

COMBUSTION EQUIPMENT

TECHNICAL FIELD

5 [0001] The present disclosure relates to combustion equipment.

This application claims the priority of Japanese Patent Application No. 2021-167370 filed on October 12, 2021, the content of which is incorporated herein by reference.

BACKGROUND

10 [0002] Patent Document 1 describes combustion equipment for supplying additives (sulfur-containing additives) to fuel to be burned, in order to suppress corrosion which is caused by heavy metal and chlorine contained in the fuel. In the combustion equipment, the content of the heavy metal in ash produced by combustion of the fuel containing the heavy metal is detected, and based on the detected value, additive amounts of sulfur which is contained in the
15 additives supplied to the fuel is determined.

Citation List

Patent Literature

[0003]

20 Patent Document 1: JP2021-1701A

SUMMARY

[0004] However, in the combustion equipment described in Patent Document 1, since the ash obtained by burning the fuel is analyzed to measure the content of the heavy metal in the
25 ash, and based on the measurement result, the additive amounts of sulfur which is contained in the additives supplied to the fuel is determined, if the content of the heavy metal in the fuel fluctuates, the problem arises in that adjustment of the additive amounts of sulfur cannot quickly respond to the fluctuation in the content of the heavy metal in the fuel, resulting in a decrease

in the prevention effect of corrosion.

[0005] In view of the above, an object of at least one embodiment of the present disclosure is to provide combustion equipment that improves prevention effect of the corrosion caused by a corrosive compound contained in fuel being burned in a combustion device.

5 [0006] In order to achieve the above objectives, a combustion equipment according to the present disclosure includes: a combustion device for burning fuel containing chlorine element; a supply device for supplying sulfur-containing additives to the combustion device; an adjustment device for adjusting a supply amount of the sulfur-containing additives with the supply device; and a detection device for detecting an amount of chlorine element in a
10 combustion gas generated by combustion of the fuel in the combustion device. The adjustment device adjusts the supply amount such that the value of F_S/F_{Cl} falls within a predetermined range, where F_{Cl} is a detection value for the detection device and F_S is a supply amount of sulfur supplied to the combustion device for supplying the sulfur-containing additives to the combustion device with the supply device.

15 [0007] With the combustion equipment according to the present disclosure, by adjusting the supply amount of the sulfur-containing additives based on the amount of chlorine element in the combustion gas generated by combustion of the fuel in the combustion device, the supply amount of the sulfur-containing additives can rapidly be adjusted according to a change in behavior of a corrosive compound contained in the fuel. Thus, it is possible to improve
20 prevention effect of the corrosion caused by the corrosive compound contained in the fuel.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. 1 is a schematic view showing the configuration of combustion equipment according to an embodiment of the present disclosure.

25 FIG. 2 shows views for describing the outline of chemical thermodynamic calculation.

FIG. 3 is an example of a result from the chemical thermodynamic calculation.

FIG. 4 is another example of the result from the chemical thermodynamic calculation.

DETAILED DESCRIPTION

[0009] Hereinafter, combustion equipment according to the embodiments of the present disclosure will be described with reference to the drawings. The embodiment to be described below indicates one aspect of the present disclosure, does not intend to limit the disclosure, and can optionally be modified within a range of a technical idea of the present disclosure.

[0010] <Configuration of combustion equipment according to embodiment of present disclosure>

As shown in FIG. 1, combustion equipment 1 according to an embodiment of the present disclosure includes a boiler 2a which is a combustion device 2, a supply device 3 for supplying sulfur-containing additives to the boiler 2a, an adjustment device 4 for adjusting a supply amount of the sulfur-containing additives with the supply device 3, and a detection device 5 for detecting the amount of chlorine in a combustion gas produced by combustion of fuel in the combustion device 2.

[0011] The fuel burned in the boiler 2a is not particularly limited, and any fuel containing chlorine element may be used. In the following embodiments, the configuration and operation of the combustion equipment 1 will be described assuming that the boiler 2a is a waste fuel-fired boiler that uses chlorine element-containing waste as fuel. The boiler 2a includes a combustion furnace 11 in which fuel is burned, a flue gas duct 12 through which a combustion gas generated in the combustion furnace 11 flows, a heat transfer tube 13 disposed in the flue gas duct 12, and a hopper 14 for supplying the fuel to the combustion furnace 11.

