

## DESCRIPTION

### Title of Invention

SYSTEM FOR REMOVING ADHERED ASH FROM BOILER PIPE GROUP

[Technical Field]

[0001]

The present invention relates to a system for removing adhered ash from a boiler pipe group.

[Background Art]

[0002]

In a thermal power plant including a coal fired boiler, or in a plant such as a waste incinerator and a gasification melting furnace including a waste heat boiler for power generation, incineration ash contained in exhaust gas generated by combustion of coal or waste is likely to adhere to and accumulate in a pipe group (a pipe group of a boiler configured to include a screen pipe, a superheater pipe, an evaporation pipe, and a water pipe of an economizer). When the incineration ash is accumulated in the pipe group, there is a possibility that the pipe group may be corroded. Moreover, power generation efficiency may deteriorate. Therefore, in general, a steam type soot blower or a shock pulse type soot blower is activated at a predetermined time interval (regular cycle) to remove ash accumulated in the

pipe group (hereinafter, referred to as "adhered ash"), that is, to perform "removing adhered ash".

However, when the amount of adhered ash accumulated in the pipe group is small, the amount of adhered ash removed is small even when the soot blower is activated. Accordingly, a less advantageous effect is achieved in removing adhered ash, compared to costs of power, steam, or gas consumed or utilized by the soot blower. On the other hand, when the amount of adhered ash accumulated in the pipe group is large, the adhered ash cannot be sufficiently removed by activating the soot blower at the above-described regular cycle. The adhered ash left behind in the pipe group without being removed may be solidified until the soot blower is subsequently activated. Consequently, there is a possibility that it may be difficult to remove the adhered ash by using the soot blower.

Therefore, in order to properly remove the adhered ash of the pipe group by using the soot blower, various systems for removing the adhered ash from the boiler pipe group have been developed.

[0003]

For example, Patent Document 1 discloses a system for changing the above-described cycle in accordance with a degree of contamination of the pipe group, that is, a degree of accumulation of the adhered ash in the pipe group. In

addition, Patent Document 2 discloses a system for activating the soot blower in view of conditions other than the degree of contamination of the pipe group. In addition, Patent Document 3 discloses a system for measuring each of an upstream pressure and a downstream pressure of an exhaust gas flowing through the pipe group, and activating the soot blower, when a difference between the pressures is equal to or greater than a predetermined value.

[0004]

As the soot blower, a steam type has been mainly used. In recent years, a shock pulse type which does not use steam has been developed and introduced to market.

When the steam type soot blower is activated, the steam type soot blower continues to inject the steam for a predetermined time, and when the predetermined time elapses, the steam type soot blower stops injecting the steam.

On the other hand, the shock pulse type soot blower is also called a pressure wave type soot blower, a shock wave type soot blower, or a shock pulse generator (SPG). When the shock pulse type soot blower is activated, combustible gas filling the inside of the soot blower explodes, and a shock pulse (also referred to as a "shock wave" or a "pressure wave") is emitted. When the shock pulse type soot blower is activated once, it is necessary to refill the shock pulse type soot blower with the gas for the subsequent

activation. In general, the filling takes approximately 1 to 10 minutes.

[Citation List]

[Patent Document]

[0005]

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 62-210316

[Patent Document 2] Japanese Unexamined Patent Application Publication No. 63-286609

[Patent Document 3] Japanese Unexamined Patent Application Publication No. 2017-181007

[Summary of Invention]

[Technical Subject]

[0006]

In all of techniques disclosed in Patent Documents 1 to 3, the soot blower is activated only once after a predetermined condition is satisfied, such as arrival of the above-described cycle.

However, as described above, depending on the amount of accumulated adhered ash, it is not always possible to sufficiently remove the adhered ash only by activating the soot blower once. Therefore, when the adhered ash is not effectively removed even though the soot blower is activated, according to the techniques disclosed in Patent Documents 1 to 3, it is necessary to wait for re-activation of the soot

blower after the predetermined condition is satisfied again, such as arrival of the subsequent cycle. Therefore, according to the techniques, heat exchange performance of the boiler cannot be recovered at an early stage, when the adhered ash is not sufficiently removed by activating the soot blower once.

Therefore, when the soot blower is activated, it is conceivable that the soot blower needs to be consecutively activated multiple times instead of only once.

However, although the adhered ash may be sufficiently removed by activating the soot blower once, it is uneconomical to activate the soot blower multiple times, each time the above-described predetermined condition is satisfied.

[0007]

Therefore, an object of the present invention is to provide a system for removing adhered ash from a boiler pipe group, which properly removes the adhered ash at an early stage while economic efficiency is ensured.

[Subject to be solved]

[0008]

According to the present invention, there is provided a system for removing adhered ash from a boiler pipe group, which removes adhered ash of a plurality of pipe groups of a boiler for recovering heat from an exhaust gas generated

in a furnace. The system includes a soot blower disposed between the plurality of pipe groups, an induced draft fan disposed downstream of the plurality of pipe groups to induce the exhaust gas, and a control device that controls activation of the soot blower.

The control device calculates heat transmittance of the boiler, activates the soot blower only once at a predetermined interval, when the calculated heat transmittance is equal to or greater than a predetermined value, thereafter, performs a one-time activation on the soot blower again at the predetermined interval or at an interval different from the predetermined interval, performs an adhered ash assessment process of selectively assessing any one of first assessment and second assessment, when the calculated heat transmittance is smaller than the predetermined value, performs a consecutive activation to consecutively activate the soot blower multiple times without setting the interval, when the first assessment is obtained in the adhered ash assessment process, and performs the one-time activation when the second assessment is obtained in the adhered ash assessment process.

The adhered ash assessment process is performed to include at least one condition of a first condition that a main steam amount of the plurality of pipe groups is equal to or greater than a first threshold value, a second

condition that a pressure difference between the exhaust gases in an inlet and an outlet of the plurality of pipe groups is equal to or greater than a second threshold value, a third condition that a rotation speed of the induced draft fan is equal to or greater than a third threshold value, and a fourth condition that a total combustion air amount supplied to the furnace is equal to or greater than a fourth threshold value.

When the adhered ash assessment process is performed based on only one condition of the four conditions, the first assessment is obtained when the one condition is satisfied, and the second assessment is obtained when the one condition is not satisfied, and in a case where the adhered ash assessment process is performed to include any two, three, or four conditions of the four conditions, the first assessment is obtained when all of the conditions including the two, three, or four conditions are satisfied together, and the second assessment is obtained when any one of the conditions including the two, three, or four conditions is not satisfied.

[Advantageous Effects of Invention]

[0009]

According to the system for removing the adhered ash from the boiler pipe group of the present invention, the one-time activation and the consecutive activation are

properly and separately used, based on the heat transmittance. Furthermore, when the heat transmittance is smaller than the predetermined value, the adhered ash assessment process is performed, and it is possible to properly assess whether or not to perform the consecutive activation on the soot blower. Therefore, the adhered ash can be properly removed at an early stage while economic efficiency is ensured.

[Brief Description of Drawings]

[0010]

Fig. 1 is a schematic configuration diagram of a system for removing adhered ash from a boiler pipe group according to an embodiment and a first modification example.

