

DESCRIPTION

EXHAUST HEAT RECOVERY BOILER AND METHOD FOR CONTROLLING TEMPERATURE OF HEAT TRANSFER PIPE OF EXHAUST HEAT RECOVERY BOILER

TECHNICAL FIELD

[0001] The present invention relates to an exhaust heat recovery boiler and a method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler.

BACKGROUND ART

[0002] An exhaust heat recovery boiler is provided with a heat exchanger such as a superheater, an evaporator, or an economizer that recovers heat, and a heat transfer pipe is accommodated in the heat exchanger. Exhaust gas heated to a high temperature is supplied from an upstream side of a duct of the exhaust heat recovery boiler, and heat exchange is performed by the exhaust gas being brought into contact with the heat transfer pipe. The exhaust gas contains sulfur oxide (SO_x) and water vapor (H_2O) generated in combustion. A part of sulfur oxide generates a sulfuric acid (H_2SO_4) through a reaction with water vapor. Therefore, if the surface temperature of the heat transfer pipe that performs heat exchange becomes equal to or less than the dew point of the sulfuric acid, then the sulfuric acid is condensed on the surface of the heat transfer pipe, a corrosion rate of the surface of the heat transfer pipe significantly increases, and a steel material constituting the heat transfer pipe significantly corrodes. Also, exhaust gas generated from municipal refuse incinerators contains a large amount of chlorides such as hydrogen chloride (HCl), and heat transfer pipes similarly cause corrosion when the surface temperatures of the heat transfer pipes become equal to or less than the dew point of hydrogen chloride. Moreover, chlorides containing alkali metal and heavy metal adhere to heat transfer surfaces, and the heat transfer pipes corrode due to deliquescence and melting of the chlorides. Therefore, there is a concern of troubles due to the corrosion of such boilers in which exhaust gas is brought into contact with

heat transfer pipes, and methods for curbing the corrosion have been considered. For example, PTL 1 describes a boiler that controls a corrosion rate.

[0003] The boiler described in PTL 1 includes a dew point corrosion monitoring probe, an exhaust gas duct, and an economizer. Also, the economizer is provided with a heat transfer pipe that is disposed inside the exhaust gas duct, an economizer temperature control device that controls water feed to the heat transfer pipe to adjust the temperature of the heat transfer pipe, and a system control device that controls the economizer.

The dew point corrosion monitoring probe is disposed in proximity to the heat transfer pipe of the economizer, and a corrosion rate is measured in the boiler using the dew point corrosion monitoring probe. Also, the system control device determines, from measurement data of the corrosion rate, a target operating temperature such that the corrosion rate becomes a value that is not problematic in practical use. Thereafter, the temperature of the heat transfer pipe of the economizer is controlled to become the target operating temperature. As a control method, either a method of adjusting the amount of heat generated by the boiler or a method of adjusting the amount of cooling water flowing through the heat transfer pipe of the economizer, which is controlled by the economizer temperature control device, is employed. In this manner, the boiler protects the heat transfer pipe from corrosion.

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: Japanese Patent Laid-Open No. 2006-258603

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] As described above, the boiler described in PTL 1 adjusts the temperature of the heat transfer pipe such that the corrosion rate of the heat transfer pipe becomes a value which is not problematic in practical use, by adjusting the amount of heat generated by the boiler or by adjusting the amount of cooling water flowing through the heat transfer pipe.

However, in a case where the exhaust heat recovery boiler including the heat transfer pipe is used for a waste disposal facility, the amount of waste to be disposed may be fixed in advance, and it may not be possible to cause the amount of waste to be burned to increase. Also, it may be difficult to adjust the amount of heat generated from the waste and the temperature and composition of the exhaust gas since a variety of wastes are burned. In this case, the amount of heat generated by the boiler cannot be caused to increase, and it is thus not possible to curb corrosion of the heat transfer pipe.

Also, the temperature of the water flowing inside the heat transfer pipe has a stronger influence on the surface temperature of the heat transfer pipe than the temperature of the exhaust gas that is brought into contact with the surface of the heat transfer pipe. Therefore, even if the amount of water flowing inside the heat transfer pipe is reduced, it is not possible to significantly raise the surface temperature of the heat transfer pipe as long as the temperature of the water is constant. Therefore, it is not possible to significantly raise the temperature of the heat transfer pipe although the adjustment of the amount of water caused to flow through the heat transfer pipe has an advantage to some extent. Thus, it may be difficult to raise the surface temperature of the heat transfer pipe to a temperature at which the corrosion rate becomes a value that is not problematic in practical use in a case where the method of adjusting the amount of cooling water flowing through the heat transfer pipe is employed. In this case, it is not possible to curb corrosion of the heat transfer pipe.

Thus, an object of the present invention is to provide an exhaust heat recovery boiler and a method for controlling an exhaust heat recovery boiler capable of curbing corrosion of a heat transfer pipe without performing adjustment of the amount of heat generated by the boiler and adjustment of the amount of water flowing through a heat transfer pipe in view of the aforementioned problems.

SOLUTION TO PROBLEM

[0006] (First Aspect)

An exhaust heat recovery boiler according to a first aspect includes: a duct including a flow path through which exhaust gas flows; a heat transfer pipe including a water inlet and

a water outlet and disposed inside the duct; a water feed piping connected to the water inlet of the heat transfer pipe, including a flow splitter, a flow combiner located on a side further downstream than the flow splitter, a first piping forming a part from the flow splitter to the flow combiner, and a second piping branched from the first piping at the flow splitter and then meeting the first piping again at the flow combiner, and configured to feed water that has passed through the flow combiner to the water inlet of the heat transfer pipe; a tank in fluid communication with the water outlet of the heat transfer pipe, at least a part of the second piping being disposed inside the tank; a water amount adjustment valve configured to adjust a ratio between a flow amount of water flowing through the first piping and a flow amount of water flowing through the second piping; a measurement device configured to measure at least one of a corrosion rate, a temperature, and exhaust gas composition inside the duct; and a control device configured to perform control to adjust the water amount adjustment valve in accordance with a result of the measurement performed by the measurement device.

According to the exhaust heat recovery boiler in the first aspect, water or water vapor heated to a high temperature through the heat transfer pipe flows into the tank. Since at least a part of the second piping is disposed inside the tank, water passing through the second piping is heated to a higher temperature than the temperature of the water passing through the first piping. Also, the control device can adjust the ratio between the flow amount of the water flowing through the first piping and the flow amount of the water flowing through the second by controlling the water amount adjustment valve. In other words, the control device can control the temperature of the water flowing into the heat transfer pipe by controlling the flow amount of the water at a low temperature passing through the first piping and the flow amount of the water at a high temperature passing through the second piping. Here, the temperature of the water flowing inside the heat transfer pipe more dominantly acts on the surface temperature of the heat transfer pipe than the temperature of the exhaust gas that is brought into contact with the surface of the heat transfer pipe. Therefore, the exhaust heat recovery boiler can cause the surface temperature

of the heat transfer pipe to significantly change. In other words, the control device can perform control to significantly change the surface temperature of the heat transfer pipe in accordance with a result of the measurement of at least one of the corrosion rate, the temperature, and the exhaust gas composition and can adjust the corrosion rate of the heat transfer pipe in a negative correlation with the surface temperature of the heat transfer pipe in the vicinity of the dew point. According to the exhaust heat recovery boiler, it is thus possible to curb corrosion of the heat transfer pipe.

