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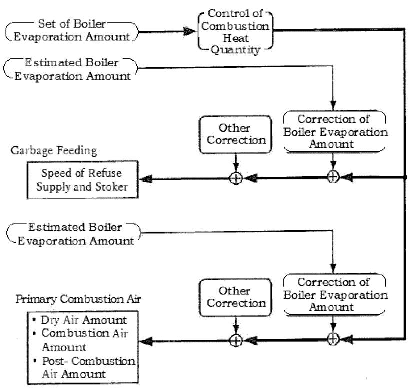
(54) WASTE INCINERATION CONTROL METHOD, AND INCINERATION CONTROL APPARATUS USING SAME

(57) According to the present invention, information about a heating value of waste that is being incinerated is accurately and continuously obtained in real time, and combustion control of the waste is carried out without any time delay with respect to a current combustion state by using the information. Combustion control of an incinerator is carried out on the basis of the following steps. (1) Estimating a heating value of the waste from an actually measured component concentration in a combustion exhaust gas. (2) Estimating a boiler evaporation amount on the basis of the calculated waste heating value. (3) Controlling supply amounts of the waste, a combustion air, and a combustion improver introduced in the incinerator on the basis of the estimated boiler evaporation amount.

Fig. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a waste combustion control method, and a combustion control apparatus using the same, and in particular, to a combustion control method and a combustion control apparatus applicable to a variety of wastes.

BACKGROUND ART

[0002] Conventionally, combustible wastes among wastes such as municipal garbage and sewage sludge have been collected from offices, homes and the like, and transported to a refuse disposal site, a waste treatment facility or the like located in each area, and subjected to a combustion treatment, and disposed of as cleaned exhaust gas and incinerated ash. At this time, combustion control of wastes such as oil and gas can be stably carried out because their properties are known, and in an actual facility, the combustion control is achieved by adjusting the amount of combustion air to a value that is preliminarily set in accordance with a combustion amount of the waste. On the other hand, a variety of wastes are not easily burned stably because their properties are not uniform. Therefore, a combustion control method for an incinerator capable of preventing occurrence of unburned combustibles and stabilizing the combustion state in the incinerator is demanded, and in order to keep the operation that allows complete combustion of garbage having a variety of heating values and makes the steam generation amount of the boiler constant, automatic combustion control is carried out using a combustion air amount, a cooling air amount, a refuse supply speed, a fire grate speed and so on as an index. As a conventional concrete control approach, various new control methods have been proposed, in addition to the method of increasing or decreasing the fire grate speed to follow the preset evaporation amount or the preset temperature by referring to the evaporation amount or the furnace outlet temperature.

[0003] For example, a combustion control method in an incinerator having the configuration as illustrated in Fig. 4 has been proposed. Concretely, from below a stoker 110 made up of a drying stoker 110a, a combustion stoker 110b, and a post-combustion stoker 110c, primary combustion air A1 is supplied, while post-combustion stage gas G' generated on the post-combustion stoker 110c is drawn out of the incinerator, and part of exhaust gas G" is blown, as a recirculating gas, into a downstream drainage area of a primary combustion chamber 112, and combustion gas G generated on the drying stoker 110a and the combustion stoker 110b is stirred and mixed by the recirculating gas G" to form a reducing zone 125 between the primary combustion chamber 112 and a secondary combustion chamber 113, and further, the post-combustion stage gas G' having drawn out of the incinerator is blown, as a reflux gas, into the secondary combustion 113, while secondary combustion air A2 is supplied into the secondary combustion chamber 113, and thus unburned gas or unburned substances in the secondary combustion chamber are completely burned (for example, see Patent Document 1: JP-A-2005-214513). In the drawing, 101 indicates an incinerator, 102 represents a waste heat boiler, 103 represents a superheater, 104 represents an economizer, 105 represents a deairing heater, 106 represents a bug filter, 107 represents an induced draft fan, 108 represents an incinerator main unit, 109 represents a garbage supplying hopper, 111 represents a sub-stoker hopper, 114 represents an ash outlet, 115 represents an exhaust gas outlet, 116 represents a primary combustion air supplying device, 117 represents a recirculating gas path, 118 represents a recirculating gas blower, 119 represents a reflux gas path, 120 represents a reflux gas blower, 121 represents a heat exchanger, 122 represents a secondary combustion air supplying conduit, 123 represents a damper, 124 represents an oxygen concentration detector, 125 represents a reducing zone, 126 represents a primary combustion air supplying conduit, and 127 represents a primary combustion air blower.

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0004] However, such a conventional combustion control method had several problems or demands.

(i) In the waste combustion control of measuring the exhaust gas temperature or the gas composition in the exhaust gas, and increasing or decreasing the amount of waste to be burned, the combustion air amount, the combustion air temperature and the like, it was difficult to carry out an appropriate combustion control without time delay.

(ii) In particular, a method of sampling and analyzing the waste has been proposed because the heating value of the waste plays an important role in the combustion control, however, the method is not suited for the combustion control because a long time is required for sampling and analysis. For example, there has been a case that sampling requires several hours, and further, analysis requires several days.

(iii) In a conventional method of estimating the combustion state by the amount of the boiler evaporation, the reduced water or the like, for cooling the combustion gas in the incinerator, and using the combustion state for combustion control, the correlation varies with the kind or the property of the waste, and the error in the estimated heating value is large, so that it is often the case that the method is not suited for combustion control.

(iv) The heating value of the waste has a correlation with the moisture amount, and the heating value can be generally estimated by measuring the specific gravity of the waste, however, it is often the case that the method is not suited for combustion control because the waste for which the specific gravity is not the burning waste at that point of time, and the error is large.

(v) While the method of estimating from information of the shade of color of the waste has been generally used as a method for estimating the heating value of the waste, the method lacks quantitativeness and is often unsuited for combustion control because the white waste abundantly contains paper-based objects, and the black waste abundantly contains pruned branches or the like.

[0005] The present invention has been made in view of the circumstances as described above, and it is an object of the present invention to solve such a problem, and to provide a method for carrying out a combustion control of the waste without any time delay with respect to a current combustion state by obtaining accurately and continuously an information about a heating value of the burning waste in real time and using the information, and a combustion control apparatus using the method.

MEANS FOR SOLVING THE PROBLEMS

[0006] The waste combustion control method according to the present invention is characterized to carry out a waste combustion control of an incinerator on the basis of the following steps in a process of subjecting a predetermined amount of a waste to a combustion treatment.

(1) Estimating a heating value of the waste from an actually measured component concentration in the combustion exhaust gas.

(2) Estimating a boiler evaporation amount on the basis of the calculated waste heating value.

(3) Controlling supply amounts of a waste, combustion air, and a combustion improver introduced in the incinerator on the basis of the estimated boiler evaporation amount.