Fig. 2 is an example of a flowchart illustrating a control in which the system for removing the adhered ash from the boiler pipe group activates a soot blower.

Figs. 3A to 3D are examples of a specific process flow in Step S16 (adhered ash assessment process) in Fig. 2.

Figs. 4A to 4C are schematic configuration diagrams illustrating a part of a system for removing adhered ash from a boiler pipe group according to a second modification example.

Fig. 5 is a schematic configuration diagram of a system for removing adhered ash from a boiler pipe group according to a third modification example.

Fig. 6 is a schematic configuration diagram of a system for removing adhered ash from a boiler pipe group according to a fourth modification example.

[Description of Embodiments]

[0011]

Hereinafter, a system for removing adhered ash from a boiler pipe group as an embodiment and modification examples will be described with reference to the drawings. Configurations described below are merely examples, and are not intended to exclude applications of various modifications or techniques which are not specified. The configurations described below can be modified and implemented in various ways within the scope not departing from the concepts. In addition, the configurations can be optionally selected when necessary, or can be appropriately combined with each other.

[0012]

[1. Overview of System for Removing Adhered Ash from Boiler Pipe Group]

Fig. 1 is a schematic configuration diagram of a system for removing adhered ash from a boiler pipe group 1 (hereinafter, referred to as a "removal system 1") of the present embodiment. Fig. 1 also serves as a diagram illustrating a first modification example (removal system 1') to be described later.

In Fig. 1 and Figs. 4A to 6 (to be described later), description will be made by illustrating an orthogonal coordinate system including an X-axis and a Y-axis. The X-axis represents a horizontal direction and the Y-axis represents a vertical direction. In addition, an arrow direction on the Y-axis represents the vertical direction and an upward direction.

[0013]

In the present embodiment, as an example, the removal system 1 applied to a waste incinerator plant including a boiler for generating power will be described. As a matter of course, the system for removing the adhered ash from the boiler pipe group of the present invention can also be applied to other plants such as a thermal power plant and a gasification melting furnace.

The boiler is roughly classified into a two drum type including a steam drum and a water drum, and a one drum type including a steam drum. The removal system 1 may be used for any one of the boilers. Although illustration of the steam drum is omitted in Fig. 1, a waste incinerator plant including the one drum type boiler will be described as an example.

[0014]

The removal system 1 is a system for removing adhered ash from a plurality of pipe groups 2 of a boiler which

recovers heat from an exhaust gas generated in a furnace, and includes a soot blower 3 disposed between the plurality of pipe groups 2, an induced draft fan 13 disposed downstream of the plurality of pipe groups 2 to induce the exhaust gas, and a control device 4 that controls activation of the soot blower 3.

[0015]

As will be described in detail later, the control device 4 calculates a heat transmittance "K" of the boiler. When the heat transmittance "K" is equal to or greater than a predetermined value  $\alpha_1$ , the control device 4 activates the soot blower 3 only once at a predetermined interval, and performs a "one-time activation" again at the predetermined interval or at an interval different from the predetermined interval.

In addition, when the calculated heat transmittance "K" is smaller than the predetermined value  $\alpha_1$  and smaller than a predetermined value  $\alpha_2$ , the control device 4 performs an adhered ash assessment process of selectively assessing any one of first assessment and second assessment. When the first assessment is obtained in the adhered ash assessment process, in principle, the control device 4 performs a "consecutive activation" for consecutively activating the soot blower 3 multiple times without setting the predetermined interval, and when the second assessment

is obtained in the adhered ash assessment process, the control device 4 performs "the one-time activation".

[0016]

The adhered ash assessment process is performed to include at least one condition of first to fourth conditions described below.

First condition: A main steam amount "Qs" of a pipe group 2 is equal to or greater than a first threshold value.

Second condition: A pressure difference  $\Delta P_g$  of the exhaust gas in an inlet and an outlet of the pipe group 2 is equal to or greater than a second threshold value.

Third condition: A rotation speed "Qr" of the induced draft fan 13 is equal to or greater than a third threshold value.

Fourth condition: A total combustion air amount "Qc" supplied to the furnace is equal to or greater than a fourth threshold value.

Based on experiences of the inventor, when each of the conditions is satisfied, there is a high possibility that a large amount of the adhered ash is accumulated in the pipe group 2. Therefore, in each of the four conditions, it is conceivable that the "consecutive activation" is desirably performed on the soot blower 3.

[0017]

In Figs. 3A to 3D to be described in detail later,

only the above-described four conditions (first condition, second condition, third condition, and fourth condition) will be described as an example. However, depending on a design, other conditions (for example, a fifth condition, a sixth condition, a seventh condition, an eighth condition, and so forth) may be added to the four conditions.

As the other conditions, for example, the fifth condition may be a condition that "a temperature of main steam of the pipe group 2 measured by an outlet steam temperature measuring device 24b (to be described later) is smaller than a fifth threshold value". For example, the sixth condition may be a condition that "the amount of water sprayed by a desuperheater 17 (to be described later) is smaller than a sixth threshold value. For example, the seventh condition may be a condition that "a gas temperature of the exhaust gas in the outlet of the pipe group 2 measured by a gas temperature measuring device 15b (to be described later, an outlet gas temperature measuring device) is equal to or greater than a seventh threshold value".

In addition, although not illustrated, in some cases, the waste incinerator plant may adopt an exhaust gas recirculation technique (Exhaust Gas Recirculation (EGR)) for circulating some of the exhaust gas existing downstream of a dust removal device 11 to the vicinity of a stoker 7. In this case, as the other conditions, for example, as the

eighth condition, a gas flow rate measuring device for measuring a gas flow rate of the circulated exhaust gas (circulated exhaust gas) may be installed separately from gas flow rate measuring devices 16a and 16b (to be described later), and a condition that "the gas flow rate of the circulated exhaust gas measured by the gas flow rate measuring device is equal to or greater than an eighth threshold value" may be added.

As in the first condition to the fourth condition, the other conditions are also bifurcated, based on an evaluation formula. Specifically, with regard to the other conditions, when a condition of the evaluation formula is satisfied, there is a high possibility that a large amount of the adhered ash may be accumulated in the pipe group 2. Therefore, it is desirable to perform the "consecutive activation" on the soot blower 3. When the condition of the evaluation formula is not satisfied, a condition that it is not necessary to perform the "consecutive activation" on the soot blower 3 (accordingly, the "one-time activation" may be performed) is selected.

When the adhered ash assessment process is performed, based on only one condition of the four conditions of the first condition to the fourth condition which are described above, the first assessment is obtained when the one condition is satisfied. The second assessment is obtained

when the one condition is not satisfied.

In addition, when the adhered ash assessment process is performed to include any two, three, or four conditions of the above-described four conditions (in some cases, the fifth condition may be added), the first assessment is obtained when all of the conditions including the two, three, or four conditions are satisfied together. The second assessment is obtained when any one of all of the conditions including the two, three, or four conditions is not satisfied.

[0018]

Hereinafter, in addition to the above-described configuration at least belonging to the removal system 1, other configurations will be described. After the configurations are described, a control (including the adhered ash assessment process) relating to the activation of the soot blower 3 will be described in detail.