[0007] (Second Aspect)

According to the exhaust heat recovery boiler in a second aspect, the tank is a steam drum (steam separator) configured to separate water and water vapor, in the exhaust heat recovery boiler described in the first aspect.

The exhaust heat recovery boiler may include a steam drum used to separate water vapor and water. According to the exhaust heat recovery boiler in the second aspect, the steam drum is used as the tank described in the first aspect. In other words, the exhaust heat recovery boiler can realize the configuration of the exhaust heat recovery boiler according to the first aspect without newly including an additional tank.

[0008] (Third Aspect)

According to the exhaust heat recovery boiler in a third aspect, at least a part of the second piping is disposed in a part of the tank in which water is stored, in the exhaust heat recovery boiler described in the first aspect or the second aspect.

According to the exhaust heat recovery boiler in the third aspect, at least a part of the second piping is in direct contact with water heated at a high temperature through the heat transfer pipe. Therefore, the water in the tank can directly heat the second piping. In other words, the exhaust heat recovery boiler can raise the temperature of the water flowing through the second piping to a higher temperature as compared with a case in which the second piping is brought into contact only with water vapor inside the tank. Also, the exhaust heat recovery boiler can feed the water heated to the higher temperature to the heat transfer pipe.

[0009] (Fourth Aspect)

The exhaust heat recovery boiler in a fourth aspect further includes a water temperature gauge configured to measure a water temperature between the flow combiner of the water feed piping and the water inlet of the heat transfer pipe, and the control device adjusts and controls the water amount adjustment valve in accordance with a result of the measurement performed by the water temperature gauge, in the exhaust heat recovery boiler described in any one of the first to third aspects.

According to the exhaust heat recovery boiler in the fourth aspect, the water temperature of the water to be supplied to the heat transfer pipe is measured by the water temperature gauge. Therefore, the control device can adjust the temperature of the water to be supplied to the heat transfer pipe to a specific temperature by adjusting the water amount adjustment valve in accordance with the result of the measurement performed by the water temperature gauge. In other words, according to the exhaust heat recovery boiler, it is possible to feed the water adjusted to the specific temperature to the heat transfer pipe.

[0010] (Fifth Aspect)

According to the exhaust heat recovery boiler in a fifth aspect, the measurement device includes a corrosion monitoring probe including a first corrosion sensor and a probe temperature adjustment mechanism, the first corrosion sensor including an electrode member with an electrode surface exposed to an inside of the duct, and the probe temperature adjustment mechanism being configured to adjust a temperature of the electrode member, and the control device causes the corrosion monitoring probe to measure corrosion rates at a plurality of different temperatures by controlling the probe temperature adjustment mechanism of the corrosion monitoring probe, determines a temperature of the water to be supplied to the heat transfer pipe to obtain a corrosion rate below an acceptable value from a result of the measurement of the corrosion rates at the plurality of different temperatures, and adjusts and controls the temperature of the water to be supplied to the heat transfer pipe to the determined temperature, in the exhaust heat recovery boiler described in any one of the first to fourth aspects.

In the exhaust heat recovery boiler according to the fifth aspect, the corrosion monitoring probe includes the probe temperature adjustment mechanism, and the corrosion monitoring probe can thus measure the corrosion rates at the different temperatures. In this manner, the control device can acquire a relationship between the corrosion rates and the temperatures in the duct and can determine the temperature to obtain the corrosion rate below the acceptable value. Also, the control device can control the temperature of the water to be supplied to the heat transfer pipe in accordance with the determined temperature. In other words, the exhaust heat recovery boiler can perform control to obtain the corrosion rate below the acceptable value.

[0011] (Sixth Aspect)

According to the exhaust heat recovery boiler in a sixth aspect, the measurement device includes a second corrosion sensor including an electrode member exposed to an inside of the duct and being capable of measuring a corrosion rate, and the control device performs control to cause the ratio of the flow amount of the water flowing through the second piping with respect to the flow amount of the water flowing through the first piping to increase when the corrosion rate measured by the second corrosion sensor exceeds an acceptable value, in the exhaust heat recovery boiler described in any one of the first to fifth aspects.

According to the exhaust heat recovery boiler in the sixth aspect, the temperature of the water to be supplied to the heat transfer pipe is raised by controlling the ratio of the flow amounts when the corrosion rate exceeds the acceptable value. Therefore, the exhaust heat recovery boiler can prevent the corrosion rate from exceeding the acceptable value.

[0012] (Seventh Aspect)

According to the exhaust heat recovery boiler in a seventh aspect, the measurement device includes a thermometer configured to measure a temperature in a vicinity of the heat transfer pipe, and the control device performs control to cause the ratio of the flow amount of the water flowing through the second piping with respect to the flow amount of the water flowing through the first piping to increase when the temperature in the vicinity of the heat

transfer pipe measured by the thermometer is below a predetermined reference temperature, in the exhaust heat recovery boiler described in any one of the first to sixth aspects.

It is known that a temperature and a corrosion rate have a negative correlation in the vicinity of the dew point. Therefore, the corrosion rate is estimated if the temperature is known. Therefore, if the surface temperature of the heat transfer pipe is maintained at a specific temperature or higher, then the corrosion rate can be maintained at a specific value or less. The exhaust heat recovery boiler according to the seventh aspect raises the temperature of the water to be supplied to the heat transfer pipe in accordance with the temperature measured by the thermometer. Therefore, the exhaust heat recovery boiler can maintain the corrosion rate at a specific value or less.

[0013] (Eighth Aspect)

According to the exhaust heat recovery boiler in an eighth aspect, the measurement device includes at least one of an SO_x analyzer configured to measure a concentration of sulfur oxide, an HCl analyzer configured to measure a concentration of hydrogen chloride, and a moisture meter configured to measure a concentration of moisture inside the duct, the sulfur oxide, the hydrogen chloride, and the moisture being exhaust gas composition, and the control device predicts a dew point temperature and determines a reference temperature in accordance with at least one of results of the measurement of the concentration of the sulfur oxide, the concentration of the hydrogen chloride, and the concentration of the moisture, in the exhaust heat recovery boiler described in the first to seventh aspects.

It is known that the corrosion rate changes due to the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture as well as the temperature. Therefore, the exhaust heat recovery boiler can more accurately estimate the corrosion rate in consideration of at least one of the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture, which are measured, in estimating the corrosion rate.

[0014] (Ninth Aspect)

According to the exhaust heat recovery boiler in a ninth aspect, the water amount adjustment valve includes a first valve attached to the first piping and configured to adjust the flow amount of the water flowing through the first piping and a second valve attached to the second piping and configured to adjust the flow amount of the water flowing through the second piping, in the exhaust heat recovery boiler described in any one of the first to eighth aspects.

The exhaust heat recovery boiler according to the ninth aspect can individually adjust the flow amount of the water flowing through the first piping and the flow amount of the water flowing through the second piping with the different valves. Therefore, the exhaust heat recovery boiler can easily control the flow amount of the water flowing through the first piping and the flow amount of the water flowing through the second piping.