[0007] In an incinerator having a waste heat boiler, the combustion heat quantity generated by waste combustion, and the boiler evaporation amount generated from the waste heat boiler that absorbs the combustion exhaust gas heat quantity are in proportion to each other, and an automatic combustion control has been constructed using the boiler evaporation amount as an index. In a further verification process, the present inventors found that more stable combustion control can be realized by estimating a boiler evaporation amount on the basis of information indicating the current combustion state, and applying the estimated value to control of a garbage feeding speed, and control of the combustion air amount, rather than using an actually measured boiler evaporation amount. The present invention made it possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

[0008] The waste combustion control method according to the present invention is carried out by calculating the waste heating value on the basis of the following steps.

(R1) Measuring component concentrations of oxygen and moisture in the exhaust gas.

(R2) From the measured component concentrations of oxygen and moisture, estimating a carbon dioxide concentration in the exhaust gas according to the following formula 1.

$$[CO2] = Ro \times (100 - [H2O])/100 - [O2] \qquad \text{...Formula 1}$$

[0009] Here, the value in brackets [ ] indicates concentration by percentage, Ro indicates a factor preset by subtracting the oxygen component amount to be taken into the ash content from the atmospheric oxygen concentration.

[0010] (R3) From the oxygen concentration, moisture concentration and carbon dioxide concentration, calculating a nitrogen concentration in the exhaust gas.

[0011] (R4) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculating the converted component concentrations of the oxygen, carbon dioxide and moisture multiplied by the conversion factor.

[0012] (R5) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.

[0013] (R6) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.

[0014] (R7) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.

[0015] (R8) From the calculated heating value, the latent heat quantity, and the waste amount, calculating an estimated heating value A per treated waste amount.

As described above, by acquiring the information indicating the current combustion state in real time, and estimating the combustion heat quantity and the boiler evaporation amount on the basis of the information, it becomes possible to carry out a waste combustion control without time delay. At this time, it is possible to determine carbon, hydrogen and moisture in the waste directly related with the heating value of the waste which is to be fuel, from the exhaust gas composition directly after combustion that is acquired in real time, and to calculate an oxygen consumption amount, a combustion heat quantity, a latent heat quantity, and a waste amount (treatment amount) on the basis of the determined carbon, hydrogen and moisture. The present inventor found, in the verification process, that the carbon dioxide (CO2) concentration in the exhaust gas can be estimated on the basis of the oxygen (02) concentration and the moisture (H2O) concentration in the exhaust gas, and further, by using a unit supply amount of the combustion air as a calculation basis of an oxygen consumption amount or the like, an oxygen consumption, a combustion heat quantity, a latent heat quantity, and a waste treatment amount per unit supply amount of the combustion air are calculated accurately, and a heating value per treated waste amount (estimated heating value A) can be estimated accurately. In other words, even for the waste having many variables such as properties, by calculation from each calculated value per unit supply amount of the combustion air using actually measured values of component concentrations in the exhaust gas, a heating value reflecting such variables can be estimated. Therefore, it was made possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

[0016] The waste combustion control method according to the present invention is featured by calculating the waste heating value according to the following steps.

(S1) Measuring component concentrations of oxygen, carbon dioxide and moisture in the exhaust gas.

(S2) From each of the measured component concentrations, calculating a nitrogen concentration in the exhaust gas.

(S3) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculate converted component concentrations of the oxygen, carbon dioxide and moisture by multiplication by the conversion factor.

(S4) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.

(S5) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.

(S6) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.

(S7) From the calculated heating value, the latent heat quantity, and the waste amount, calculating an estimated heating value B per treated waste amount.

According to the above configuration, as the exhaust gas composition directly after combustion, it is possible to determine carbon, hydrogen and moisture in the waste directly related with the heating value of the waste which is to be fuel, from the actually measured values of CO2 concentration, 02 concentration, and H2O concentration, and to calculate an oxygen consumption amount, a combustion heat quantity, a latent heat quantity, and a waste amount (treatment amount) on the basis of the determined carbon, hydrogen and moisture. By using a unit supply amount of the combustion air as a calculation basis at this time, it was made possible to calculate an oxygen consumption, a combustion heat quantity, a latent heat quantity, and a waste treatment amount per unit supply amount of the combustion air accurately, and to calculate a heating value per treated waste amount (estimated heating value B) accurately. In other words, even for the waste having many variables such as properties, by calculation from each calculated value per unit supply amount of the combustion air using actually measured values of component concentrations in the exhaust gas, a heating value reflecting such variables can be estimated. Therefore, it was made possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

[0017] The waste combustion control method according to the present invention is featured by calculating the waste heating value according to the following steps.

(T1) Measuring component concentrations of oxygen and moisture in the exhaust gas.
(T2) From the measured oxygen component concentration, calculating an actually measured excess air ratio.
(T3) For a preset correlation with a heating value of a waste, and an excess air ratio and a moisture amount in the combustion gas used as indexes, applying the actually measured moisture amount and the actually measured excess air ratio, and calculating an estimated heating value C.

As described above, the heating value of the waste has a correlation with the moisture amount in the combustion gas, and is largely influenced by the supply amount of the combustion air, namely by the excess air ratio. By calculating the excess air ratio which is a major variable in the heating value measurement of the waste, as an actually measured value by measuring the oxygen component concentration in the exhaust gas, the present invention made it possible to estimate the heating value from the correlation with the moisture amount in the combustion gas by using the preset excess air ratio as an index (estimated heating value C). In other words, even for the waste having many variables such as properties, by calculation of the excess air ratio of the combustion air using the actually measured values of component concentrations in the exhaust gas, a heating value reflecting such variables can be estimated. Therefore, it was made possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

[0018] The present invention provides a combustion control apparatus using the waste combustion control method, comprising at least, a waste supply amount measuring part, a combustion air supply amount measuring part, and a component concentration measuring part for oxygen, carbon dioxide and moisture in an exhaust gas, wherein supply amounts of a waste, combustion air, and a combustion improver to be introduced into the incinerator are controlled by using the calculated waste heating value, or either one of the estimated heating values A to C. With such a configuration, it became possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 is a schematic view illustrating a basic practicing steps of the combustion control method according to the present invention.
Fig. 2 is a schematic view showing a basic configuration example of a combustion control apparatus according to the present invention.
Fig. 3 is a schematic view illustrating a comparison between an actually measured value and an estimated value of the boiler evaporation amount.
Fig. 4 is a schematic view illustrating a stoker type incinerator according to a conventional combustion control method.

MODE FOR CARRYING OUT THE INVENTION

<Waste combustion control method according to present invention>

[0020] The waste combustion control method according to the present invention (hereinafter, also referred to as "the present method") is featured by carrying out a waste combustion control of an incinerator according to the following steps in a process of subjecting a predetermined amount of a waste to a combustion treatment. It becomes possible to carry out a waste combustion control without time delay for the current combustion state by continuously, accurately acquiring information about a heating value of the burning waste in real time, and using the information.