[0019]

## [2. System Configuration]

As illustrated in Fig. 1, the removal system 1 includes a hopper 5 that stores an incineration object such as waste, a feeder 6 that extrudes the incineration object stored in the hopper 5 from below the hopper 5 (in a Y-axis direction and from below), a stoker 7 that incinerates the incineration object while transporting the incineration

object extruded by the feeder 6, and an ash chute 8 that discharges the residue incinerated by the stoker 7.

[0020]

In addition, the removal system 1 exchanges heat of the exhaust gas including flying ash generated by incineration of the incineration object in the stoker 7 with an economizer 9 (a type of pipe groups, also known as a "economizer") disposed in each pipe group 2 and downstream thereof. The removal system 1 discharges the exhaust gas from which the dust is removed, from a chimney 12 to an atmosphere via a temperature reducing tower 10 that cools the heat-exchanged exhaust gas and a dust removal device 11 (for example, a bag filter) that removes soot and dust of the cooled exhaust gas.

[0021]

Paths of the exhaust gas from the stoker 7 to an opening of the chimney 12 are formed by using a water-cooling wall or a duct, and are substantially sealed. Out of the paths, the path extending upward in the Y-axis direction from directly above the stoker 7 is called a "pass 1" ("pass" means "pass" in English), the path bent in an upper end of the pass 1, adjacent to the pass 1, and extending downward in the Y-axis direction is called a "pass 2", and the path bent in a lower end of the pass 2, adjacent to the pass 2, and extending upward in the Y-axis direction

is called a "pass 3". As indicated by an arrow flow in Fig. 1, the exhaust gas generated in the stoker 7 flows to rise in the pass 1, to fall in the pass 2, and to rise in the pass 3. In addition, in order to induce the flow of the exhaust gas from the pass 1 toward the chimney 12, the induced draft fan 13 is disposed in the path between the dust removal device 11 and the chimney 12.

[0022]

The removal system 1 includes a pressure measuring device 14a (inlet pressure measuring device) disposed in pass 1 to measure a pressure of the exhaust gas, and a pressure measuring device 14b (outlet pressure measuring device) disposed in the path of the exhaust gas between the economizer 9 and the temperature reducing tower 10 to measure the pressure of the exhaust gas.

[0023]

Each disposition of the pressure measuring devices 14a and 14b is not limited thereto. Depending on the design of the plant, the inlet pressure measuring device 14a may be installed at any desired place upstream of the pipe group 2 disposed on the most upstream side in the plurality of pipe groups 2 serving as a removal target of the adhered ash in the path of the exhaust gas, that is, in the "inlet of the plurality of pipe groups 2". Depending on the design of the plant, the outlet pressure measuring device 14b may be

installed at any desired place downstream of the pipe group 2 disposed on the most downstream side in the plurality of pipe groups 2 serving as a removal target of the adhered ash in the path of the exhaust gas, that is, in the "outlet of the plurality of pipe groups 2". However, it is desirable that any desired places are as close as possible to the plurality of pipe groups 2 serving as a removal target of the adhered ash.

[0024]

The removal system 1 includes a gas temperature measuring device 15a (inlet gas temperature measuring device) that measures the temperature of the exhaust gas while being disposed below the pipe group 21 located on the most upstream side (lower side) of the plurality of pipe groups 2 disposed in the pass 3, serving as a removal target of the adhered ash, and a gas temperature measuring device 15b (outlet gas temperature measuring device) that measures the temperature of the exhaust gas while being disposed in the path of the exhaust gas between the pipe group 22c located on the most downstream side (upper side) of the plurality of pipe groups 2 disposed in the pass 3 and the economizer 9.

[0025]

Each disposition of the gas temperature measuring devices 15a and 15b is not limited thereto. Depending on

the design of the plant, the inlet gas temperature measuring device 15a may be installed at any desired place upstream of the pipe group 2 disposed on the most upstream side in the plurality of pipe groups 2 serving as a removal target of the adhered ash in the path of the exhaust gas, that is, in the "inlet of the plurality of pipe groups 2". Depending on the design of the plant, the outlet gas temperature measuring device 15b may be installed at any desired place downstream of the pipe group 2 disposed on the most downstream side in the plurality of pipe groups 2 serving as a removal target of the adhered ash in the path of the exhaust gas, that is, in the "outlet of the plurality of pipe groups 2". However, it is desirable that any desired places are as close as possible to the plurality of pipe groups 2 serving as a removal target of the adhered ash.

[0026]

In other words, in the present embodiment and the modification example to be described later, the "plurality of pipe groups 2" serving as a removal target of the adhered ash mean the pipe groups disposed between the two pressure measuring devices 14a and 14b and between the two gas temperature measuring devices 15a and 15b.

As an example, Fig. 1 illustrates a configuration in which the plurality of pipe groups 2 are disposed in the pass 3. Although the economizer 9 also includes the pipe

group (refer to Fig. 6), in the configuration in Fig. 1, the economizer 9 is disposed downstream of the outlet of the plurality of pipe groups 2, that is, downstream of the outlet gas temperature measuring device 15b. Therefore, in the present embodiment, the pipe group included in the economizer 9 is not considered as the pipe group serving as a removal target of the adhered ash. As will be described later, an example in which the pipe group included in the economizer 9 is also considered as the "plurality of pipe group 2" is a fourth modification example of the present embodiment.

[0027]

In the pass 3, the pipe groups 2 configured to include a hanging pipe (screen pipe) 21 are disposed in the most upstream side (the most downward side in the Y-axis direction) of the flow of the exhaust gas, and the pipe groups 2 configured to include each of superheater pipes (superheaters) 22a, 22b, and 22c are sequentially disposed toward the downstream side (upper side in the Y-axis direction) from the pipe group 21.

[0028]

As an example, Fig. 1 illustrates a configuration in which a soot blower 3 (3a) is disposed between the plurality of pipe groups 2 having the same type. That is, out of the pipe groups configured to include superheater pipes, the

soot blower 3a is disposed between the pipe group 2 configured to include a superheater pipe 22a located on the most upstream side and the pipe group 2 (pipe group 2 configured to include a superheater pipe 22b) disposed adjacent to the pipe group 2 downstream of the pipe group 2. The disposition of the soot blower 3 (3a) is not limited thereto. The soot blower 3 may be disposed between different types of the pipe groups adjacent to each other, out of the pipe groups 2 configured to include different types of the pipe groups 2, for example, the screen pipe of the boiler, the superheater pipe, an evaporation pipe, and a water pipe of the economizer. The soot blower 3 may adopt a steam type or a shock pulse type. Here, description will be continued on an assumption that the soot blower 3 is a shock pulse type soot blower.

[0029]

The removal system 1 includes at least one of a gas flow rate measuring device 16a disposed in the pass 2 to measure a flow rate of the exhaust gas, and a gas flow rate measuring device 16b disposed in the path of the exhaust gas between the dust removal device 11 and the induced draft fan 13 to measure a flow rate of the exhaust gas. As described above, the path of the exhaust gas from the stoker 7 to an opening of the chimney 12 is substantially sealed. Therefore, information on the gas flow rate of the exhaust

gas required for calculating the heat transmittance "K" (to be described later) can be obtained by installing one gas flow rate measuring device.