[0015] (Tenth Aspect)

A method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler according to a tenth aspect includes: by using the exhaust heat recovery boiler including a duct including a flow path through which exhaust gas flows, a heat transfer pipe including a water inlet and a water outlet and disposed inside the duct, a water feed piping connected to the water inlet of the heat transfer pipe, including a flow splitter, a flow combiner located on a side further downstream than the flow splitter, a first piping forming a part from the flow splitter to the flow combiner, and a second piping branched from the first piping at the flow splitter and then meeting the first piping again at the flow combiner, and configured to feed water that has passed through the flow combiner to the water inlet of the heat transfer pipe, and a tank connected to the water outlet, at least a part of the second piping being disposed inside the tank, a measurement process of measuring at least one of a corrosion rate, a temperature, and exhaust gas composition inside the duct; a temperature determination process of determining a temperature of the water to be supplied to the heat transfer pipe in accordance with a result of the measurement in the measurement process; and a temperature adjustment process of adjusting a ratio between a flow amount of water flowing through the first piping and a flow amount of water flowing through the second

piping to adjust a surface temperature of the heat transfer pipe to the temperature determined in the temperature determination process.

In the method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler according to the tenth aspect, the temperature of the water to flow into the heat transfer pipe is adjusted, and the surface temperature of the heat transfer pipe is adjusted, by adjusting the flow amount of the water at a low temperature passing through the first piping and the flow amount of the water at a high temperature passing through the second piping. Therefore, the method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler can cause the surface temperature of the heat transfer pipe to significantly change similarly to the first aspect. Therefore, the method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler can curb corrosion of the heat transfer pipe.

[0016] (Eleventh Aspect)

According to the method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler in an eleventh aspect, the measurement process includes a process of measuring corrosion rates at a plurality of different temperatures inside the duct, and the temperature determination process includes a process of determining the temperature of the water to be supplied to the heat transfer pipe to obtain a corrosion rate below an acceptable value from a result of the measurement of the corrosion rates at the plurality of different temperatures, in the method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler described in the tenth aspect.

The method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler according to the eleventh aspect can obtain a corrosion rate below an acceptable value similarly to the fifth aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0017] Fig. 1 is a structure diagram illustrating a configuration of an exhaust heat recovery boiler according to a first embodiment of the present invention.

Fig. 2 is a detailed diagram illustrating details of a part corresponding to an economizer of the exhaust heat recovery boiler illustrated in Fig. 1.

Fig. 3 is a sectional view illustrating a configuration of a corrosion monitoring probe of the exhaust heat recovery boiler illustrated in Fig. 2.

Fig. 4 is a plan view illustrating a main part of the corrosion monitoring probe illustrated in Fig. 3.

Fig. 5 is a flow chart illustrating a procedure of a control process for the exhaust heat recovery boiler illustrated in Fig. 1.

DESCRIPTION OF EMBODIMENTS

[0018] Hereinafter, embodiments of the present invention will be described with reference to the drawings. The same reference signs will be applied to the same or corresponding components in the drawings described below, and repeated description will be omitted.

[0019] [First Embodiment]

<Configuration>

Fig. 1 is a structure diagram illustrating a configuration of an exhaust heat recovery boiler according to a first embodiment of the present invention. Referring to Fig. 1, an exhaust heat recovery boiler 100 includes a duct 120, a superheater 140, an economizer 300, a steam drum 160, a high-pressure steam receiver 180, and an evaporator (not illustrated). The exhaust heat recovery boiler 100 is a device that causes water vapor to be generated using heat of exhaust gas. Although the exhaust heat recovery boiler 100 is of a longitudinal type in which the exhaust gas flows in the longitudinal direction in an example, the exhaust heat recovery boiler 100 may be of a gas transverse flow type in which the exhaust gas flows in the transverse direction. The water vapor generated by the exhaust heat recovery boiler 100 is supplied to a steam turbine (not illustrated) and is then used to drive a generator in an example.

[0020] Hereinafter, each component of the exhaust heat recovery boiler 100 will be described separately.

An upstream side of the duct 120 is in fluid communication with an exhaust gas duct (not illustrated) of a combustion facility such as a municipal refuse incinerator in an example. The combustion facility supplies high-temperature exhaust gas to the exhaust gas duct. Therefore, a flow path through which the exhaust gas flows is formed in the duct 120. The exhaust gas contains sulfur oxide, hydrogen chloride, water vapor, and the like generated in combustion in the combustion facility.

The economizer 300 is located on a side downstream the flow path formed in the duct 120 than the superheater 140, which will be described later. Water is supplied from a water feed section 900 to the economizer 300. Then, the economizer 300 preheats the supplied water using the exhaust gas and supplies the preheated water to the steam drum 160.

The steam drum 160 is a container that accommodates water and water vapor and has a function of separating the water and the water vapor. The water vapor separated by the steam drum 160 is supplied to the superheater 140, which will be described later. On the other hand, the water separated by the steam drum 160 is supplied to an evaporator (not illustrated).

The evaporator is a heat exchanger that further heats the water supplied from the steam drum 160. The evaporator changes at least a part of the water into water vapor by heating the supplied water.

The superheater 140 is a heat exchanger that further overheats the supplied water vapor. The superheater 140 supplies the supplied water vapor as overheated steam to the high-pressure steam receiver 180.

The high-pressure steam receiver 180 accommodates the overheated steam. Also, the high-pressure steam receiver 180 is connected to a steam turbine and supplies the accommodated overheated steam to the steam turbine in an example.

In this manner, each component of the exhaust heat recovery boiler 100 has the configuration as described above, and it is thus possible to convert the water supplied to the economizer 300 into overheated steam and to feed the overheated steam to the steam turbine.

[0021] Next, a configuration of a part corresponding to the economizer 300 of the exhaust heat recovery boiler 100 will be described in more detail with reference to Fig. 2. Fig. 2 is a detailed diagram illustrating details of a part corresponding to the economizer 300 of the exhaust heat recovery boiler 100. Referring to Fig. 2, the exhaust heat recovery boiler 100 further includes a water feed piping 400, a water amount adjustment valve 500, a measurement device 600, a water temperature gauge 700, and a control device 800.

The economizer 300 includes a heat transfer pipe 320. The heat transfer pipe 320 includes a water inlet 322 and a water outlet 324, and water flows from the water inlet 322 toward the water outlet 324. Also, the heat transfer pipe 320 is disposed inside the duct 120. In other words, the heat transfer pipe 320 is disposed at such a position that the surface of the heat transfer pipe 320 can be brought into contact with the exhaust gas flowing inside the duct 120. In this manner, the heat transfer pipe 320 has a function of causing heat exchange between the water flowing inside the heat transfer pipe 320 and the exhaust gas that is brought into contact with the surface of the heat transfer pipe 320.

[0022] The water feed piping 400 is connected to the water feed section 900 and the water inlet 322 of the heat transfer pipe 320. The water feed piping 400 includes a flow splitter 462, a flow combiner 464 located on a side further downstream than the flow splitter 462, a first piping 420, and a second piping 440. The first piping 420 forms a part from the flow splitter 462 to the flow combiner 464. The second piping 440 is branched from the first piping 420 at the flow splitter 462 and then meets the first piping 420 again at the flow combiner 464. Also, the water feed piping 400 supplies water that has passed through the flow combiner 464 to the water inlet 322 of the heat transfer pipe 320. Therefore, the water feed piping 400 can branch the water supplied from the water feed section 900 into water flowing through the first piping 420 and water flowing through the second piping 440 using the flow splitter 462 and can cause the water flowing through the first piping 420 and the water flowing through the second piping 440 to meet using the flow combiner 464. In other words, the water feed piping 400 can feed the water that has passed through the first piping 420 or the second piping 440 to the water inlet 322.