(1) Estimating a heating value of the waste from an actually measured component concentration in the combustion exhaust gas.
(2) Estimating a boiler evaporation amount on the basis of the calculated waste heating value.
(3) Controlling supply amounts of a waste, combustion air, and a combustion improver introduced in the incinerator on the basis of the estimated boiler evaporation amount.

Hereinafter, embodiments of the waste combustion control method and the combustion control apparatus according to the present invention are described in detail by referring to drawings.

(1) Estimation of waste heating value

[0021] A heating value of the waste is estimated from an actually measured component concentration in the combustion exhaust gas. Concretely, a calculation is carried out, for example, by using either one of the following three methods (estimated heating values A to C). Alternatively, an optimum heating value can be set by comparing two or three of the estimated heating values A to C. The preset value can be set in consideration of prespecified characteristics of the waste or combustion characteristics of the incinerator and so on. By setting either one of the estimated heating values as an optimum estimated heating value, or by calculating an arithmetic mean value or a weighted mean value of the estimated heating values, it is possible to estimate a more accurate heating value of the waste W.

(R) Estimated heating value A: As in the later-described (R1) to (R8), a carbon dioxide concentration is estimated on the basis of the actually measured component concentrations of oxygen and moisture, and a nitrogen concentration which is to be a basis is calculated by using these, and from the component concentrations of oxygen, carbon dioxide, and moisture converted on the basis of the nitrogen concentration, a heating value, a latent heat quantity and a waste amount of each component are calculated, and estimation is carried out from the calculated values.
(S) Estimated heating value B: As in the later-described (S1) to (S7), a nitrogen concentration is calculated by using the actually measured component concentrations of oxygen, moisture, and carbon dioxide, and from the component concentrations of oxygen, carbon dioxide, and moisture converted on the basis of the nitrogen concentration, a heating value, a latent heat quantity and a waste amount of each component are calculated, and estimation is carried out from the calculated values.
(T) Estimated heating value C: As in the later-described (T1) to (T3), an actually measured excess air ratio is calculated from the actually measured oxygen concentration, and estimation is carried out on the basis of the actually measured excess air ratio and the actually measured moisture concentration.

(2) Estimation of boiler evaporation amount

[0022] A boiler evaporation amount is estimated on the basis of the waste heating value calculated in the above (1). Concretely, on the basis of the relation between the waste heating value and the boiler evaporation amount as indicated by the following formulas 2 and 3, the boiler evaporation amount can be obtained from the calculated waste heating value.

$$\text{(Waste combustion heat quantity)} = \text{(Waste heating value)} \times \text{(Waste input amount)}$$
$$= \text{(Boiler evaporation amount} \times \text{Steam enthalpy + Outgoing heating value - Incoming heating value)} \quad \text{...Formula 2}$$

$$\text{(Boiler evaporation amount)} = \text{(Waste combustion heat quantity - Outgoing heating value + Incoming heating value)/(Steam enthalpy)} \quad \text{...Formula 3}$$

Here, the waste input amount, the steam enthalpy, the outgoing heating value, and the incoming heating value can be calculated in real time by each measured value in the present process.

(3) Control of supply amounts of waste, combustion air and combustion improver

[0023] Supply amounts of a waste, combustion air, and a combustion improver to be introduced into the incinerator are controlled on the basis of the estimated boiler evaporation amount. Concretely, as illustrated in Fig. 1, a waste combustion control without time delay with respect to the combustion state can be carried out, for example, by carrying out feedback control based on the estimated boiler evaporation amount, and making a correction by other factors (for example, the internal temperature of the incinerator) for the supply amounts of the waste, fuel air, and combustion improver.

[Regarding calculation method of waste heating value]

[0024] The waste heating value is calculated on the basis of the estimated heating values A to C and combinations thereof as described above. Hereinafter, the steps of the calculation method of each estimated heating value is described in detail.

[0025]

(R) Calculation of estimated heating value A

(R1) Measuring component concentrations of oxygen and moisture in the exhaust gas.

By measuring component concentrations of oxygen and moisture in the combustion exhaust gas with an 02 concentration meter and an H2O concentration meter provided inside or at the outlet of the incinerator, information of the combustion state can be obtained in real time.

(R2) From the measured component concentrations of oxygen and moisture, estimating the carbon dioxide concentration in the exhaust gas according to the following formula 1.

$$[CO2] = Ro \times (100 - [H2O])/100 - [O2] \qquad \text{...Formula 1}$$

[0026] Here, the value in brackets [ ] indicates concentration by percentage, Ro indicates a factor preset by subtracting the oxygen component amount to be taken into the ash content from the atmospheric oxygen concentration.
That is, in such a state that the waste completely burns and oxygen and nitrogen in the waste do not influence on the component concentrations of oxygen and nitrogen in the exhaust gas, the carbon dioxide concentration [CO2] and the oxygen concentration [O2] in the combustion air satisfy the relations represented by the following formulas 4 to 7 (d: dry state, w: wet state).

$$[CO2(d)] + [O2(d)] = 21 \qquad \text{...Formula 4}$$

$$[CO2(d)] = [CO2(w)] \times 100/(100 - [H2O]) \qquad \text{...Formula 5}$$

$$[O2(d)] = [O2(w)] \times 100/(100 - [H2O]) \qquad \text{...Formula 6}$$

$$[CO2(w)] = 21 \times (100 - [H2O])/100 - [O2(w)] \qquad \text{...Formula 7}$$

However, it has been demonstrated that "21" in the formula 7 is not established, but is, for example, "19: Ro" in an actual operation state. It is understood that the oxygen component amount taken into the ash generated by the burning reaction corresponds to the difference. [CO2(d)] and [O2(d)] can be set by carrying out analysis or measurement such as a manual analysis in advance during an actual operation.

[0027] (R3) From the oxygen concentration, moisture concentration and carbon dioxide concentration, calculating a nitrogen concentration in the exhaust gas.
Concretely, calculate the concentration of nitrogen (N2) in the exhaust gas from the actually measured oxygen concentration, moisture concentration and estimated carbon dioxide concentration according to the following formula 8.

$$[N2(w)] = 100 - ([O2(w)] + [CO2(w)] + [H2O]) \text{...Formula 8}$$

[0028] (R4) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculating the converted component concentrations of the oxygen, carbon dioxide and moisture multiplied by the conversion factor.