[0030]

Each disposition of the gas flow rate measuring devices 16a and 16b is not limited thereto. At least one may be installed in the path of the exhaust gas. From a viewpoint of reducing a cleaning frequency of the gas flow rate measuring device, it is desirable to dispose the gas flow rate measuring device downstream of the dust removal device 11. That is, when any one of the gas flow rate measuring devices 16a and 16b is selected, it is desirable to install the gas flow rate measuring device 16b.

In addition, instead of installing the gas flow rate measuring device 16a, the gas flow rate of the exhaust gas in the pass 2 may be calculated, and may be used in calculating the heat transmittance "K" (to be described later).

[0031]

The removal system 1 includes a desuperheater (desuperheater) 17 that sprays water into the superheater pipe to properly cool the steam passing through the inside of the pipe group 2 configured to include the superheater pipe. In Fig. 1, the desuperheater 17 is disposed in the pipe group 2 configured to include the superheater pipes

22c disposed on the most downstream side out of the four pipe groups 2 disposed in the pass 3. The amount of water sprayed by the desuperheater 17 is measured by a spray water amount measuring device 18.

[0032]

The removal system 1 includes a steam temperature measuring device 24a (an inlet steam temperature measuring device) disposed inside the superheater pipe 22a located on the most upstream side out of the superheater pipes included in the plurality of pipe groups 2 serving as a removal target of the adhered ash to measure a steam temperature and a steam temperature measuring device 24b (an outlet steam temperature measuring device) disposed inside the superheater pipe 22c located on the most downstream side to measure a steam temperature. The steam temperature measuring devices 24a and 24b are installed in the superheater pipe out of the plurality of pipe groups 2.

[0033]

The removal system 1 includes a main steam amount measuring device 25 that measures a main steam amount flowing inside the superheater pipe. Here, the main steam amount measuring device 25 is disposed inside the superheater pipe 22a located on the most upstream side of the superheater pipes included in the plurality of pipe groups 2.

The removal system 1 includes a primary air supply device 26 located below the stoker 7, a secondary air supply device 27 located in the pass 1 above the stoker 7, and a combustion air amount measuring device 28 that measures a total amount of primary air and secondary air (total combustion air amount) supplied from the air supply devices 26 and 27 to the path of the exhaust gas.

[0034]

Various types of information measured by the respective pressure measuring device 14a and 14b, respective gas temperature measuring device 15a and 15b, the gas flow rate measuring device 16a and 16b, the spray water amount measuring device 18, the respective steam temperature measuring device 24a and 24b, the main steam amount measuring device 25, and the combustion air amount measuring device 28 are input to the control device 4. The control device 4 is an electronic control device (e.g., computer) included in the removal system 1, and is equipped with a processor or a timer operated on a clock, and a storage device (all are not illustrated).

[0035]

### [3. Control Configuration (Flowchart)]

As described above, the control device 4 calculates the heat transmittance "K" of the boiler, and in accordance with the heat transmittance "K", while properly performing

an adhered ash assessment process, the control device 4 performs a "one-time activation" or a "consecutive activation" on the soot blower 3.

Hereinafter, the control (including the adhered ash assessment process) relating to the activation of the soot blower 3 will be described in detail with reference to the flowcharts illustrated in Figs. 2 and 3A to 3D. Here, the description will be continued on an assumption that the dust removal device 11 is a bag filter.

[0036]

First, an operator operates an activating switch or a control panel (not illustrated) to start an operation of a plant such as an incinerator, and activates the removal system 1 so that the control device 4 performs respective processes subsequent to "start" in a flowchart illustrated in Fig. 2.

Initial values of times  $t_1$ , "Tmin", "Tmax", and  $\Delta t$  appearing in this flowchart, an initial value of a dirty heat transmittance "Kd", an initial value of a flag "F", the respective predetermined values  $\alpha_1$  and  $\alpha_2$ , and a recovery threshold value "R" are set as follows, and are stored in a storage device in advance before the "start" in the flowchart.

A value of the heat transmittance initially calculated when the removal system 1 is activated is the initial value.

Accordingly, it is not necessary to set a clean heat transmittance "Kc" in advance before the "start" in this flowchart.

[0037]

The time t1 is an initial time (remaining time of a timer) when the timer is counted down, and corresponds to an interval when the "one-time activation" is performed on the soot blower 3. The initial value of the time t1 is a predetermined value that satisfies a relationship " $0 < T_{min} < t1 \leq T_{max}$ ". "Tmin" is a minimum value of the interval (shortest interval) for activating the soot blower 3, and is set to one hour, for example. In addition, "Tmax" is a maximum value of an interval (longest interval) for activating the soot blower 3, and is set to three hours, for example.

For example, the initial value of the time t1 is set to a time obtained by " $\frac{2}{3} \times T_{max} - \Delta t$  (for example,  $\Delta t$  is 0.5 hours)". For simplified description, here, the values of "Tmin" and "Tmax" are respectively set to an integral multiple of  $\Delta t$ . In addition, the time t1 is subsequently changed from the initial value in Steps S7 and S19 (to be described later).

[0038]

The dirty heat transmittance "Kd" is a heat transmittance when it is considered that the pipe group 2

serving as a removal target is contaminated due to the accumulated adhered ash.

The initial value of the dirty heat transmittance "Kd" is set to a predetermined value (for example,  $K_d=0.5$ ) that satisfies a relationship of " $0 < K_d < \alpha_2$ ". Thereafter, the dirty heat transmittance "Kd" is changed from the initial value in Step S3 (to be described later).

The initial value of the flag "F" is set to  $F=0$  (first value). Thereafter, the flag "F" is changed to any one of  $F=0$  (first value),  $F=1$  (second value), and  $F=2$  (third value) in Steps S9, S20, and S14 (to be described later).

[0039]

In each of Steps S5 and S15 (to be described later), the first predetermined value  $\alpha_1$  and the second predetermined value  $\alpha_2$  are threshold values for assessing whether or not to perform the "one-time activation" on the soot blower 3, compared to the heat transmittance "K" (clean heat transmittance "Kc"). In addition, in Step S15 (to be described later), the second predetermined value  $\alpha_2$  is a threshold value for assessing whether or not to perform the adhered ash assessment process, compared to the heat transmittance "K" (clean heat transmittance "Kc"). A relationship of " $0 < \alpha_2 < \alpha_1$ " is satisfied. Here, for simplified description, the description will be continued on an assumption that a relationship " $0 < \alpha_2 < 1 < \alpha_1$ " is

satisfied.

The clean heat transmittance " $K_c$ " is a heat transmittance calculated immediately after the soot blower 3 is activated. In other words, the clean heat transmittance " $K_c$ " is the heat transmittance when it is considered that a heat exchange rate is an improved state after the adhered ash of the pipe group 2 is somewhat removed since the time is immediately after the soot blower 3 is activated.