[0023] The water amount adjustment valve 500 includes a first valve 520 and a second valve 540 in an example. The first valve 520 is attached to the first piping 420. In this manner, the first valve 520 can adjust the flow amount of the water flowing through the first piping 420. On the other hand, the second valve 540 is attached to the second piping 440. In this manner, the second valve 540 can adjust the flow amount of the water flowing through the second piping 440. In other words, the water amount adjustment valve 500 can adjust the ratio between the flow amount of the water flowing through the first piping 420 and the flow amount of the water flowing through the second piping 440.

[0024] The steam drum 160 is in fluid communication with the water outlet 324 of the heat transfer pipe 320. In this manner, the water heated through the heat transfer pipe 320 flows into the steam drum 160. In other words, the temperature of the water accommodated in the steam drum 160 is higher than the temperature of the water supplied by the water feed section 900. Also, at least a part of the second piping 440 is disposed inside the steam drum 160. Therefore, the water passing through the second piping 440 is heated by water or water vapor inside the steam drum 160. Then, the temperature of the water that has passed through the second piping 440 is higher than the temperature of the water that has passed through the first piping 420. Therefore, the temperature of the water to be supplied to the heat transfer pipe 320 changes if the ratio between the flow amount of the water flowing through the first piping 420 and the flow amount of the water flowing through the second piping 440 is adjusted. Also, at least a part of the second piping 440 is disposed at a part of the steam drum 160 in which water is stored in the present embodiment. In other words, the second piping 440 is brought into contact with the water stored in the steam drum 160.

[0025] The measurement device 600 measures at least one of a corrosion rate, a temperature, and exhaust gas composition inside the duct 120. More specifically, the measurement device 600 includes a corrosion monitoring probe 620 (hereinafter, referred to as a probe 620) in an example. The probe 620 includes a probe temperature adjustment mechanism 624, which will be described later, and can thus measure the corrosion rate inside the duct 120 at a set temperature.

[0026] Here, an example of the probe 620 will be described in more detail. Fig. 3 is a sectional view illustrating a configuration of the probe 620 of the exhaust heat recovery boiler 100. Also, Fig. 4 is a plan view illustrating a main part of the probe 620. Referring to Figs. 3 and 4, the probe 620 include a first corrosion sensor including a pair of electrode members 622a and 622b for measuring a corrosion rate, the probe temperature adjustment mechanism 624, an electrode 626 for measuring a temperature, such as a thermocouple, a holder 628, a cover 630, a conductive wire 636, a conductive wire 637, a connection pipe 638, an impedance measurement device 640, and a temperature gauge 650. Also, the probe temperature adjustment mechanism 624 includes a temperature adjustment gas source 648, a temperature adjustment valve 642, a gas feed pipe 644, a flowmeter 645, and a probe electrode temperature control device 646,

[0027] In the present embodiment, the electrode members 622a and 622b are made of two conductive bodies of the same material. More specifically, the electrode members 622a and 622b are made of the same material as the material of the heat transfer pipe 320 in view of detection of the corrosion rate of the heat transfer pipe 320 in an example. Also, the electrode members 622a and 622b are rectangular parallelepipeds with substantially square planner shape and are adjacent to each other at a clearance therebetween (see Fig. 4). In this manner, a flow path forming section 634 for forming a flow path of condensed water is formed between the electrode members 622a and 622b. In addition, the electrode members 622a and 622a are embedded in the holder 628. Each of surfaces on one side (hereinafter, referred to as front side surfaces) of the electrode members 622a and 622b is exposed to the inside of the duct 120, and each of the other surfaces (hereinafter, referred to as rear side surfaces) is connected to the conductive wire 636. Then, the conductive wire 636 passes through the inside of the connection pipe 638 and is connected to the impedance measurement device 640. In this manner, the impedance measurement device 640 can measure the impedance between the electrode members 622a and 622b by applying an AC voltage to the electrode members 622a and 622b. Also, the impedance measurement device 640 is connected to the control device 800. In this manner, the control device 800 can

acquire the measured impedance. Then, the control device 800 can obtain a reaction resistance and a solution resistance in a distinguished manner by performing frequency analysis on the measured impedance. Moreover, the control device 800 can calculate the corrosion rate from the reaction resistance and the solution resistance using a known method. In other words, the control device 800 can acquire data regarding the corrosion rate.

[0028] The electrode 626 for measuring a temperature is embedded in the holder 628 similarly to the electrode members 622a and 622b. A surface on one side of the electrode 626 is exposed to the inside of the duct 120, and the other surface is connected to the conductive wire 637. The conductive wire 637 passes through the inside of the connection pipe 638 and is then connected to the temperature gauge 650. In this manner, the temperature gauge 650 can measure the temperature of the part corresponding to the electrode 626, that is, the temperature in the vicinity of the electrode members 622a and 622b for measuring a corrosion rate. Also, the temperature gauge 650 is connected to the control device 800. In this manner, the control device 800 can acquire data regarding the temperature in the vicinity of the electrode members 622a and 622b.

[0029] The cover 630 forms a heat medium space 632 through close contact with the holder 628. In this manner, each of the surfaces of the electrode members 622a and 622b connected to the conductive wire 636 and the surface of the electrode 626 connected to the conductive wire 637 is exposed to the heat medium space 632. Also, the connection pipe 638 for causing a heat medium such as air or water to flow to the heat medium space 632 is attached to the cover 630. Moreover, the gas feed pipe 644 is inserted into the connection pipe 638. The gas feed pipe 644 connects the temperature adjustment gas source 648 such as a compressor or a gas cylinder to the heat medium space 632. Also, the temperature adjustment valve 642 and the flowmeter 645 are provided between the temperature adjustment gas source 648 and the heat medium space 632. Therefore, temperature adjustment gas supplied from the temperature adjustment gas source 648 is supplied to the heat medium space 632 through adjustment of the temperature adjustment valve 642. In other words, the temperature of the heat medium space 632 approaches the temperature of the

temperature adjustment gas to be supplied. In this manner, the probe electrode temperature control device 646 can adjust the temperatures of the electrode members 622a and 622b for measuring a corrosion rate and of the electrode 626 for measuring a temperature to set temperatures. In other words, the probe 620 can measure the corrosion rate at the set temperature through the adjustment of the temperature of the electrode members 622a and 622b for measuring a corrosion rate using the probe temperature adjustment mechanism 624.

The probe 620 included in the measurement device 600 has been described hitherto. Note that the probe 620 need not have the aforementioned configuration as long as the probe 620 has a function with which the corrosion rate inside the duct 120 can be measured at a set temperature.