(R4-1) Calculation of conversion factor for nitrogen concentration in combustion air

[0029] With reference to nitrogen that is an invariable factor before and after the burning reaction, a factor (conversion factor) t for converting into a partial pressure at the time of supply of the combustion air (Reference nitrogen concentration

Tn: 79 when the combustion air is 100) is calculated according to the following formula 9.

$$t = Tn\ (=79)/[N2(w)] \quad \text{...Formula 9}$$

(R4-2) Calculation of converted component concentrations of oxygen, carbon dioxide, and moisture

[0030] The converted component concentrations of oxygen, carbon dioxide, and moisture are calculated by multiplying each of component concentrations of oxygen, carbon dioxide, and moisture by the conversion factor t. According to the following formula 10, calculate converted oxygen concentration Tx, converted carbon dioxide concentration Td, and converted moisture concentration Tw, respectively. At this time, respective numerical values are an oxygen amount, a carbon dioxide amount and a moisture amount per unit supply amount of the combustion air.

$$Tx = [O2(w)] \times t,\ Td = [CO2(w)] \times t,\ Tw = [H2O] \times t \quad \text{...Formula 10}$$

[0031] (R5) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.
On the basis of the oxygen concentration in the combustion air (reference oxygen concentration) To, an oxygen consumption amount Do per unit supply amount of the combustion air used in the combustion treatment from the converted oxygen concentration Tx is calculated according to the following formula 11.

$$Do = To - Tx \quad \text{...Formula 11}$$

Here, To = (100-Tn), and can be replaced by 21[%].

[0032] (R6) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.

(R6-1) Calculation of heating value in relation to carbon dioxide and moisture per unit supply amount of combustion air

[0033] From the calculated oxygen consumption amount Do, a heating value Hd in relation to carbon dioxide and a heating value Hw in relation to moisture generated in the combustion treatment per unit supply amount of the combustion air are calculated. That is, the total amount of oxygen required for complete combustion of the carbon component and the hydrogen component in the waste W corresponds to the oxygen consumption amount Do, and the amount of oxygen consumed by the carbon component of the oxygen consumption amount Do is equivalent to the converted carbon dioxide concentration Td from the following reaction formula 1, and the remainder corresponds to the oxygen amount consumed by the hydrogen component (the following reaction formula 2). In other words, Hc and Hh in the reaction formulas 1 and 2 represent heat of reaction (heating value) in the respective reactions.

$$C + O2 \rightarrow CO2 + Hc \ldots \quad \text{Reaction formula 1}$$

$$4H + O2 \rightarrow 2H2O + Hh \ldots \quad \text{Reaction formula 2}$$

Therefore, the heating values Hd and Hw can be calculated on the basis of the heating values Hc and Hh according to the following formulas 12 and 13.

$$Hd = Hc \times Td \quad \text{...Formula 12}$$

$$Hw = Hh \times (Do - Td) \quad \text{...Formula 13}$$

(R6-2) Calculation of latent heat quantity from total moisture amount On the basis of the latent heat quantity of water

Lo, a latent heat quantity Lw of a total amount Tw of the moisture amount generated by combustion and the moisture amount contained in the waste is calculated according to the following formula 14.

$$Lw = Lo \times Tw \quad \ldots \text{Formula 14}$$

[0034] (R7) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.
From the supply amount Wi of the waste W subjected to the combustion treatment, and the supply amount Ai of the combustion air at that time, the amount of waste treated per unit supply amount of the combustion air (converted waste amount) Wo is calculated according to the following formula 15.

$$Wo = Wi/Ai \quad \ldots \text{Formula 15}$$

[0035] (R8) From the calculated heating value, the latent heat quantity, and the waste amount, calculating an estimated heating value A per treated waste amount.
From the calculated heating value (Hd + Hw), the latent heat quantity Lw and the waste amount Wo, an estimated heating value A per treated waste amount is calculated according to the following formula 16.

$$A = (Hd + Hw - Lw)/Wo \quad \ldots \text{Formula 16}$$

At this time, the calculated estimated heating value A is a numerical value per unit supply amount of the combustion air, and can be converted into the estimated heating value A per unit supply amount of the waste W by using the actually measured supply amount of the combustion air. An evaluation value for the quality (characteristics) of the waste W having high objectivity can be obtained.

(S) Calculation of estimated heating value B

[0036] (S1) Measuring component concentrations of oxygen, carbon dioxide and moisture in the exhaust gas.
By measuring component concentrations of oxygen, moisture, and carbon dioxide in the combustion exhaust gas with an 02 concentration meter, an H2O concentration meter and CO2 concentration meter provided inside or at the outlet of the incinerator, information of the combustion state can be obtained in real time.
[0037] The subsequent steps (S2) to (S7) can be carried out in the same manner as in the above steps (R3) to (R8). The description is omitted herein.

(S2) From each of the measured component concentrations, calculating a nitrogen concentration in the exhaust gas.
(S3) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculate converted component concentrations of the oxygen, carbon dioxide and moisture by multiplication by the conversion factor.
(S4) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.
(S5) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.
(S6) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.
(S7) From the calculated heating value, the latent heat quantity, and the waste amount, calculate an estimated heating value B per treated waste amount.

(T) Calculation of estimated heating value C

(T1) Measuring component concentrations of oxygen and moisture in exhaust gas

[0038] This can be carried out in the same manner as the step (R1). The description is omitted herein.

(T2) Calculating an actually measured excess air ratio

[0039] From the measured oxygen concentration, an actually measured excess air ratio λo is calculated according to the following formula 17.

$$\lambda o = To(=21)/(To - [O2]) \qquad \text{...Formula 17}$$

(T3) Calculating an estimated heating value C

[0040] For a preset correlation with a heating value of a waste, and an excess air ratio λ and a moisture amount (concentration) in the combustion gas (exhaust gas) used as indexes, applying the actually measured moisture amount and the actually measured excess air ratio, and calculating an estimated heating value C. Concretely, a waste that is to be a basis is preset, and a correlation diagram of moisture concentration-estimated heating value C using an actually measured excess air ratio as an index is prepared, and by applying an actually measured moisture concentration [H2O] and an actually measured excess air ratio λo for the correlation, it is possible to obtain the estimated heating value C. By preparing a plurality of correlation diagrams according to the properties (quality) of the waste which is to be a basis, it is possible to calculate the estimated heating value C more accurately. Concretely in place of the correlation diagram, by preparing a correlation function of moisture concentration-estimated heating value C using an actually measured excess air ratio as an index and applying an actually measured moisture concentration [H2O] and an actually measured excess air ratio λo, it is possible to calculate the estimated heating value C.

<Combustion control apparatus according to present invention>

[0041] The combustion control apparatus according to the present invention (hereinafter, also referred to as the "present apparatus") comprises at least, a waste supply amount measuring part, a combustion air supply amount measuring part, and a component concentration measuring part for oxygen, carbon dioxide and moisture in an exhaust gas, wherein supply amounts of a waste, combustion air, and a combustion improver to be introduced into the incinerator are controlled by using the calculated waste heating value, or either one of the estimated heating values A to C above described. Concretely, the present apparatus comprises examples of a waste supply amount measuring part, a combustion air supply amount measuring part, and a component concentration measuring part provided in a waste treatment apparatus comprising an incinerator (hereinafter, also referred to as "present treatment apparatus") illustrated, for example, in Fig. 2.