The first predetermined value  $\alpha_1$  is set to a value at which heat exchange of the pipe group 2 is clearly satisfactory when the clean heat transmittance " $K_c$ " is  $\alpha_1$  or higher and the adhered ash is not accumulated or the accumulated amount of the adhered ash is extremely small. Here, for simplified description, the first predetermined value  $\alpha_1$  is set to a value which can be achieved for the first time as follows. Immediately after the flag "F" is changed to  $F=2$  in Step S20 (to be described later), the clean heat transmittance " $K_c$ " is not  $\alpha_1$  or higher when only the "one-time activation" is performed on the soot blower, that is, only by a single activation of the soot blower. As the "consecutive activation", the soot blower 3 is consecutively activated at least twice or more times. For example, the first predetermined value  $\alpha_1$  is set to  $\alpha_1=1.2$  ( $W/m^2K$ ).

In addition, when the clean heat transmittance " $K_c$ " is  $\alpha_2$  or higher and lower than  $\alpha_1$ , although the heat exchange of the pipe group 2 is not clearly satisfactory, the operation of the plant is not still significantly affected by the accumulation of adhered ash. Therefore, the second predetermined value  $\alpha_2$  is set to a value which is sufficient when the "one-time activation" is performed on the soot blower. In other words, when the clean heat transmittance " $K_c$ " is lower than  $\alpha_2$ , the second predetermined value  $\alpha_2$  is set to a value which requires the adhered ash assessment process (to be described later). Here, for simplified description, the second predetermined value  $\alpha_2$  is set to a value which can be achieved for the first time as follows. Immediately after the flag " $F$ " is changed to  $F=2$  in Step S20 (to be described later), the clean heat transmittance " $K_c$ " is not  $\alpha_2$  or higher when only the "one-time activation" is performed on the soot blower 3, that is, only by a single activation of the soot blower. As the "consecutive activation", the soot blower 3 is consecutively activated at least twice or more times. For example, the second predetermined value  $\alpha_2$  is set to  $\alpha_2=0.8$  (W/m<sup>2</sup>K).

Therefore, in the flowchart in Fig. 2 (to be described later), when the flag " $F$ " is once changed to  $F=2$  in Step S20 (to be described later), as long as a second assessment is not made in the adhered ash assessment process (to be

described later), the control device 4, consecutively performs the "consecutive activation" on the soot blower 3 at least twice.

Here, for simplified description, the values of  $\alpha_1$  and  $\alpha_2$  are set as described above on an assumption that a relationship " $0 < \alpha_2 < 1 < \alpha_1$ " is satisfied. However, as long as a relationship " $0 < \alpha_2 < \alpha_1$ " is satisfied, according to the design, the values of  $\alpha_1$  and  $\alpha_2$  may be properly set. In this case, immediately after the flag "F" is changed to "F"=2 in Step S20 (to be described later), the "consecutive activation" is performed on the soot blower 3 in principle. However, the "consecutive activation" is not always performed, and the "one-time activation" may be performed in some cases.

Compared with a recovery rate ( $K_c/K_d$ ), the recovery threshold value "R" is a threshold value for assessing an effect of removing the adhered ash (degree of improvement in the heat transmittance "K"), and an initial value thereof is set to a predetermined value (for example,  $R=1$ ) that satisfies a relationship of " $1 \leq R$ ". Here, the recovery rate is a variable indicating to what extent the heat transmittance "K" is recovered (improved) before and after the soot blower 3 is activated, and is a value obtained by dividing the clean heat transmittance " $K_c$ " by the dirty heat transmittance " $K_d$ ".

Each of the first predetermined value  $\alpha_1$ , the second predetermined value  $\alpha_2$ , and the recovery threshold value "R" is a constant that is not changed from the respective initial values appropriately set according to the design. In addition, each of the above-described "Tmin", "Tmax", and  $\Delta t$  is also a constant that is not changed from the respective initial values appropriately set according to the design.

[0040]

In Step S1, the control device 4 assesses whether or not a predetermined time elapses after the operation of the plant (for example, an incinerator) starts. This is because environmental conditions (for example, a temperature or a pressure) inside the plant are not stable until the predetermined time elapses after the operation of the plant starts. The control device 4 repeatedly performs the process in Step S1 after the operation of the plant starts until the predetermined time elapses, and performs the process in Step S2 when the predetermined time elapses.

[0041]

In Step S2, the control device 4 calculates the heat transmittance "K", based on temperature information and flow rate information. After the heat transmittance "K" is calculated, the control device 4 performs the process in Step S3.

The heat transmittance "K" is expressed by (Equation 1) below.

[Equation 1]

$$K = \frac{Q}{(A \times LMTD)} \text{ [W/m}^2\text{K]} \quad \dots \text{ (Equation 1)}$$

However, each variable is as follows.

$Q$  : Exchanged heat amount [W]  $\{=(Tg_{out} - Tg_{in}) \times Cp_g \times W_g\}$   
 $A$  : Heat transfer area [m<sup>2</sup>]  
 $LMTD$  : Logarithmic average temperature difference [K]  $\{=(dT_1 - dT_2)/\{\ln(dT_1/dT_2)\}}\}$   
 $Tg_{in}$  : Superheater inlet gas temperature [K]  
 $Tg_{out}$  : Superheater outlet gas temperature [K]  
 $Ts_{in}$  : Superheater inlet steam temperature [K]  
 $Ts_{out}$  : Superheater outlet steam temperature [K]  
 $dT_1$  :  $Tg_{in} - Ts_{out}$   
 $dT_2$  :  $Tg_{out} - Ts_{in}$   
 $Cp_g$  : Gas specific heat [J/kgK]  
 $W_g$  : Gas flow rate [kg/s]

[0042]

The temperature information and the flow rate information are measured as follows, and are sent to the control device 4. That is, a superheater inlet gas temperature "Tgin" is measured by the inlet gas temperature measuring device 15a, and a superheater outlet gas temperature "Tgout" is measured by the outlet gas temperature measuring device 15b. A superheater inlet steam temperature "Tsin" is measured by the inlet steam temperature measuring device 24a, and a superheater outlet steam temperature "Tsout" is measured by the outlet steam temperature measuring device 24b. In addition, a gas flow rate "Wg" is measured by any one of the gas flow rate measuring devices 16a and 16b, or is acquired by calculation. Gas specific heat "Cpg" is specific heat of the exhaust gas,

and is a constant corresponding to a component of the exhaust gas. In addition, a heat transfer area "A" is a total heat transfer area of the superheater in the plurality of pipe groups 2.

[0043]

In Step S3, the control device 4 causes a storage device (not illustrated) to store the heat transmittance "K" calculated in Step S2 as either the clean heat transmittance "Kc" or the dirty heat transmittance "Kd", in accordance with the value of the flag "F" at the time of the process in Step S3.

Specifically, the control device 4 causes the storage device to store the heat transmittance, as  $K_c = K$  when the flag "F" is the first value, here  $F=0$ , as  $K_d = K$  when the flag "F" is the second value, here when  $F=1$ , and as  $K_d = K$  when the flag "F" is the third value, here  $F=2$ .

Immediately after this flowchart starts, the flag "F" is the initial value, that is,  $F=0$ . Therefore, the control device 4 causes the storage device to store the heat transmittance "K" calculated immediately before, as the clean heat transmittance "Kc" (that is,  $K_c = K$ ).

The control device 4 performs the process in Step S4.