[0030] Reference of Fig. 2 will be made again. In the exhaust heat recovery boiler 100, the probe 620 is disposed in the vicinity of the heat transfer pipe 320 in an example. In this manner, the probe 620 can measure the corrosion rate that is approximated to the corrosion rate of the heat transfer pipe 320. Here, the vicinity of the heat transfer pipe 320 means the position at which the heat transfer pipe 320 and the material disposed at a position in the vicinity have the same corrosion rate when the same material as that of the heat transfer pipe 320 is disposed at the position in the vicinity.

[0031] The water temperature gauge 700 is located between the flow combiner 464 of the water feed piping 400 and the water inlet 322 of the heat transfer pipe 320 in an example. In this manner, the water temperature gauge 700 has a function of measuring a water temperature between the flow combiner 464 of the water feed piping 400 and the water inlet 322 of the heat transfer pipe 320. In other words, the water temperature gauge 700 can measure the water temperature supplied to the heat transfer pipe 320.

The control device 800 can cause the probe 620 to measure corrosion rates at a plurality of different temperatures by controlling the probe temperature adjustment mechanism 624 of the probe 620. Also, the control device 800 can determine the temperature of the water to be supplied to the heat transfer pipe 320 to obtain a corrosion rate below the acceptable value from a result of measuring the corrosion rates at the plurality of

different temperatures obtained by the probe 620. Note that the acceptable value is a value that can be arbitrarily determined. More specifically, the acceptable value can be determined in accordance with a facility lifetime, running conditions, and the like. Also, the control device 800 adjusts and controls the temperature of the water to be supplied to the heat transfer pipe 320 to the determined temperature by adjusting the water amount adjustment valve 500 in accordance with a result of the measurement performed by the water temperature gauge 700.

[0032] <Method for Controlling Temperature of Heat Transfer Pipe of Exhaust Heat Recovery Boiler>

Next, a method for controlling a temperature of the heat transfer pipe 320 of the exhaust heat recovery boiler 100 according to the present embodiment will be described. For explaining the method for controlling the temperature of the heat transfer pipe 320 of the exhaust heat recovery boiler 100, an initial state of each component constituting the exhaust heat recovery boiler 100 will be described.

In the initial state, exhaust gas is included inside the duct 120. Also, the water feed section 900 has supplied water to the water feed piping 400. Therefore, the water that has been supplied has been supplied to the heat transfer pipe 320 via the water feed piping 400. Also, the water that has been supplied to the heat transfer pipe 320 is heated by the heat transfer pipe 320 and is then supplied to the steam drum 160.

[0033] On the assumption of the above description, the method for controlling the temperature of the heat transfer pipe 320 of the exhaust heat recovery boiler 100 will be described with reference to the drawings. Fig. 5 is a flow chart illustrating a procedure of a method for controlling the temperature of the heat transfer pipe 320 of the exhaust heat recovery boiler 100.

[0034] Referring to Fig. 5, the control device 800 checks the temperature of the water to be supplied to the heat transfer pipe 320 using the water temperature gauge 700 in Step S100. Then, the control device 800 acquires information regarding the temperature of the water to be supplied. In Step S200, control is performed such that the temperature of the probe

620 is changed to and maintained at a predetermined temperature for a specific period of time through control of the probe temperature adjustment mechanism 624.

Next, the control device 800 acquires the temperature of the probe 620 from an output of the probe 620 in Step S300. Then, the control device 800 confirms that the probe 620 is at a predetermined temperature.

Next, the control device 800 measures a corrosion rate corresponding to the temperature for a specific period of time from the output of the probe 620 and acquires information regarding the corrosion rate in Step S400.

Then, the control device 800 determines whether or not the corrosion rate at the predetermined temperature acquired from the output of the probe 620 is equal to or greater than an acceptable value in Step S500. In a case where the corrosion rate at the predetermined temperature is not equal to or greater than the acceptable value, the control device 800 returns the processing to Step S200. Then, the control device 800 sets a temperature, at which the corrosion rate has not been measured, which is lower than the temperature of the probe 620 set in previous Step S200, as a new predetermined temperature in Step S200 performed again. Thereafter, the control device 800 causes the temperature of the probe 620 to drop to the newly set predetermined temperature through control of the probe temperature adjustment mechanism 624. In this manner, the control device 800 can acquire information regarding the corrosion rate at the temperature, at which the corrosion rate has not been measured, through the following repetition.

On the other hand, in a case where the corrosion rate is equal to or greater than the acceptable value in Step S500, the control device 800 moves on to the processing in Step S600. The control device 800 can acquire the information regarding the corrosion rates at a plurality of different temperatures by the control device 800 repeating the processing in Steps S200 to S400 until the corrosion rate becomes equal to or greater than the acceptable value as described above.

[0035] Next, in Step S600, the control device 800 recognizes a relationship between the temperature and the corrosion rate from the information regarding the temperature and the

corrosion rate obtained from an output of the probe 620. Note that it is known that the temperature and the corrosion rate in the vicinity of the sulfuric acid dew point have a negative correlation.

Next, the control device 800 determines an acceptable temperature at which the corrosion rate can be equal to or less than the acceptable value in Step S700. More specifically, the control device 800 compares a corrosion rate corresponding to the first highest temperature from among the plurality of temperatures at which the measurement has been done with the acceptable value first. Next, the control device 800 compares a corrosion rate corresponding to the second highest temperature from among the plurality of temperatures at which the measurement has been done with the acceptable value. Then, the control device 800 compares a corrosion rate corresponding to the third highest temperature from among the plurality of temperatures at which the measurement has been done with the acceptable value. In this manner, the control device 800 performs comparison with the acceptable value in order from the corrosion rate corresponding to the highest temperature from among the plurality of temperatures at which the measurement has been done. Then, the control device 800 finds a temperature at which the corrosion rate becomes equal to or greater than the acceptable value for the first time from among the temperatures at which the measurement has been done and sets the temperature that is highest after the found temperature as the acceptable temperature. Thereafter, the control device 800 determines the acceptable temperature as the temperature of the water to be supplied. Note that the control device 800 may determine a temperature that is higher than the acceptable temperature by a specific temperature as the temperature of the water to be supplied in order to further reduce the corrosion rate.

[0036] Next, the control device 800 determines whether the temperature of the water that is being currently supplied, that is, the temperature of the water to be supplied, which has been checked in Step S100, exceeds the acceptable temperature in Step S800. More specifically, the control device 800 compares the temperature of water to be supplied, which has been

checked in Step S100, with the temperature of water to be supplied, which has been determined in Step S700.

When the temperature of the water to be supplied, which has been checked in Step S100, is lower than the temperature, which has been determined in Step S700, the control device 800 raises the temperature of the water to be supplied such that the temperature of the water that is being currently supplied becomes the temperature of the water to be supplied, which has been determined in Step S700, in Step S700. Note that the control device 800 raises the temperature of the water to be supplied through control of the water amount adjustment valve 500. In this manner, the exhaust heat recovery boiler 100 performs control to maintain the corrosion rate at or below the acceptable value.

On the other hand, when the temperature of the water to be supplied, which has been checked in Step S100, is higher than the temperature of the water to be supplied, which has been determined in Step S700, the control device 800 lowers the temperature of the water that is being currently supplied to the temperature of the water to be supplied, which has been determined in Step S500, in Step S800. Note that the control device 800 lowers the temperature of the water to be supplied through control of the water amount adjustment valve 500.

