pipe **131b** is more effectively suppressed.

(62) As described above, according to the third modification, in the combustion device **10C** including the ammonia supply pipe **131** having the double pipe structure, vaporization of liquid ammonia used as fuel can be more effectively suppressed.

(63) From the viewpoint of effectively suppressing heat transfer from the air flow path **123** to the ammonia supply pipe **131**, it is preferable to form the heat shielding pipe **141** with a material having low thermal conductivity. However, the material of the heat shielding pipe **141** is selected in consideration of various properties such as strength and heat resistance.

(64) The example in which the first heat shielding pipe **141a** and the second heat shielding pipe **141b** are provided as the heat shielding pipe **141** has been described above. However, only one of the first heat shielding pipe **141a** and the second heat shielding pipe **141b** may be provided as the heat shielding pipe **141**. Even in this case, since the starting fuel supply pipe **132** is suppressed

from being directly heated by the air passing through the air flow path **123**, an effect of effectively suppressing vaporization of ammonia can be achieved. However, from the viewpoint of effectively suppressing direct heating of the starting fuel supply pipe **132** by the air passing through the air flow path **123**, the first heat shielding pipe **141a** and the second heat shielding pipe **141b** are preferably provided as the heat shielding pipe **141**.

(65) The example in which the first starting fuel supply pipe **132a** and the second starting fuel supply pipe **132b** are provided as the starting fuel supply pipe **132** has been described above. However, only the first starting fuel supply pipe **132a** may be provided as the starting fuel supply pipe **132**, and only the first heat shielding pipe **141a** may be provided as the heat shielding pipe **141**. Only the second starting fuel supply pipe **132b** may be provided as the starting fuel supply pipe **132**, and only the second heat shielding pipe **141b** may be provided as the heat shielding pipe **141**.

(66) The air passing through the air flow path **123** advances toward the combustion chamber **13c** while swirling in the circumferential direction of the burner **14**. Therefore, a centrifugal force acts on the air passing through the air flow path **123**. Therefore, air is likely to stick to the first heat shielding pipe **141a** as compared with the second heat shielding pipe **141b**. Therefore, from the viewpoint of suppressing direct heating of the starting fuel supply pipe **132** by the air passing through the air flow path **123**, the necessity of increasing the axial length of the first heat shielding pipe **141a** is higher than the necessity of increasing the axial length of the second heat shielding pipe **141b**. For example, in the example of FIG. 4, the distal end of the first heat shielding pipe **141a** is closer to the combustion chamber **13c** than the distal end of the second heat shielding pipe **141b** is. As a result, the axial length of the first heat shielding pipe **141a** can be increase as much as possible, and direct heating of the first starting fuel supply pipe **132a** by the air passing through the first air flow path **123a** can be effectively suppressed.

(67) Although the embodiments of the present disclosure have been described with reference to the accompanying drawings, it is naturally understood that the present disclosure is not limited to the above embodiments. It is clear that those skilled in the art can conceive various modifications or variations within the scope described in the claims, and it is understood that they are naturally also within the technical scope of the present disclosure.

(68) In the above, the examples have been described in which the rotational power generated by the turbocharger **11** is used as energy for driving the generator **12** in the gas turbine system **1**, the gas turbine system **1A**, the gas turbine system **1B**, and the gas turbine system **1C**. However, in the gas turbine system **1**, the gas turbine system **1A**, the gas turbine system **1B**, and the gas turbine system **1C**, the rotational power generated by the turbocharger **11** may be used for other applications (for example, for the purpose of driving a mobile body such as a ship).

(69) The examples in which the combustion device **10**, the combustion device **10A**, the combustion device **10B**, and the combustion device **10C** are used in the gas turbine system have been described above. However, the combustion device **10**, the combustion device **10A**, the combustion device **10B**, and the combustion device **10C** may be used in a device other than the gas turbine system (for example, an industrial furnace or the like in which energy recovered from exhaust heat or the like is used for combustion in a combustor).

(70) Each of the ammonia supply pipe **31**, the starting fuel supply pipe **32**, the heat shielding pipe **41**, the ammonia supply pipe **131**, the starting fuel supply pipe **132**, and the heat shielding pipe **141** has been described above by referring to the respective drawings. In each of the drawings, the wall thickness, the inner diameter, and the outer diameter of each of these pipes are constant at individual positions in the axial direction. However, the wall thickness, the inner diameter, or the outer diameter of each of these pipes may not be constant at individual positions in the axial direction. In addition, each of these pipes may not be linear. For example, each of these pipes may be bent inside or outside the casing **13a**. Moreover, in the example of FIG. 1, the air flow path **23** extends between the outer curved surface of the liner **13b** and the inner curved surface of the casing

13a and then sends to the combustion chamber **13c**. However, the paths of the air flow paths **23** and **123** are not limited to this example (namely, reverse-flow type).