[0044]

In Step S4, the control device 4 assesses whether or not the flag "F" is  $F=0$ . When the flag "F" is  $F=0$ , that is,

immediately after the "start" of the flowchart, or immediately after the soot blower 3 is activated in Step S13 (to be described later), the control device 4 performs the process in Step S5.

When the flag "F" is not F=0 (in a case of F=1 or F'=2), the control device 4 performs the process in Step S10 so that the process flow proceeds toward the activation of the soot blower 3 in Step S13 (to be described later).

[0045]

In Step S5, the control device 4 assesses whether or not the value of the clean heat transmittance "Kc" stored in the storage device is equal to or greater than the first predetermined value  $\alpha 1$ .

When the value of the clean heat transmittance "Kc" is equal to or greater than the first predetermined value  $\alpha 1$ , it is considered that the heat exchange of the pipe group 2 is clearly satisfactory and the adhered ash is not accumulated or the accumulated amount of the adhered ash is extremely small. Therefore, the control device 4 performs the process in Step S6 so that the process flow proceeds to the process of changing an activation interval of the soot blower 3 to be longer.

When the value of the clean heat transmittance "Kc" is smaller than  $\alpha 1$ , the heat exchange of the pipe group 2 is not always satisfactory. Therefore, the control device 4

performs the process in Step S15.

[0046]

In Step S6, the control device 4 assesses whether or not the time  $t_1$  is shorter than "Tmax" which is the longest interval.

When the value of the time  $t_1$  is shorter than "Tmax" (here, three hours), the control device 4 performs the process in Step S7 to change the value of the time  $t_1$  to be greater (to lengthen the time  $t_1$ ).

When the value of the time  $t_1$  is "Tmax", the time  $t_1$  cannot be changed to be longer any more. Therefore, the control device 4 performs the process in Step S8 without changing the value of the time  $t_1$  (by skipping Step S7).

[0047]

In Step S7, the control device 4 changes the value of the time  $t_1$  to a value of " $t_1 + \Delta t$ ". In other words, the control device 4 changes the value of  $t_1$  of the above-described storage device, as  $t_1 = t_1 + \Delta t$ , and causes the storage device to store the value again. That is, the control device 4 resets the interval to be longer, compared to the value set immediately before. This is because, when the clean heat transmittance " $K_c$ " is equal to or greater than the first predetermined value  $\alpha_1$ , the soot blower 3 is excessively activated at the current interval. The excessive activation is not desirable from a viewpoint of

cost effectiveness. Therefore, the "one-time activation" is performed on the soot blower 3 at an interval longer than before.

The control device 4 performs the process in Step S8.

[0048]

The control device 4 starts a timer (counter) in Step S8. In the started timer, a count value is counted down from the time t1 to 0 in accordance with a clock included in the control device 4. For example, when the time t1 at a start time is two hours, two hours (7,200 seconds) are counted, and the timer is stopped when the count value reaches 0. After the timer is stopped, the control device 4 performs the process in Step S9.

[0049]

In Step S9, the control device 4 changes the value of the flag "F" stored in the storage device to F=1, and causes the storage device to store the value again. The control device 4 returns the process flow to Step S2, and performs the process in Step S2 again.

Since the processes in Step S2, Step S3, and Step S4 have already been described, the processes from Step S4 to the process in Step S10 as the subsequent step will be briefly described below.

That is, the control device 4 calculates the heat transmittance "K" after setting an interval by using the

timer (Step S2), and in subsequent Step S3, since the flag "F" is  $F=1$ , the heat transmittance "K" calculated immediately before is stored in the storage device as the dirty heat transmittance "Kd" (that is,  $K_d=K$ ). Since the flag "F" is  $F=1$  at the current time, the control device 4 assesses in Step S4 that the flag "F" is not  $F=0$ , and performs the process in Step S10 as the subsequent process.

[0050]

In Step S10, the control device 4 assesses whether or not the bag filter serving as the dust removal device 11 is in a process of backwashing. Since the control device 4 controls performing the "backwashing" of the bag filter, it is possible to assess whether or not the bag filter is in the process of backwashing.

The control device 4 repeatedly performs the process in Step S10 when it is assessed that the bag filter is in the process of backwashing, and performs the process in Step S11 when it is assessed that the bag filter is not in the process of backwashing. In this manner, the control device 4 does not activate the soot blower 3 while the backwashing of the bag filter is performed, and can activate the soot blower 3 after waiting for the completion of backwashing.

[0051]

The reason why the control device 4 repeats the process in Step S10 when it is assessed that the bag filter is in

the process of backwashing is as follows.

The backwashing of the bag filter is usually performed by stopping the flow of the exhaust gas. Therefore, when the shock pulse type soot blower 3 is activated during the backwashing of the bag filter, a pressure inside a duct serving as a flue through which the exhaust gas flows significantly increases, thereby causing a possibility that a failure may occur in the plant. However, in the removal system 1, the control device 4 does not activate the soot blower 3 during the backwashing of the bag filter, and activates the soot blower 3 after waiting for the completion of the backwashing. Therefore, occurrence of the above-described failure can be prevented.

Here, since an example in which the soot blower 3 adopts the shock pulse type has been described, Step S10 is provided. However, when the soot blower 3 adopts the steam type, Step S10 can be omitted. Therefore, in this case, the step subsequent to Step S4 is Step S11.

[0052]

In Step S11, the control device 4 assesses whether or not the value of the flag "F" stored in the storage device is F=1. When the flag "F" is F=1, the control device 4 performs the process in Step S12. In addition, when the flag "F" is not F=1, that is, in a case of F=2, the control device 4 performs the process in Step S13.

Here, since the flag "F" is F=1 at the current time, the control device 4 performs the process in Step S12. In Step S12, the control device 4 returns the count value of the timer to the time t1, that is, resets the count value. Next, the control device 4 performs the process in Step S13.

In Step S13, the control device 4 activates the soot blower 3 only once.

The control device 4 performs the process in Step S14.

In Step S11, when the flag "F" is not F=1, that is, in a case of F=2, the control device 4 skips Step S12, and performs the process in Step S13. Therefore, the count value of the timer is not reset. In the case of F=2, in principle, the control device 4 performs the "consecutive activation" on the soot blower 3 until the clean heat transmittance "Kc" is equal to or greater than the second predetermined value  $\alpha 2$ . However, in this case, the reason is to consecutively activate the soot blower 3 at a higher speed even though one process is omitted.

[0053]

In Step S14, the control device 4 changes the value of the flag "F" stored in the storage device to F=0, and causes the storage device to store the value again. The reason is as follows. The heat transmittance "K" calculated in the process of subsequent Step S2 is a value immediately after the soot blower 3 is activated. Therefore, in the process

in subsequent Step S3, this value is further stored in the storage device, as the clean heat transmittance "Kc".

The control device 4 returns the process flow to Step S2, and performs the process in Step S2. Since the processes in Step S2, Step S3, Step S4, and Step S5 have already been described, repeated description will be omitted.

[0054]

In this manner, a case where the process in Step S15 is performed by the control device 4 as a step subsequent to Step S5 (a case where the value of the clean heat transmittance "Kc" is smaller than  $\alpha_1$  in Step S5) will be described.

In Step S15, the control device 4 assesses whether or not the value of the clean heat transmittance "Kc" stored in the storage device is smaller than the second predetermined value  $\alpha_2$ .