[0012] Although the configuration of the supply device 3 is not particularly limited, it is possible to use, for example, the supply device 3 that includes a tank 21 for storing the sulfur-containing additives, a supply line 22 through which the tank 21 and the hopper 14 communicate with each other, and a supply pump 23 disposed on the supply line 22. Although a downstream end of the supply line 22 is connected to the hopper 14, it may be configured such that the downstream end is connected to the combustion furnace 11 for allowing the sulfur-containing additives to directly be supplied into the combustion furnace 11. Further, the supply device 3 is not limited to having only one tank 21, but may have at least two tanks. In

this case, the same type of sulfur-containing additives may be stored in the respective tanks, or different types of sulfur-containing additives may be stored in the respective tanks. Further, separate supply lines 22 may be disposed through which the respective tanks and the hopper 14 or the combustion furnace 11 communicate with each other, or it may be configured such that the supply lines extending from the respective tanks toward the hopper 14 or the combustion furnace 11 merge, and then a single line is connected to the hopper 14 or the combustion furnace 11. For the latter configuration, a switching device (for example, a switching valve or the like) for switching communication between one of the respective tanks and the hopper 14 or the combustion furnace 11 may be provided.

[0013] Although the configuration of the adjustment device 4 is not particularly limited, it is possible to use, for example, the adjustment device 4 that includes a bypass line 24 bypassing the supply pump 23, a flow control valve 25 disposed on the bypass line 24, and a flow sensor 26 disposed downstream of the bypass line 24 on the supply line 22. In this configuration, by controlling the opening degree of the flow control valve 25 such that a detection value by the flow sensor 26 becomes a set value, a part of the sulfur-containing additives discharged by the supply pump 23 is returned upstream of the supply pump 23, making it possible to adjust the supply amount of the sulfur-containing additives supplied to the boiler 2a. As an alternative configuration, although not shown, a device for changing the discharge amount of the supply pump 23 may be used as the adjustment device 4, as long as the configuration allows the supply pump 23 to adjust the discharge amount.

[0014] Since the high content of chlorine element in the fuel is one of the causes of corrosion in the heat transfer tube 13 or the like, the detection device 5 is preferably used as a device for detecting the amount of chlorine element in the fuel by detecting the amount of hydrogen chloride in the combustion gas. However, the detection device 5 is not limited to a hydrogen chloride meter or the like for detecting the amount of hydrogen chloride, but may be a device for directly measuring the amount of chlorine element, for example, a gas chromatograph mass spectrometer.

[0015] The combustion equipment 1 may include a control device 6 electrically connected

to the detection device 5, the flow control valve 25, and the flow sensor 26. The combustion equipment 1 may include an exhaust line 8 through which the flue gas duct 12 and a stack 7 communicate with each other, and a fan 9 disposed on the exhaust line 8.

[0016] <Operation of combustion equipment according to embodiment of present disclosure>

Next, an operation of the combustion equipment 1 according to an embodiment of the present disclosure will be described. Waste serving as fuel is supplied to the combustion furnace 11 via the hopper 14. Further, by driving the supply pump 23, the sulfur-containing additives stored in the tank 21 is supplied to the hopper 14 via the supply line 22. Consequently, the sulfur-containing additives and the waste are supplied to the combustion furnace 11. In the combustion furnace 11, the waste mixed with the sulfur-containing additives is burned.

[0017] The combustion gas generated by burning the waste in the combustion furnace 11 flows out of the combustion furnace 11 and flows through the flue gas duct 12, by driving the fan 9. When flowing through the flue gas duct 12, the combustion gas exchanges heat with a fluid (such as water) flowing inside the heat transfer tube 13, thereby heating the fluid and cooling the combustion gas. The heated fluid can be utilized, for example, as steam, to drive a power generation turbine (not shown). The combustion gas having heated the fluid sequentially flows through the flue gas duct 12 and the exhaust line 8, and are released into the atmosphere via the stack 7.

[0018] During the above-described operation, the detection device 5 detects an amount (mass flow rate) F_{Cl} of chlorine element in the combustion gas and transmits the detection result to the control device 6. The range of a mass ratio F_S/F_{Cl} is preset in the control device 6 in order to adjust the supply amount of the sulfur-containing additives for the purpose of suppressing adhesion of ash in the combustion gas to the heat transfer tube 13 or the like, or suppressing corrosion which is caused by the ash in the combustion gas adhering to the heat transfer tube 13 or the like. Here, F_S is the supply amount (mass flow rate) of sulfur supplied to the combustion device 2 by the supply device 3 supplying the sulfur-containing additives to

the combustion device 2. Since the sulfur content of the sulfur-containing additives stored in the tank 21 is known, the adjustment device 4 can adjust the supply amount of the sulfur-containing additives such that the value of F_S/F_{Cl} falls within the predetermined range.