[0042] The present treatment apparatus is provided with a reservoir pit 1 in which waste W is reserved, a hopper 2 into which the waste W in the reservoir pit 1 is introduced by a conveyance means 1a (for example, crane or the like), and a stoker 3 to which the waste W introduced into the hopper 2 is fed by a waste supplying device 4. The stoker 3 is driven reciprocally to supply an incinerator main unit 10 with the waste W. The incinerator main unit 10 is provided with a primary combustion zone 10A disposed above the stoker 3, a secondary combustion zone 10B disposed above the primary combustion zone 10A, a primary combustion air supplying device 5 for supplying the stoker 3 and the primary combustion zone 10A with primary combustion air, a secondary combustion air supplying device 6 for supplying the secondary combustion zone 10B with secondary combustion air, an ash discharging part 7 for discharging dust and ash D, and an exhaust gas discharging part 8 for discharging exhaust gas E in the incinerator.

The waste W conveyed to the stoker 3 is dried in the primary combustion zone 10A by high temperature combustion gas generated by combustion, and partly burned by the primary combustion air, and further completely burned. The gas generated by combustion includes moisture (H2O, including water vapor by evaporation of moisture contained in the waste W), hydrocarbon gas (HC) generated by dry distillation, carbon monoxide (CO) generated by incomplete combustion, carbon dioxide (CO2) generated by complete combustion and so on. The unburned substances or incompletely burned substances in the primary combustion zone 10A are completely burned in the secondary combustion zone 10B by the secondary combustion air supplied to the lower part, the middle part and the upper part of the secondary combustion zone 10B. The dust and ash D generated by combustion is discharged from the ash discharging part 7, and the exhaust gas E in the incinerator is discharged from the exhaust gas discharging part 8. Nitrogen oxides (NOx) generated by combustion under a high temperature state, and chlorine compounds and sulfur oxides (SOx) originated from chlorine, sulfur or the like contained in the waste W are very small in quantity, and less influence on the heating value, and thus they are not directly described herein.

(a) Waste supply amount measuring part

[0043] As a sensor part for measuring the quantity and the quality of the waste W introduced into the hopper 2, a waste introduction weight detection sensor 12 and a laser distance meter 13 are provided. The volume of the waste W to be introduced is measured by measuring the distance to the surface of the waste W by the laser distance meter 13. The weight of the waste W is measured by the waste introduction weight detection sensor 12. By detecting the volume and the weight of the waste W, it is possible to detect the variation in specific gravity of the waste W at predetermined time intervals. As described above, knowing the specific gravity of the waste W allows prediction of the quality (moisture amount etc.,) of the waste W.

(b) Combustion air supply amount measuring part

[0044] In the primary combustion zone 10A, the combustion air is supplied from the primary combustion air supplying device 5 in several stages so that an optimum combustion state is formed for the waste W that is placed on the stoker 3 and transferred. For example, in the sequence of a drying step, a combustion step and a post-combustion step, the respective supply amounts of combustion air are controlled while the quantity (volume) and the surface temperature of the waste W, and the flow amount of the combustion gas in each step is monitored. Further, in the secondary combustion zone 10B, the combustion air is supplied from the secondary combustion air supplying device 6 in several stages so as to carry out a cooling treatment or a diluting treatment of the exhaust gas E, as well as complete combustion of a component that is unburned or incompletely burned in the primary combustion zone 10A. For example, by monitoring a component concentration in the exhaust gas (the details are described later), the temperature, and a flow amount of the exhaust gas E and so on, the respective supply amounts of combustion air supplied from the upper part and the lower part (additionally middle part) of the secondary combustion zone 10B are controlled. Here, the supply amount of the combustion air is a total flow amount measured by flow meters (not shown) provided in each stage of the primary combustion air supplying device 5 and the secondary combustion air supplying device 6. As the flow meter, for example, a flow meter with a flow rate control function can be used. Further, in the configuration example of the present treatment apparatus, in the primary combustion zone 10A, a gas current meter 17 is provided as a sensor regarding the gas flow direction, and an infrared radiation thermometer 18 is provided as a sensor part for detecting process data regarding the temperature distribution, and a steam flow meter 19 for measuring a steam flow amount is provided at a terminal end of the incinerator main unit 10 as a sensor for measuring a steam amount corresponding to the energy associated with the combustion.

(c) Measuring part for measuring component concentration in exhaust gas

[0045] In the incinerator main unit 10, a sensor part that detects the combustion state and the combustion result of the waste W is provided. Concretely, an 02 concentration meter 14, a CO2 concentration meter 15, and an H2O concentration meter 16 are provided at least one of the secondary combustion zone 10B and the primary combustion zone 10A (Fig. 2 illustrates the example wherein they are provided only in the secondary combustion zone 10B, and the CO2 concentration meters 15 are arranged, however, as described above, the present invention is not limited to this example). Here, for the 02 concentration meter 14, the CO2 concentration meter 15, and the H2O concentration meter 16, it is preferred to use the method of detecting the component concentration and the temperature of the gas by irradiating the gas in the incinerator main unit 10 with laser light having a constant intensity while scanning the wavelength by a laser emitter (not shown), and measuring the remaining laser light by the laser receiver. It is preferred in that the exhaust gas that is an object to be measured can be detected without contact, and each detection information at the same site can be obtained simultaneously. Also, a known sensor for detecting a component concentration of each gas may be used. It is possible to estimate the composition of the burned waste W from each component concentration in the exhaust gas, and to estimate the heating value of the waste W from the relation with the supply amount of the combustion air. Hereinafter, regarding each component concentration, for example, the oxygen component concentration is also referred to as oxygen concentration, and the nitrogen component concentration is also referred to as nitrogen concentration.

<Demonstration experiment of present method>

[0046] Regarding the present treatment apparatus to which the waste is supplied, the combustion control function and the technical effect of the present method were verified by using the estimated heating value A.

[Verification result]

[0047] The verification result is shown in Figs. 3(A) to 3(C).

(i) Fig. 3(A) shows an estimated value of the boiler evaporation amount estimated from the estimated heating value A calculated from the actually measured value of boiler evaporation amount, and the oxygen concentration and the moisture concentration in the exhaust gas at that time when the present treatment apparatus is continuously operated for 12 hours.

(ii) Fig 3(B) is an enlarged view of a part of Fig. 3(A). It can be recognized that the estimated value of the boiler evaporation amount precedes to the actually measured value of the boiler evaporation amount. The difference was about 240 sec.