When the value of the clean heat transmittance "Kc" is not smaller than the second predetermined value  $\alpha_2$ , that is, in a case of  $\alpha_2 \leq Kc < \alpha_1$ , although heat conduction in the pipe group 2 is not clearly satisfactory, it is considered that the operation of the plant is not still significantly affected by the accumulation of the adhered ash. Therefore, the control device 4 performs the process in Step S8 described above to proceed to the process flow for activating the soot blower 3 at an interval.

When the value of the clean heat transmittance "Kc" is smaller than the second predetermined value  $\alpha 2$ , to assess whether or not the value of the clean heat transmittance "Kc" is lowered due to the adhered ash, the control device 4 performs the process in Step S16, that is, the adhered ash assessment process.

[0055]

The control device 4 performs the adhered ash assessment process in Step S16. A specific process example in the adhered ash assessment process will be described later with reference to Figs. 3A to 3D.

In the adhered ash assessment process is a process of selectively selecting and assessing any one of a "situation where a large amount of the adhered ash is accumulated in the plurality of pipe groups 2 and the heat exchange between the exhaust gas and the boiler is not sufficiently performed" (first assessment) and a "situation where the clean heat transmittance "Kc" is calculated to be smaller than the second predetermined value  $\alpha 2$  depending on the operation environment of the plant or various operation conditions, although a small amount of the adhered ash is accumulated and does not adversely affect the heat exchange" (second assessment).

When the first assessment is obtained in the adhered ash assessment process, the control device 4 performs the

process in Step S17 to consecutively activate the soot blower 3 in accordance with the recovery rate ( $K_c/K_d$ ).

When the second assessment is obtained in the adhered ash assessment process, the control device 4 performs the process in Step S21 to confirm a state of the plant or determine whether or not the plant needs to be stopped.

[0056]

In Step S17, the control device 4 calculates the recovery rate ( $K_c/K_d$ ) from the clean heat transmittance " $K_c$ " and the dirty heat transmittance " $K_d$ " which are stored in the storage device, and assesses whether or not the recovery rate is equal to or greater than the recovery threshold value " $R$ " stored in the above-described storage device.

When the recovery rate is smaller than the recovery threshold value " $R$ ", there is a low possibility that the heat transmittance " $K$ " may be improved even when the soot blower 3 is activated any more. Therefore, the control device 4 performs the process in Step S21.

When the recovery rate is equal to or greater than the recovery threshold value " $R$ ", an effect of removing the adhered ash can be expected by activating the soot blower 3. Therefore, to remove the adhered ash at an early stage, the control device 4 performs the process in Step S18 so that the process flow proceeds toward the process of performing the "consecutive activation" on the soot blower

3.

[0057]

In Step S18, the control device 4 assesses whether or not the time  $t_1$  is longer than "Tmin" which is the shortest interval.

When the time  $t_1$  is longer than "Tmin", the control device 4 performs the process in Step S19 to shorten the interval when the "one-time activation" is performed on the soot blower 3. The reason is as follows. Due to a property of the ash, the adhered ash cannot be effectively removed at the interval of the initial "one-time activation". Therefore, in view of a fact that the first assessment is obtained in the adhered ash assessment process, after the "consecutive activation" is completed, when the control device 4 performs the "one-time activation" on the soot blower 3, the "one-time activation" is performed on the soot blower 3 at an interval shorter than before (in other words, at a timing earlier than before).

In Step S19, the control device 4 changes the value of the time  $t_1$  to a value at " $t_1 - \Delta t$ ". In other words, the control device 4 changes the value of  $t_1$  of the above-described storage device, as  $t_1 = t_1 - \Delta t$ , and causes the storage device to store the value again. The control device 4 performs the process in Step S20.

When the time  $t_1$  is "Tmin", the time  $t_1$  cannot be

changed to be smaller any more. Therefore, the control device 4 performs the process in Step S20 without changing the value of the time  $t_1$  (by skipping Step S19).

[0058]

In Step S20, the control device 4 changes the value of the flag "F" stored in the above-described storage device to  $F=2$ , and causes the storage device to store the value again. The control device 4 returns the process flow to Step S2, and performs the process in Step S2.

Since the processes in Step S2, Step S3, and Step S4 have already been described, the processes from Step S4 to the process in Step S10 as the subsequent step will be briefly described below.

That is, the control device 4 calculates the heat transmittance "K" when the recovery rate is equal to or greater than the recovery threshold value "R" (Step S2), and in subsequent Step S3, since the flag "F" is  $F=2$ , the heat transmittance "K" calculated immediately before is stored in the above-described storage device as the dirty heat transmittance "Kd" (that is,  $K_d=K$ ). In subsequent Step S4, since the flag "F" is  $F=2$  at the current time, the control device 4 assesses that the flag "F" is not  $F=0$ , and performs subsequent Step S10. In Step S10, the control device 4 performs the process in Step S11 when the control device 4 assesses that the bag filter is not in the process

of backwashing. In Step S11, since the flag "F" is F=2 at the current time, the control device 4 skips Step S12, and performs the process in Step S13.

That is, when the flag "F" is F=2, the control device 4 performs the process in Step S13 to immediately activate the soot blower 3 without resetting the timer.

[0059]

After the soot blower 3 is activated in Step S13, as described above, the control device 4 changes the flag "F" to F=0 in Step S14, and returns the process flow to Step S2 again.

Here, in the subsequent process flow, when the control device 4 sequentially proceeds again to the processes in Step S2, Step S3, Step S4, Step S5, Step S15, Step S16, Step S17, Step S18, Step S19 (skipped in some cases), and Step S20, the control device 4 thereafter proceeds to the processes in Steps S2, Step S3, Step S4, Step S10, Step S11, and Step S13.

Therefore, in this case, since Step S13 is performed in the process flow without starting the timer in Step S8, the "consecutively activation" is performed on the soot blower 3.

[0060]

As the description of the flowchart in Fig. 2, when the second assessment is obtained in the adhered ash

assessment process in Step S16, or when the recovery rate is smaller than the recovery threshold value "R" in Step S17, Step S21 performed by the control device 4 will be finally described.

In Step S21, the control device 4 assesses whether or not an operator or a worker starts work for confirming the state of the plant or stopping the operation of the plant (for example, an operation of a control panel). Since the control device 4 controls the operations of various devices disposed in the plant, the control device 4 can assess whether or not the work is started.

When the control device 4 assesses that the work is not started, the control device 4 performs the process in Step S8. That is, in this case, it is found that the adhered ash cannot be effectively removed even when the soot blower 3 is activated in Step S17. Therefore, from a viewpoint of cost effectiveness, the "consecutively activation" is not performed on the soot blower 3. However, to reduce a possibility that the ash may be further accumulated in the pipe group 2, the control device 4 proceeds to the process flow of performing the "one-time activation" on the soot blower 3.

On the other hand, when the control device 4 assesses that the work is started, thereafter, the control device 4 does not perform any one of the processes in Steps S1 to

S20, and performs the process required for another work. Thereafter, the operation of the whole removal system 1 including the control device 4 is completed, that is, the operation of the plant is stopped.