Claims

1. A method comprising: passing air through an air flow path of a combustion device, wherein the air flow path communicates with an opening of a liner, the opening is at an end of the liner, the liner defines a combustion chamber, and the air flow path is a path for supplying the air to the combustion chamber; flowing ammonia through a space defined by and inside an ammonia supply pipe of the combustion device, wherein the ammonia supply pipe is inserted through the opening of the liner, and the ammonia supply pipe is a pipe for supplying the ammonia to the combustion chamber; and flowing starting fuel through a space defined by and between the ammonia supply pipe and a starting fuel supply pipe of the combustion device, wherein the starting fuel supply pipe is disposed between the ammonia supply pipe and the air flow path, wherein the starting fuel supply pipe covers a curved surface of the ammonia supply pipe, and the starting fuel supply pipe is a pipe for supplying the starting fuel to the combustion chamber, wherein the ammonia supply pipe is inserted in the starting fuel supply pipe.

2. A combustion device comprising: a liner including an opening at an end, wherein the liner defines a combustion chamber; an air flow path communicating with the opening of the liner, wherein air passes through the air flow path, wherein the air flow path is a path for supplying the air to the combustion chamber; the air that passes through the air flow path, wherein the air is within the air flow path; an ammonia supply pipe inserted through the opening of the liner, wherein the ammonia supply pipe defines a space through which ammonia flows inside the ammonia supply pipe, wherein the ammonia supply pipe is a pipe for supplying the ammonia to the combustion chamber; the ammonia that flows through the space defined by the ammonia supply pipe, wherein the ammonia is within the ammonia supply pipe; a starting fuel supply pipe disposed between the ammonia supply pipe and the air flow path, wherein the starting fuel supply pipe covers a curved surface of the ammonia supply pipe, wherein the starting fuel supply pipe defines a space through which starting fuel flows between the ammonia supply pipe and the starting fuel supply pipe, wherein the starting fuel supply pipe is a pipe for supplying the starting fuel to the combustion chamber; and the starting fuel that flows through the space defined by and between the ammonia supply pipe and the starting fuel supply pipe, wherein the starting fuel is within the starting fuel supply pipe, wherein the ammonia supply pipe is inserted in the starting fuel supply pipe.

3. The combustion device according to claim 2, further comprising: a heat shielding pipe disposed between the starting fuel supply pipe and the air flow path.

4. The combustion device according to claim 2, wherein the ammonia supply pipe has a double pipe structure comprising an inner pipe and an outer pipe, the air flow path comprises a first air flow path disposed on a radially inner side with respect to the inner pipe and a second air flow path disposed on a radially outer side with respect to the outer pipe, and the starting fuel supply pipe comprises a first starting fuel supply pipe disposed between the inner pipe and the first air flow path and a second starting fuel supply pipe disposed between the outer pipe and the second air flow path.

5. The combustion device according to claim 3, wherein the ammonia supply pipe has a double pipe structure comprising an inner pipe and an outer pipe, the air flow path comprises a first air flow path disposed on a radially inner side with respect to the inner pipe and a second air flow path disposed on a radially outer side with respect to the outer pipe, and the starting fuel supply pipe comprises a first starting fuel supply pipe disposed between the inner pipe and the first air flow path and a second starting fuel supply pipe disposed between the outer pipe and the second air flow path.

6. The combustion device according to claim 4, further comprising: a first heat shielding pipe

disposed between the first starting fuel supply pipe and the first air flow path; and a second heat shielding pipe disposed between the second starting fuel supply pipe and the second air flow path.

7. The combustion device according to claim 5, wherein: the heat shielding pipe includes a first heat shielding pipe and a second heat shielding pipe, the first heat shielding pipe is disposed between the first starting fuel supply pipe and the first air flow path, and the second heat shielding pipe is disposed between the second starting fuel supply pipe and the second air flow path.

8. A gas turbine system comprising: the combustion device according to claim 2.

9. A gas turbine system comprising: the combustion device according to claim 3.

10. A gas turbine system comprising: the combustion device according to claim 4.

11. A gas turbine system comprising: the combustion device according to claim 5.

12. A gas turbine system comprising: the combustion device according to claim 4.

13. A gas turbine system comprising: the combustion device according to claim 7.

14. The gas turbine system according to claim 8, further comprising: a compressor configured to send the air that passes through the air flow path, wherein the compressor is fluidly connected to the air flow path; an ammonia tank configured to supply the ammonia to the ammonia supply pipe, wherein the ammonia tank is fluidly connected to the ammonia supply pipe; and a starting fuel tank configured to supply the starting fuel to the starting fuel supply pipe, wherein the starting fuel tank is fluidly connected to the starting fuel supply pipe.