[0019] The range of F_S/F_{Cl} can be determined in advance by calculation, experiment, or the like. Although the determination method by calculation will be described later, in order to suppress the corrosion which is caused by the ash in the combustion gas adhering to the heat transfer tube 13 or the like, it is preferable to satisfy $F_S/F_{Cl} > 0.3$, and in order to suppress the adhesion of the ash in the combustion gas to the heat transfer tube 13 or the like, it is preferable to satisfy $0.6 < F_S/F_{Cl} < 1.0$.

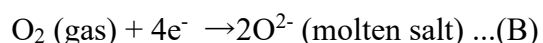
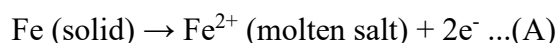
[0020] As described above, in the combustion equipment 1, by adjusting the supply amount of the sulfur-containing additives based on the amount of chlorine element in the combustion gas generated by combustion of the fuel in the combustion device 2, the supply amount of the sulfur-containing additives can rapidly be adjusted according to a change in behavior of a corrosive compound contained in the fuel. Thus, it is possible to improve prevention effect of the corrosion caused by the corrosive compound contained in the fuel.

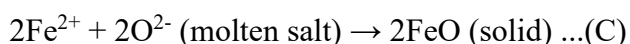
[0021] <Calculation method for determining range of F_S/F_{Cl} >

As described in the operation of the combustion equipment 1, since the combustion gas flowing through the flue gas duct 12 is cooled by exchanging heat with the fluid flowing inside the heat transfer tube 13, the ash in the combustion gas may be precipitated, adhere to the heat transfer tube 13 or the like, and corrode the heat transfer tube 13 or the like. If the fuel burned in the combustion device 2 contains chlorine element, the adhering ash contains chlorine element. In such a case, according to the studies of the inventors of the present disclosure, corrosion is caused by the following two mechanisms.

[0022] Mechanism 1: Reaction by molten salt in adhering ash

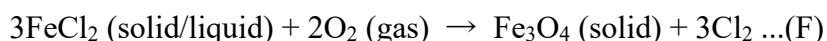
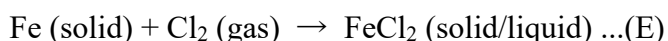
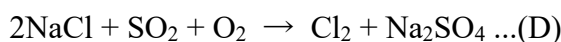
Corrosion reaction by molten salt is an electrochemical reaction, and corrosion (oxidation of iron) is caused by the following reactions (A) to (C).





[0023] Mechanism 2: Reaction by chlorine compound in adhering ash

Chlorine gas is generated by the following reaction (D) between chlorine in the adhering ash and sulfur dioxide in the combustion gas, and corrosion (oxidation of iron) is caused by the chlorine gas as in the following reactions (E) and (F).



[0024] The inventors of the present disclosure performed chemical thermodynamic calculation to estimate generation behavior of molten salt which is key to ash adhesion and corrosion. As shown in FIG. 2, the chemical thermodynamics calculation inputs each element content of supplies such as fuel, additives, and air introduced into the combustion furnace 11 (see FIG. 1) with Gibbs free energy information of each compound and each solution phase as a database ((1) in FIG. 2), performs calculation such that the Gibbs free energy of the entire system in the combustion furnace 11 is minimized ((2) in FIG. 2), and outputs an amount and a composition of each compound and each solution phase ((3) in FIG. 2). Here, each compound is a pure compound of gas phase, liquid phase, and solid phase. The solution phase has a non-stoichiometric proportion of constituent elements like molten salt or a solid solution, and molten salt is a liquid phase and a solid solution is a solid phase. The F_S/F_{Cl} value is changed by performing calculation of parametrically varying the calculation inputs, that is, the elements S and Cl supplied to the combustion furnace 11.

[0025] Such chemical thermodynamic calculation yields a relationship between F_S/F_{Cl} and the amount of O^{2-} in the liquid phase of the output. A graph showing the relationship is illustrated in FIG. 3. The influence of the basicity ($p\text{O}^{2-}$) of molten salt is known as the influence of the composition of molten salt, and it has been reported that the dissolution rate of a protective coating increases in a region of high basicity such as $p\text{O}^{2-} < 5$ (see T. Ishitsuka, K. Nose, Corrosion Science 44/2002/247-263). According to FIG. 3, in the range of $F_S/F_{Cl} > 0.3$, $p\text{O}^{2-} \geq 5$ is satisfied in a temperature range of 350°C to 550°C. Thus, it is considered that the

dissolution rate of the protective coating can be kept low. Therefore, by maintaining the condition of $F_S/F_{Cl} > 0.3$, it is possible to suppress the corrosion due to molten salt in the adhering ash.