Next, the temperature of the water to be supplied to the heat transfer pipe 320 is checked using the water temperature gauge 700 in Step S900. Then, the control device 800 acquires information regarding the temperature of the water to be supplied and checks if the temperature of the water to be supplied has reached the temperature of the water to be supplied, which has been determined in Step S700.

If the processing in Step S900 is ended, then the control device 800 repeats the processing from Step S100 again after elapse of a specific period of time in Step S1000. In this manner, the exhaust heat recovery boiler 100 performs such control that heat energy can be efficiently recovered by preventing the surface temperature of the heat transfer pipe 320 from being heated to an excessively high temperature, which leads to a decrease in

amount of recovered heat, and preventing the surface temperature of the heat transfer pipe 320 from becoming an excessively low temperature, which leads to corrosion.

[0037] <Effects and Advantages>

Next, effects and advantages of the exhaust heat recovery boiler 100 according to the present embodiment will be described below.

(First Advantage)

The exhaust heat recovery boiler 100 according to the present embodiment includes the control device 800 configured to control the temperature of water to be supplied to the heat transfer pipe 320 in accordance with a corrosion rate measured by the probe 620. Therefore, the exhaust heat recovery boiler 100 can cause the surface temperature of the heat transfer pipe 320 to significantly change, by adjusting the temperature of the water to be supplied to the heat transfer pipe 320. Also, the exhaust heat recovery boiler 100 is not required to raise the temperature of the exhaust gas that is brought into contact with the heat transfer pipe 320 and is not required to cause the flow amount of the exhaust gas flowing through the duct 120 to increase in order to cause the surface temperature of the heat transfer pipe 320 to change. Therefore, the exhaust heat recovery boiler 100 can maintain the corrosion rate of the heat transfer pipe 320 at or below the acceptable value and can curb corrosion of the heat transfer pipe 320.

[0038] (Second Advantage)

Also, the exhaust gas used to recover heat is discharged from the duct 120 after the heat transfer pipe 320 performs heat recovery. If the surface of the heat transfer pipe 320 is heated to an excessively high temperature, the temperature of the exhaust gas and the temperature of the surface of the heat transfer pipe 320 become close to each other, and the amount of heat recovered from the exhaust gas at the position of the heat transfer pipe 320 thus decreases. Therefore, the exhaust heat recovery boiler 100 discards the exhaust gas at the high temperature. The discarding of the exhaust gas at the high temperature is equivalent to not recovering the heat energy that can be recovered by the exhaust heat recovery boiler 100. However, the exhaust heat recovery boiler 100 controls the

temperature of the water to be supplied to the heat transfer pipe 320 in accordance with the corrosion rate, and the temperature of the gas to be discharged from the duct 120 does not become excessively high. In other words, the exhaust heat recovery boiler 100 can efficiently recover the heat energy with a limited heat transmission area without discarding an unnecessarily large amount of heat energy of the exhaust gas.

[0039] (Third Advantage)

Also, a part of the second piping 440 of the water feed piping 400 is disposed inside the steam drum 160. In this manner, the water passing through the second piping 440 is heated by water or water vapor at a high temperature inside the steam drum 160. In other words, the exhaust heat recovery boiler 100 can raise the temperature of the water to be supplied to the heat transfer pipe 320 without including an additional heating means for heating the water to be supplied to the heat transfer pipe 320.

[0040] (Fourth Advantage)

Also, a part of the second piping 440 is in contact with the water at a high temperature inside the steam drum 160. Therefore, the water passing through the second piping 440 is heated more quickly than in a case where the water stored in the steam drum 160 and the second piping 440 are not brought into contact with each other (when the second piping 440 is heated by water vapor inside the steam drum 160). In other words, if the flow amount of the water passing through the second piping 440 is the same, the temperature of the water that has passed through the second piping 440 becomes a higher temperature in a configuration in which the second piping 440 is brought into contact with the water stored in the steam drum 160 than in a configuration in which the second piping 440 is not brought into contact with the water stored in the steam drum 160. Therefore, the exhaust heat recovery boiler 100 can heat the water that has passed through the second piping 440 to a higher temperature.

[0041] (Fifth Advantage)

Also, the exhaust heat recovery boiler 100 includes the water temperature gauge 700 capable of measuring the temperature of the water to be supplied to the heat transfer pipe

320. In addition, the control device 800 controls the temperature of the water to be supplied to the heat transfer pipe 320 in accordance with a result of the measurement performed by the water temperature gauge 700. In this manner, the exhaust heat recovery boiler 100 can feed water at a specific temperature to the heat transfer pipe 320 and can easily perform temperature adjustment for the heat transfer pipe 320.

[0042] <Modifications>

Next, modifications of the exhaust heat recovery boiler 100 according to the present embodiment will be described below.

(First Modification)

The exhaust heat recovery boiler 100 may include a tank that is in fluid communication with the water outlet 324 of the heat transfer pipe 320 in addition to the steam drum 160. In this case, at least a part of the second piping 440 is disposed inside the tank. This is because water or water vapor inside the tank can heat the water flowing through the second piping 440 even in this case. Also, the exhaust heat recovery boiler 100 can use, as heat sources for heating the second piping 440, the water heated by the heat transfer pipe 320 and the water vapor obtained by the water being further heated, using the tank that is in fluid communication with the water outlet 324. In other words, the exhaust heat recovery boiler 100 can heat the water to be supplied to the heat transfer pipe 320 without including any additional heating means such as a heater. Note that the tank described herein means a facility that accommodates at least either water or water vapor, and the steam drum 160 is an example of the tank. Moreover, the high-pressure steam receiver 180 is also an example of the tank.

[0043] (Second Modification)

Also, the probe 620 is disposed in the vicinity of the heat transfer pipe 320 in the present embodiment. However, the probe 620 may be disposed at any location inside the duct 120 as long as the probe 620 can measure data that is required to estimate the corrosion rate of the heat transfer pipe 320. In a case where a flow of the exhaust gas is localized, and the temperature distribution inside the duct is considered to be not uniform, for example, then

it is only necessary to dispose the probe at a location that is considered to be the most suitable for the estimation of the corrosion rate of the heat transfer pipe 320 after recognizing the temperature distribution inside the duct in advance. This is because the temperature of the water to be supplied to the heat transfer pipe 320 can be determined in accordance with an estimated corrosion rate of the heat transfer pipe 320 as long as the corrosion rate can be estimated using the data measured by the probe 620.

[0044] (Third Modification)

Also, the measurement device 600 may include a second corrosion sensor configured to measure a corrosion rate in the vicinity of the heat transfer pipe 320. In this case, the control device 800 performs control to cause the ratio of the flow amount of the water flowing through the second piping 440 with respect to the flow amount of the water flowing through the first piping 420 to increase when the corrosion rate measured by the second corrosion sensor exceeds an acceptable value. This is because the exhaust heat recovery boiler 100 can prevent the corrosion rate of the heat transfer pipe 320 from exceeding the acceptable value and prevent the heat transfer pipe 320 from excessively corroding, by placing the second corrosion sensor in a limited space inside the duct 120 without including the probe 620.