(iii) Fig. 3(C) shows the correlation between estimated values and actually measured values. The result having a very good correlation is obtained.

[0048] As described above, by the waste combustion control method according to the present invention, and the combustion control apparatus using the same, it becomes possible to obtain excellent technical effects as follows.

(i) By continuously measuring the heating value of the waste without delay, it is possible to realize an optimum combustion control.

(ii) In a facility having a power generation equipment, by operating the estimated value of the boiler evaporation amount ahead of the actually measured value (about 240 sec. ahead in the demonstration experiment), it is possible to increase the generating efficiency by stabilization of the evaporation amount and minimization of the exhaust gas.

(iii) Since the heating value of the waste currently burning is determined, it is possible to respond to the transient response such as abnormal combustion while keeping the automatic operation.

(iv) Since extensive modification on the existing automatic combustion control is not required, application to the existing facility can be made easily at low cost, and the applicability is extensive.

(v) Since operation of the waste treatment facility is facilitated, it is no longer necessary to rely on the qualities of the operators, and it becomes possible to achieve labor saving by reduction in workforce.

Claims

1. A waste combustion control method according to the present invention is carried out a waste combustion control of an incinerator on the basis of the following steps in a process of subjecting a predetermined amount of a waste to a combustion treatment.

(1) Estimating a heating value of the waste from an actually measured component concentration in the combustion exhaust gas.

(2) Estimating a boiler evaporation amount on the basis of the calculated waste heating value.

(3) Controlling supply amounts of a waste, combustion air, and a combustion improver introduced in the incinerator on the basis of the estimated boiler evaporation amount.

2. The waste combustion control method according to claim 1, wherein the waste heating value is calculated on the basis of the following steps.

(R1) Measuring component concentrations of oxygen and moisture in the exhaust gas.

(R2) From the measured component concentrations of oxygen and moisture, estimating a carbon dioxide concentration in the exhaust gas according to the following formula 1.

$$[CO2] = Ro \times (100 - [H2O])/100 - [O2] \qquad \text{...Formula 1}$$

Here, the value in brackets [ ] indicates concentration by percentage, Ro indicates a factor preset by subtracting the oxygen component amount to be taken into the ash content from the atmospheric oxygen concentration.

(R3) From the oxygen concentration, moisture concentration and carbon dioxide concentration, calculating a nitrogen concentration in the exhaust gas.

(R4) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculating the converted component concentrations of the oxygen, carbon dioxide and moisture multiplied by the conversion factor.

(R5) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.

(R6) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.

(R7) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.

(R8) From the calculated heating value, the latent heat quantity, and the waste amount, calculating an estimated heating value A per treated waste amount.

3. The waste combustion control method according to claim 1, wherein the waste heating value is calculated on the basis of the following steps. (S1) Measuring component concentrations of oxygen, carbon dioxide and moisture in the exhaust gas.

(S2) From each of the measured component concentrations, calculating a nitrogen concentration in the exhaust gas.

(S3) On the basis of the calculated nitrogen concentration, calculating a conversion factor for the nitrogen concentration in the combustion air and calculate converted component concentrations of the oxygen, carbon dioxide and moisture by multiplication by the conversion factor.

(S4) From the converted component concentrations of the oxygen, carbon dioxide and moisture, calculating an oxygen consumption amount per unit supply amount of the combustion air used in the combustion treatment.

(S5) From the calculated oxygen consumption amount, calculating a heating value in relation to carbon dioxide and moisture generated in the combustion treatment per unit supply amount of the combustion air, and a latent heat quantity from the total amount of the generated moisture amount and the moisture amount contained in the waste.

(S6) From the supply amount of the waste subjected to the combustion treatment, calculating a treated waste amount per unit supply amount of the combustion air.

(S7) From the calculated heating value, the latent heat quantity, and the waste amount, calculating an estimated heating value B per treated waste amount.

4. The waste combustion control method according to claim 1, wherein the waste heating value is calculated on the basis of the following steps.

(T1) Measuring component concentrations of oxygen and moisture in the exhaust gas.

(T2) From the measured oxygen component concentration, calculating an actually measured excess air ratio.

(T3) For a preset correlation with a heating value of a waste, and an excess air ratio and a moisture amount in the combustion gas used as indexes, applying the actually measured moisture amount and the actually measured excess air ratio, and calculating an estimated heating value C.

5. A combustion control apparatus using the waste combustion control method according to any one of claims 1 to 4, comprising at least, a waste supply amount measuring part, a combustion air supply amount measuring part, and a component concentration measuring part for oxygen, carbon dioxide and moisture in an exhaust gas, wherein supply amounts of a waste, a combustion air, and a combustion improver to be introduced into the incinerator are controlled by using the calculated waste heating value, or either one of the estimated heating values A to C.