[0026] Further, such chemical thermodynamic calculation yields a relationship between F_S/F_{Cl} and the melting percentage of ash. A graph showing the relationship is illustrated in FIG. 4. According to FIG. 4, in the range of $0.6 < F_S/F_{Cl} < 1$, in the temperature range of 350°C to 550°C, the melting percentage of ash can be kept low as compared with the range of $0.6 \geq F_S/F_{Cl}$ and $F_S/F_{Cl} \geq 1$. Therefore, by maintaining the condition of $0.6 < F_S/F_{Cl} < 1$, it is possible to suppress adhesion of ash.

[0027] The contents described in the above embodiments would be understood as follows, for instance.

[0028] [1] A combustion equipment according to one aspect includes: a combustion device (2) for burning fuel containing chlorine element; a supply device (3) for supplying sulfur-containing additives to the combustion device (2); an adjustment device (4) for adjusting a supply amount of the sulfur-containing additives with the supply device (3); and a detection device (5) for detecting an amount of chlorine element in a combustion gas generated by combustion of the fuel in the combustion device (2). The adjustment device (4) adjusts the supply amount such that the value of F_S/F_{Cl} falls within a predetermined range, where F_{Cl} is a detection value for the detection device (5) and F_S is a supply amount of sulfur supplied to the combustion device (2) for supplying the sulfur-containing additives to the combustion device (2) with the supply device (3).

[0029] With the combustion equipment according to the present disclosure, by adjusting the supply amount of the sulfur-containing additives based on the amount of chlorine element in the combustion gas generated by combustion of the fuel in the combustion device, the supply amount of the sulfur-containing additives can rapidly be adjusted according to a change in behavior of a corrosive compound contained in the fuel. Thus, it is possible to improve prevention effect of the corrosion caused by the corrosive compound contained in the fuel.

[0030] [2] A combustion equipment according to another aspect is the combustion

equipment as defined in [1], where the range is $F_S/F_{Cl} > 0.3$.

[0031] With such configuration, it is possible to suppress corrosion which is caused by ash in the combustion gas adhering to the heat transfer tube or the like.

[0032] [3] A combustion equipment according to still another aspect is the combustion equipment as defined in [1] or [2], where the range is $0.6 < F_S/F_{Cl} < 1.0$.

[0033] With such configuration, it is possible to suppress adhesion of the ash in the combustion gas to the heat transfer tube or the like.

[0034] [4] A combustion equipment according to yet another aspect is the combustion equipment as defined in any one of [1] to [3], where the range is determined based on a result

from chemical thermodynamic calculation, and the chemical thermodynamics calculation inputs each element content of supplies introduced into the combustion device (2), performs calculation such that Gibbs free energy of an entire system in the combustion device (2) is minimized, and outputs an amount and a composition of each compound and each solution phase to perform calculation of parametrically varying sulfur and chlorine supplied to the combustion device (2).

[0035] With such configuration, the range of F_S/F_{Cl} can be determined without experiment.

CLAIMS

1. A combustion equipment, comprising:
 - a combustion device for burning fuel containing chlorine element;
 - 5 a supply device for supplying sulfur-containing additives to the combustion device;
 - an adjustment device for adjusting a supply amount of the sulfur-containing additives with the supply device; and
 - a detection device for detecting an amount of chlorine element in a combustion gas generated by combustion of the fuel in the combustion device,
 - 10 wherein the adjustment device adjusts the supply amount such that the value of F_S/F_{Cl} falls within a predetermined range, where F_{Cl} is a detection value for the detection device and F_S is a supply amount of sulfur supplied to the combustion device for supplying the sulfur-containing additives to the combustion device with the supply device.
- 15 2. The combustion equipment according to claim 1,
 - wherein the range is $F_S/F_{Cl} > 0.3$.
3. The combustion equipment according to claim 1 or 2,
 - wherein the range is $0.6 < F_S/F_{Cl} < 1.0$.
- 20 4. The combustion equipment according to any one of claims 1 to 3,
 - wherein the range is determined based on a result from chemical thermodynamic calculation, and
 - wherein the chemical thermodynamics calculation inputs each element content of supplies
 - 25 introduced into the combustion device, performs calculation such that Gibbs free energy of an entire system in the combustion device is minimized, and outputs an amount and a composition of each compound and each solution phase to perform calculation of parametrically varying sulfur and chlorine supplied to the combustion device.