[0045] (Fourth Modification)

Although the first corrosion sensor includes the pair of electrode members 622a and 622b and acquires data regarding the corrosion rate by measuring and analyzing an impedance between the electrode members 622a and 622b in the present embodiment, the measurement method and the sensor structure are not limited thereto. A short-circuit current when dissimilar electrodes are short-circuited due to a condensed phase may be measured, or a resonance frequency of a crystal oscillator on the surfaces of the electrodes may be measured. It is possible to acquire the data of the corrosion rate through analysis of outputs from any of the sensors. Also, it is possible to estimate the corrosion rate of the heat transfer pipe 320 from the outputs of the first corrosion sensor using the electrode members of the same material as the heat transfer pipe 320 for the first corrosion sensor. Note that it

is possible to recognize a trend of corrosion of the heat transfer pipe 320 in advance by changing the electrode material to a material that is more corrosive than the material for the heat transfer pipe 320.

[0046] (Fifth Modification)

Also, the measurement device 600 may include a thermometer configured to measure the temperature in the vicinity of the heat transfer pipe 320. In this case, the control device 800 performs control to cause the ratio of the flow amount of the water flowing through the second piping 440 with respect to the flow amount of the water flowing through the first piping 420 to increase when the temperature measured by the thermometer is below a predetermined reference temperature. As described above, it is known that the temperature and the corrosion rate in the vicinity of the sulfuric acid dew point have a negative correlation. Therefore, it is possible to estimate the corrosion rate by measuring the temperature at the part of the heat transfer pipe 320. Therefore, the exhaust heat recovery boiler 100 can curb corrosion of the heat transfer pipe 320 through control of the temperature of the water to be supplied to the heat transfer pipe 320 in accordance with the temperature measured by the thermometer, without including the probe 620. Note that the reference temperature may be arbitrarily determined in view of the relationship between the temperature and the corrosion rate.

[0047] (Sixth Modification)

The measurement device 600 may include at least one of an SO_x analyzer configured to measure the concentration of sulfur oxide, an HCl analyzer configured to measure the concentration of hydrogen chloride, and a moisture meter configured to measure the concentration of moisture in the vicinity of the heat transfer pipe 320 in addition to the thermometer in the fourth modification. In this case, the control device 800 determines a reference temperature with which the temperature measured by the thermometer is to be compared, in accordance with one of results of the measurement of the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture measured. In a case where the temperature measured by the thermometer is below the

reference temperature, then the control device 800 performs control to cause the ratio of the flow amount of the water flowing through the second piping 440 with respect to the flow amount of the water flowing through the first piping 420 to increase.

As described above, it is known that the corrosion rate changes due to the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture as well as the temperature. It is possible to more accurately estimate the corrosion rate in consideration of at least one of the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture measured in this manner. Also, the exhaust heat recovery boiler 100 can curb corrosion of the heat transfer pipe 320 in consideration of the more accurate corrosion rate.

[0048] (Seventh Modification)

Also, the control device 800 may predict the sulfuric acid dew point from the concentration of sulfur oxide and the concentration of moisture using the Otsuka's expression, and the sulfuric acid dew point may be regarded as a reference temperature in the sixth modification. Note that the Otsuka's expression is represented by expression (1).

[Formula 1]

$$T_{DP} = 20 \log V + A \dots (1)$$

where

[Formula 2]

T_{DP} : Sulfuric acid dew point (°C)

V : Concentration of sulfur trisulfide in exhaust gas (vol%)

A : Constant based on moisture in exhaust gas (concentration of moisture: 5% = 184, 10% = 194, 15% = 201)

It is known that the sulfuric acid dew point can be calculated from the concentration of sulfur oxide and the concentration of moisture using the Otsuka's expression. In this manner, the exhaust heat recovery boiler 100 can prevent the temperature in the vicinity of the heat transfer pipe 320 from dropping below the sulfuric acid dew point and can curb corrosion of the heat transfer pipe 320. Note that the control device 800 may set, as a

reference temperature, a temperature that is higher than the temperature of the sulfuric acid dew point in order to further curb corrosion of the heat transfer pipe 320. Also, the Otsuka's expression is an example, and the control device 800 may predict the dew point temperature from the exhaust gas composition using another expression. Note that the exhaust gas composition include sulfur oxide, hydrogen chloride, moisture, and the like.

[0049] (Eighth Modification)

The measurement device 600 need not include the thermometer in the fourth modification in a case where the measurement device 600 includes at least one of the SO_x analyzer configured to measure the concentration of sulfur oxide, the HCl analyzer configured to measure the concentration of hydrogen chloride, and the moisture meter configured to measure the concentration of moisture in the vicinity of the heat transfer pipe 320. In this case, the control device 800 performs control to cause the ratio of the flow amount of the water flowing through the second piping 440 with respect to the flow amount of the water flowing through the first piping 420 to increase when at least one of the results of the measurement of the concentration of sulfur oxide, the concentration of hydrogen chloride, and the concentration of moisture exceeds or drops below a predetermined value.

As described above, it is known that the dew point temperature can be predicted from the exhaust gas composition. Therefore, in a case where the temperature inside the duct 120 is predictable, for example, in a case where the temperature inside the duct 120 is substantially constant, it is possible to compare the dew point temperature predicted from the exhaust gas composition with the predicted temperature inside the duct 120. In this manner, the exhaust heat recovery boiler 100 can prevent the predicted temperature inside the duct 120 from dropping below the predicted dew point temperature and can prevent corrosion of the heat transfer pipe 320. In other words, the exhaust heat recovery boiler 100 can curb corrosion of the heat transfer pipe 320 as long as the measurement device 600 can measure the exhaust gas composition. Note that the predetermined value to be compared with the result of the measurement performed by the measurement device 600 may be arbitrarily determined.

[0050] (Ninth Modification)

In the case of the eighth modification, the control device 800 may perform the control to cause the ratio of the flow amount of the water flowing through the second piping 440 with respect to the flow amount of the water flowing through the first piping 420 to increase such that the temperature of the water to be supplied to the heat transfer pipe 320 is higher than the dew point temperature predicted from the exhaust gas composition.

In this manner, the exhaust heat recovery boiler 100 can adjust the temperature of the water flowing inside the heat transfer pipe 320 to be a higher temperature than the dew point temperature. Also, since heat is recovered from the exhaust gas with the water flowing inside the heat transfer pipe 320, the temperature of the exhaust gas that is brought into contact with the heat transfer pipe 320 is higher than the temperature of the water flowing inside the heat transfer pipe 320. In other words, both the temperature of the water flowing inside the heat transfer pipe 320 and the temperature of the exhaust gas that is brought into contact with the heat transfer pipe 320 are higher than the dew point temperature, and the surface temperature of the heat transfer pipe 320 is a temperature that is higher than the dew point temperature, of course. The exhaust heat recovery boiler 100 can thus curb corrosion of the heat transfer pipe 320.

[0051] (Tenth Modification)

In the present embodiment, the water amount adjustment valve 500 includes the first valve 520 and the second valve 540. However, the water amount adjustment valve 500 need not include one of the first valve 520 or the second valve 540. This is because the water amount adjustment valve 500 can adjust the ratio between the flow amounts of the water flowing through the first piping 420 and the second piping 440 even if the water amount adjustment valve 500 includes either the first valve 520 or the second valve 540. Also, this is because the exhaust heat recovery boiler 100 can adjust the temperature of the water to be supplied to the heat transfer pipe 320 as long as it is possible to adjust the ratio between the flow amounts. In addition, the water amount adjustment valve 500 may include a three-way valve configured to cause water to flow either through the first piping 420 or

through the second piping 440. This is because the three-way valve can similarly adjust the ratio between the flow amounts of the water flowing through the first piping 420 and the second piping 440. The water amount adjustment valve 500 may have any configuration as long as the water amount adjustment valve 500 can adjust the ratio between the flow amount of the water flowing through the first piping 420 and the flow amount of the water flowing through the second piping 440.