Fig. 1

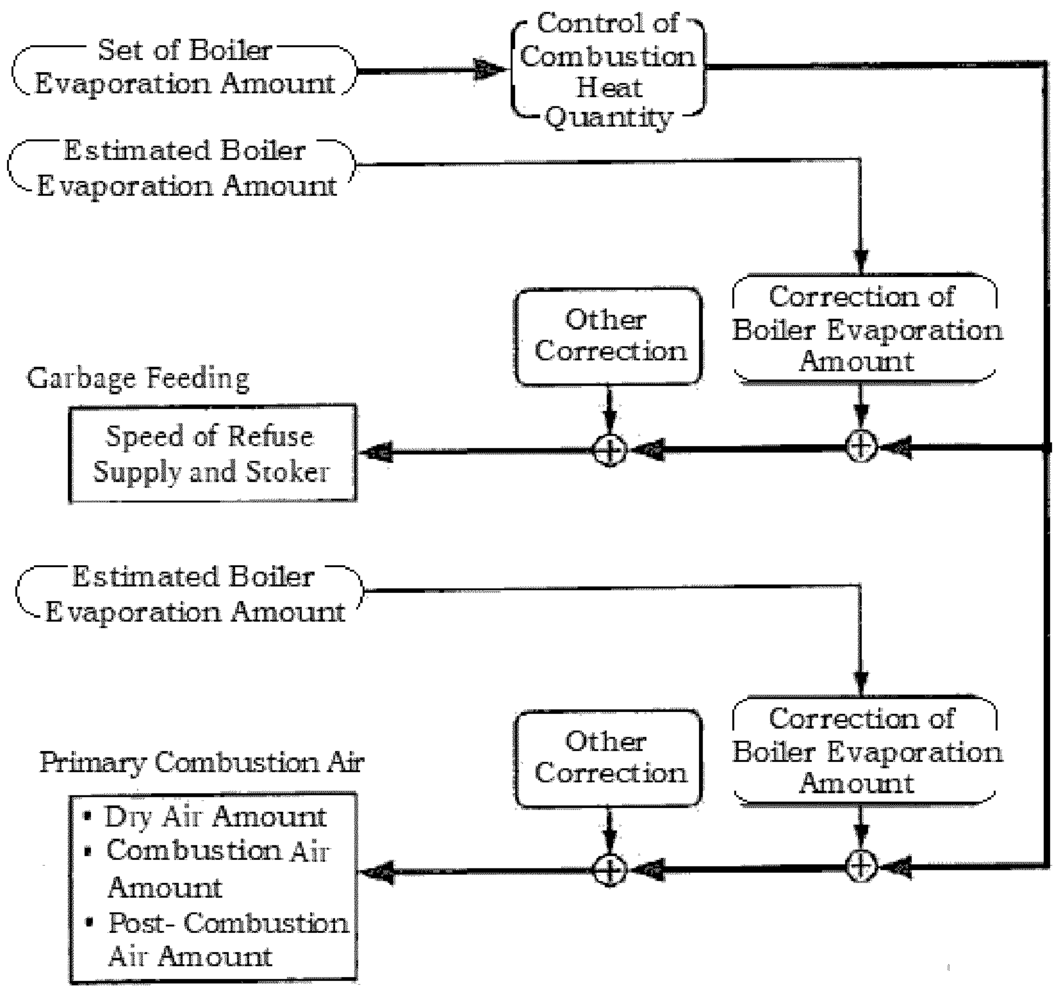

Set of Boiler Evaporation Amount
Control of Combustion Heat Quantity
Estimated Boiler Evaporation Amount
Other Correction
Correction of Boiler Evaporation Amount
Garbage Feeding
Speed of Refuse Supply and Stoker
Estimated Boiler Evaporation Amount
Other Correction
Correction of Boiler Evaporation Amount
Primary Combustion Air
• Dry Air Amount
• Combustion Air Amount
• Post- Combustion Air Amount