[0052] Although some embodiments of the present invention have been described hitherto, the aforementioned embodiments of the present invention have been provided for easy understanding of the present invention and are not intended to limit the present invention. It is a matter of course that the present invention can be modified and improved without departing from the gist of the present invention and the present invention also encompasses the equivalents thereof. The components described in the claims and the specification can be arbitrarily combined or omitted within a scope in which at least some of the aforementioned problems can be solved or within a scope in which at least some of the advantages can be achieved.

REFERENCE SIGNS LIST

[0053]	100	Exhaust heat recovery boiler
	120	Duct
	140	Superheater
	160	Steam drum
	300	Economizer
	320	Heat transfer pipe
	322	Water inlet
	324	Water outlet
	400	Water feed piping
	420	First piping
	440	Second piping
	462	Flow splitter

464	Flow combiner
500	Water amount adjustment valve
520	First valve
540	Second valve
600	Measurement device
620	Probe
624	Probe temperature adjustment mechanism
700	Water temperature gauge
800	Control device
900	Water feed section

CLAIMS

1. An exhaust heat recovery boiler comprising:
 - a duct including a flow path through which exhaust gas flows;
 - a heat transfer pipe including a water inlet and a water outlet and disposed inside the duct;
 - a water feed piping connected to the water inlet of the heat transfer pipe, including a flow splitter, a flow combiner located on a side further downstream than the flow splitter, a first piping forming a part from the flow splitter to the flow combiner, and a second piping branched from the first piping at the flow splitter and then meeting the first piping again at the flow combiner, and configured to feed water that has passed through the flow combiner to the water inlet of the heat transfer pipe;
 - a tank in fluid communication with the water outlet of the heat transfer pipe, at least a part of the second piping being disposed inside the tank;
 - a water amount adjustment valve configured to adjust a ratio between a flow amount of water flowing through the first piping and a flow amount of water flowing through the second piping;
 - a measurement device configured to measure at least one of a corrosion rate, a temperature, and exhaust gas composition inside the duct; and
 - a control device configured to perform control to adjust the water amount adjustment valve in accordance with a result of the measurement performed by the measurement device.
2. The exhaust heat recovery boiler according to claim 1, wherein the tank is a steam drum configured to separate water and water vapor.
3. The exhaust heat recovery boiler according to claim 1 or 2, wherein at least a part of the second piping is disposed at a part of the tank in which water is stored.
4. The exhaust heat recovery boiler according to any one of claims 1 to 3, further comprising

a water temperature gauge configured to measure a water temperature between the flow combiner of the water feed piping and the water inlet of the heat transfer pipe,

wherein the control device adjusts and controls the water amount adjustment valve in accordance with a result of the measurement performed by the water temperature gauge.

5. The exhaust heat recovery boiler according to any one of claims 1 to 4,

wherein the measurement device includes a corrosion monitoring probe including a first corrosion sensor and a probe temperature adjustment mechanism, the first corrosion sensor including an electrode member with an electrode surface exposed to an inside of the duct, and the probe temperature adjustment mechanism being configured to adjust a temperature of the electrode member, and

the control device causes the corrosion monitoring probe to measure corrosion rates at a plurality of different temperatures by controlling the probe temperature adjustment mechanism of the corrosion monitoring probe, determines a temperature of the water to be supplied to the heat transfer pipe to obtain a corrosion rate below an acceptable value from a result of the measurement of the corrosion rates at the plurality of different temperatures, and adjusts and controls the temperature of the water to be feeded to the heat transfer pipe to the determined temperature.

6. The exhaust heat recovery boiler according to any one of claims 1 to 5,

wherein the measurement device includes a second corrosion sensor including an electrode exposed to an inside of the duct and being capable of measuring a corrosion rate, and

the control device performs control to cause the ratio of the flow amount of the water flowing through the second piping with respect to the flow amount of the water flowing through the first piping to increase when the corrosion rate measured by the second corrosion sensor exceeds an acceptable value.

7. The exhaust heat recovery boiler according to any one of claims 1 to 6,

wherein the measurement device includes a thermometer configured to measure a temperature in a vicinity of the heat transfer pipe, and

the control device performs control to cause the ratio of the flow amount of the water flowing through the second piping with respect to the flow amount of the water flowing through the first piping to increase when the temperature in the vicinity of the heat transfer pipe measured by the thermometer is below a predetermined reference temperature.

8. The exhaust heat recovery boiler according to any one of claims 1 to 7, wherein the measurement device includes at least one of an SO_x analyzer configured to measure a concentration of sulfur oxide, an HCl analyzer configured to measure a concentration of hydrogen chloride, and a moisture meter configured to measure a concentration of moisture inside the duct, the sulfur oxide, the hydrogen chloride, and the moisture being exhaust gas composition, and

the control device predicts a dew point temperature and determines a reference temperature in accordance with at least one of results of the measurement of the concentration of the sulfur oxide, the concentration of the hydrogen chloride, and the concentration of the moisture.

9. The exhaust heat recovery boiler according to any one of claims 1 to 8, wherein the water amount adjustment valve includes a first valve attached to the first piping and configured to adjust the flow amount of the water flowing through the first piping and a second valve attached to the second piping and configured to adjust the flow amount of the water flowing through the second piping.

10. A method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler comprising:

by using the exhaust heat recovery boiler including

a duct including a flow path through which exhaust gas flows,

a heat transfer pipe including a water inlet and a water outlet and disposed inside the duct,

a water feed piping connected to the water inlet of the heat transfer pipe, including a flow splitter, a flow combiner located on a side further downstream than the flow splitter, a first piping forming a part from the flow splitter to the flow combiner, and a second

piping branched from the first piping at the flow splitter and then meeting the first piping again at the flow combiner, and configured to feed water that has passed through the flow combiner to the water inlet of the heat transfer pipe, and

a tank connected to the water outlet, at least a part of the second piping being disposed inside the tank,

a measurement process of measuring at least one of a corrosion rate, a temperature, and exhaust gas composition inside the duct;

a temperature determination process of determining a temperature of the water to be supplied to the heat transfer pipe in accordance with a result of the measurement in the measurement process; and

a temperature adjustment process of adjusting a ratio between a flow amount of water flowing through the first piping and a flow amount of water flowing through the second piping to adjust a surface temperature of the heat transfer pipe to the temperature determined in the temperature determination process.

11. The method for controlling a temperature of a heat transfer pipe of an exhaust heat recovery boiler according to claim 10,

wherein the measurement process includes a process of measuring corrosion rates at a plurality of different temperatures inside the duct, and

the temperature determination process includes a process of determining the temperature of the water to be supplied to the heat transfer pipe to obtain a corrosion rate below an acceptable value from a result of the measurement of the corrosion rates at the plurality of different temperatures.