Fig. 2

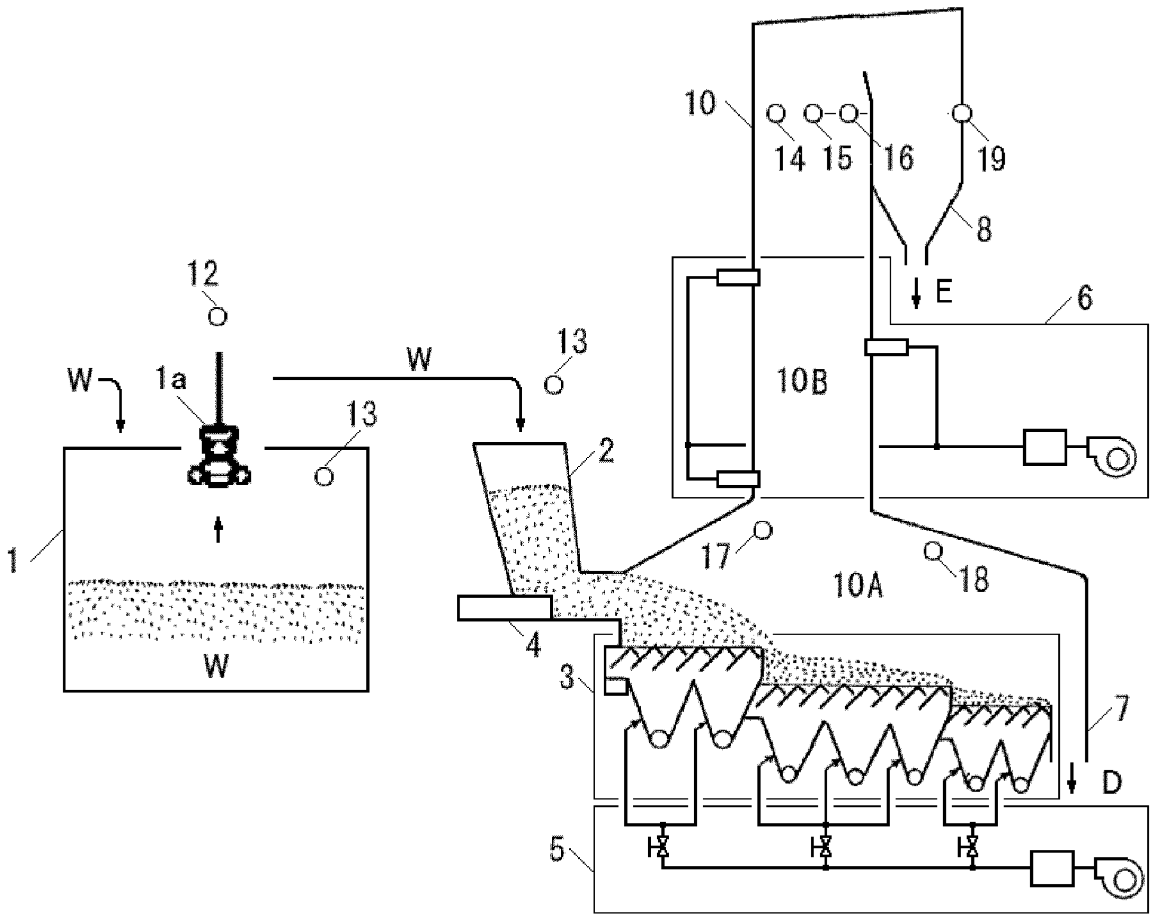


Fig. 3

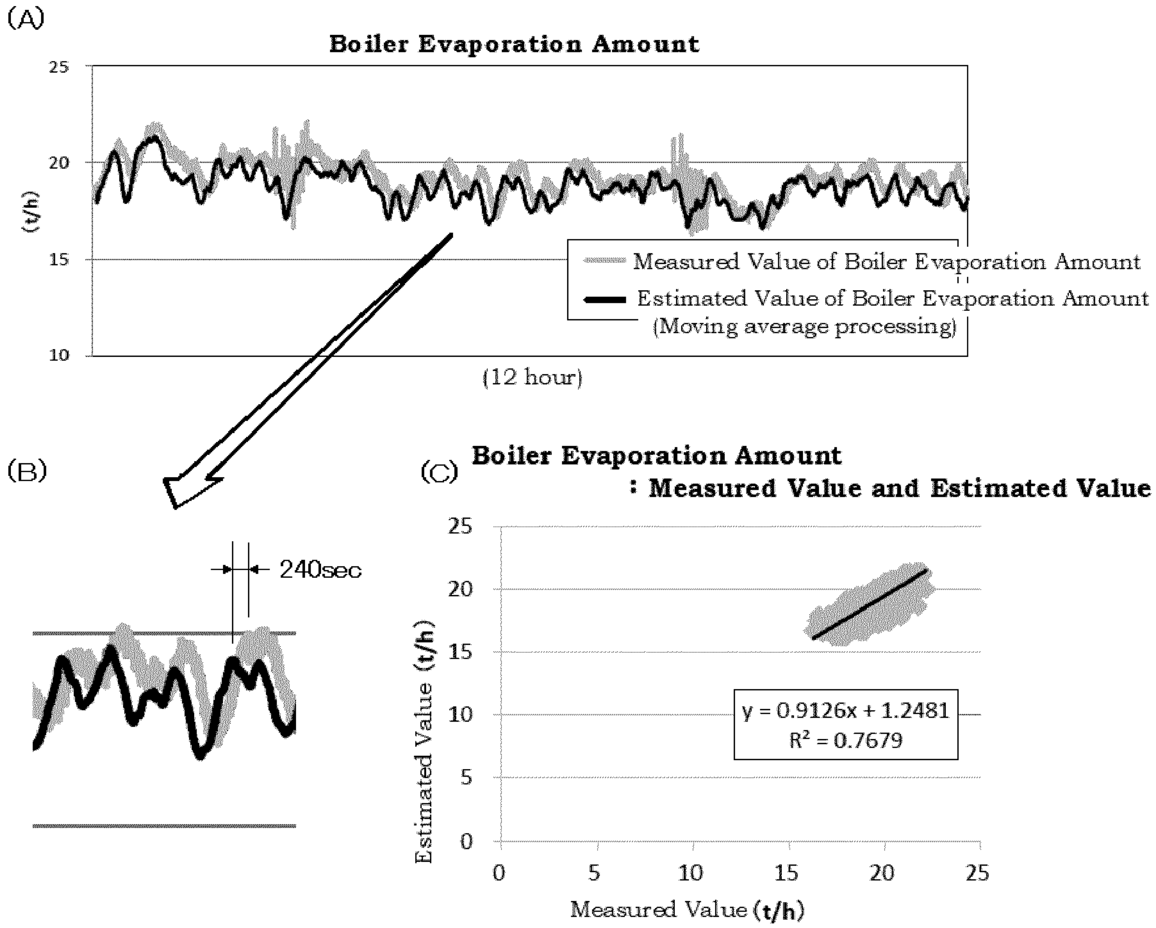
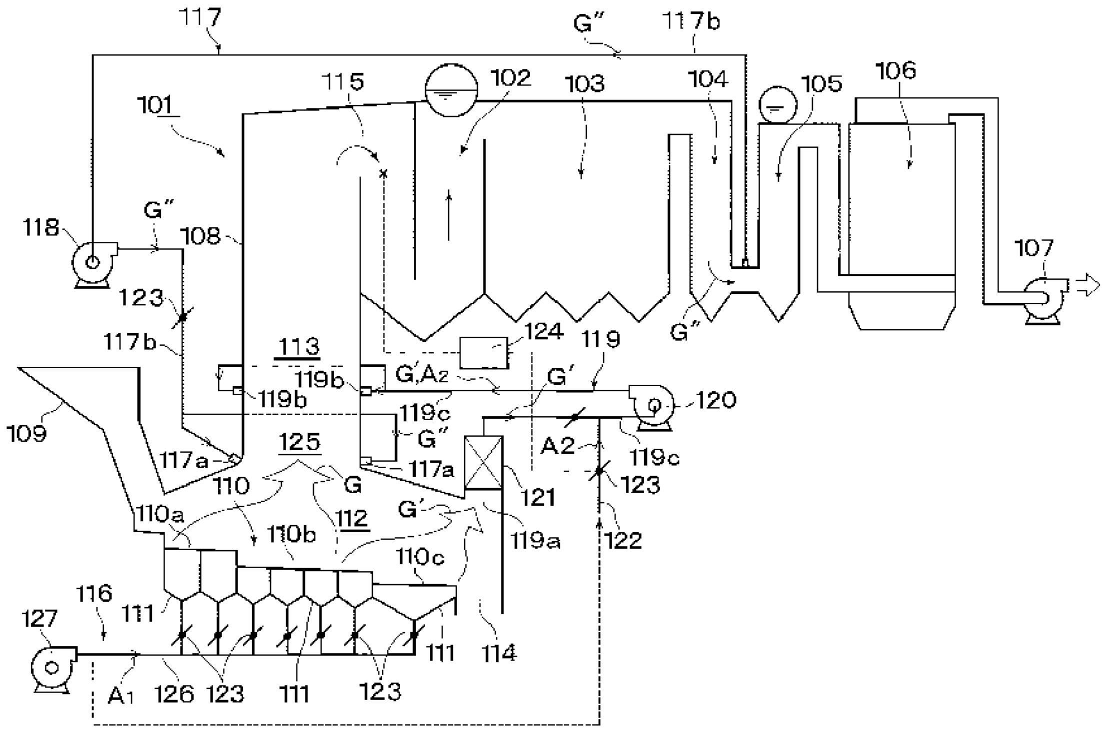

(A)
Boiler Evaporation Amount
25
20
15
10
(t/h)
Measured Value of Boiler Evaporation Amount
Estimated Value of Boiler Evaporation Amount
(Moving average processing)
(12 hour)
(B)
240sec
(C)
Boiler Evaporation Amount
: Measured Value and Estimated Value
25
20
15
10
5
0
Estimated Value (t/h)
y = 0.9126x + 1.2481
R² = 0.7679
0
5
10
15
20
25
Measured Value (t/h)

Fig. 4


117
G″
117b
115
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103
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106
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G″
108
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119b
G′,A2
G′
119b
119c
120
109
125
G″
A2
119c
117a
117a
123
110
G
121
110a
112
G′
119a
122
110b
110c
116
127
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114
A1
126
123
111
123

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060199

A. CLASSIFICATION OF SUBJECT MATTER
F23G5/50(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23G5/50

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2-40410 A (Kubota Tekko Kabushiki Kaisha), 09 February 1990 (09.02.1990), claim 1 (Family: none)	1,4,5
Y	JP 56-1522 B2 (Hitachi Zosen Corp.), 14 January 1981 (14.01.1981), claim 1 (Family: none)	1,4,5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search 24 May 2016 (24.05.16)	Date of mailing of the international search report 07 June 2016 (07.06.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/060199

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2006-64300 A (Takuma Co., Ltd.), 09 March 2006 (09.03.2006), entire text; all drawings (Family: none)	1-5
A	JP 11-94227 A (Sumitomo Heavy Industries, Ltd.), 09 April 1999 (09.04.1999), entire text; all drawings (Family: none)	1-5
A	JP 2012-87977 A (Takuma Co., Ltd.), 10 May 2012 (10.05.2012), entire text; all drawings (Family: none)	1-5
A	JP 2011-27349 A (Takuma Co., Ltd.), 10 February 2011 (10.02.2011), entire text; all drawings (Family: none)	1-5
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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