[0061]

According to this flowchart, when the "one-time activation" is performed on the soot blower 3 at an interval set by the timer, in a case where the clean heat transmittance " $K_c$ " is equal to or greater than the first predetermined value  $\alpha_1$ , the interval is changed to be longer than the previous interval. In a case where the clean heat transmittance " $K_c$ " is smaller than the first predetermined value  $\alpha_1$ , the interval is not changed from the previous interval or is changed to be shorter than the previous interval.

Furthermore, according to the present flowchart, the heat transmittance " $K$ " is calculated each time the soot blower 3 is activated, even when the "consecutive activate" is performed on the soot blower 3 without any interval set by the timer. As long as the value of the recovery rate " $R$ " based on the calculated heat transmittance " $K$ " (clean heat transmittance " $K_c$ ", dirty heat transmittance " $K_d$ ") increases, the control device 4 performs the "consecutive activation" on the soot blower 3 until the clean heat transmittance " $K_c$ " is equal to or greater than the second

predetermined value  $\alpha_2$ .

That is, the number of times of activation of the soot blower 3 in the "consecutive activation" is variable, and when an increasing speed value of the value of the recovery rate "R" is great (when an increasing speed is high), the number of times of activation automatically decreases. When the increasing speed value is small (when the increasing speed is slow), the number of times of activation automatically increases.

The increasing speed can be obtained by calculation as follows. The value of the recovery rate calculated each time the control device 4 performs Step S17 and time information when the value is calculated are sequentially stored in the above-described storage device. The value of the recovery rate calculated at the current time and the value of the latest recovery rate and a difference (time interval or time difference) between two time information of both the values are used. Specifically, the control device 4 calculates the increasing speed by using Equation 
$$\{(\text{recovery rate calculated at current time}) - (\text{latest recovery rate})\} / (\text{time difference})$$
. For example, when a gas refilling time of the shock pulse type soot blower is shorter than three minutes (three min), for example, a case where the increasing speed is high means a case where the number of times of "consecutive activations" is completed

twice (shorter than six min) or three times (shorter than nine min) and the increasing speed is equal to or higher than 0.04 (/min). For example, a case where the increasing speed is slow means a case where the increasing speed requiring four times or more (12 min or longer) as the number of times of consecutive activations is lower than 0.04 (/min).

[0062]

Next, with regard to details of the adhered ash assessment process, that is, Step S16, a process flow will be described with reference to Figs. 3A to 3D.

Here, based on experiences of the inventor, only the above-described four conditions will be used as targets, and the following four patterns will be separately described according to how many of these conditions are used. However, as described above, in addition to the above-described four conditions, other conditions may be added depending on the design.

In the following description, on an assumption that the control device 4 performs the process in Step S161 as the subsequent process in Step S15 in Fig. 2, the process will be described.

Description will be made sequentially from Fig. 3A.

Fig. 3A is a process flow (pattern 1) in which the adhered ash assessment process is performed, based on all

of the four conditions described above. The control device 4 assesses whether or not a main steam amount "Qs" measured by the main steam amount measuring device 25 in Step S161 is equal to or larger than a lower limit main steam amount "qsmin" (first threshold value) allowed in the operation of the plant. When the main steam amount Qs is smaller than "qsmin", the control device 4 assumes that the "second assessment" is obtained, and subsequently performs the process in Step S21 in Fig. 2. When the main steam amount "Qs" is equal to or larger than "qsmin", the control device 4 performs the subsequent step, here, the process in Step S162.

[0063]

The control device 4 calculates a pressure difference of the exhaust gas in the inlet and the outlet of the plurality of pipe groups 2, that is, a gas differential pressure  $\Delta P_g$  inside the furnace, by using pressure information measured by the pressure measuring devices 14a and 14b in Step S162, and assesses whether or not the gas differential pressure  $\Delta P_g$  inside the furnace is equal to or higher than a lower limit gas differential pressure "pgmin" inside the furnace (second threshold value) allowed in the operation of the plant. When the gas differential pressure  $\Delta P_g$  inside the furnace is lower than "pgmin", the control device 4 assumes that the "second assessment" is obtained,

and subsequently performs the process in Step S21 in Fig. 2. When the gas differential pressure  $\Delta P_g$  inside the furnace is equal to or higher than "pgmin", the control device 4 performs the subsequent step, here, the process in Step S163.

[0064]

In Step S163, the control device 4 assesses whether or not a rotation speed "Qr" of the induced draft fan 13 is equal to or higher than a lower limit rotation speed "qrmin" (third threshold value) allowed in the operation of the plant. When the rotation speed "Qr" is lower than "qrmin", the control device 4 assumes that the "second assessment" is obtained, and subsequently performs the process in Step S21 in Fig. 2. When the rotation speed "Qr" is equal to or higher than "qrmin", the control device 4 performs the subsequent step, here, the process in Step S164. Since the control device 4 controls the rotation speed "Qr" of the induced draft fan 13, the control device 4 grasps the rotation speed "Qr".

[0065]

In Step S164, the control device 4 assesses whether or not a total combustion air amount "Qc" measured by the combustion air amount measuring device 28 is equal to or larger than a lower limit total combustion air amount "qcmin" (fourth threshold value) allowed in the operation of the

plant. When the total combustion air amount "Qc" is smaller than "qcmin", the control device 4 assumes that the "second assessment" is obtained, and subsequently performs the process in Step S21 in Fig. 2. When the total combustion air amount "Qc" is equal to or larger than "qcmin", the control device 4 performs the process in the subsequent step. Here, on an assumption that the "first assessment" is obtained, the subsequent process in Step S17 in Fig. 2 is performed.

An order of the process flows of the four processes in Steps S161 to S164 is not limited thereto, and may be appropriately changed.

[0066]

In the process flow (pattern 2) in Fig. 3B, three assessment elements in Steps S161 to S163 are performed in the four assessment elements included in the process flow in Fig. 3A. Fig. 3B is an example of a flowchart in which the adhered ash assessment process is performed, based on any three of the four conditions described above, and any three of the four assessment elements in Steps S161 to S164 may be used, or in the process order, any process may be performed first.

[0067]

In the process flow (pattern 3) in Fig. 3C, two assessment elements in Steps S161 and S162 are performed in

the four assessment elements included in the process flow in Fig. 3A. Fig. 3C is an example of a process flow in which the adhered ash assessment process is performed based on any two of the four conditions described above, and any two of the four assessment elements in Steps S161 to S164 may be used, or in the assessment order, any assessment may be made first.

[0068]

In the process flow (pattern 4) in Fig. 3D, only the assessment element in Step S161 is performed in the four assessment elements included in the process flow in Fig. 3A. Fig. 3D is an example of a flowchart in which the adhered ash assessment process is performed, based on any one of the four conditions described above, and any one of the four assessment elements in Steps S161 to S164 may be used.

In any case of the above-described the pattern 1 to the pattern 4, it is preferable to provide Step S161 in which information on the main steam amount "Qs" which is not used in calculating the heat transmittance "K".

[0069]

#### [4. Advantageous Effect]

As described above, in the removal system 1, the control device 4 properly and separately uses the "one-time activation" and the "consecutive activation" of the soot blower 3, based on the calculated heat transmittance "K".

Therefore, the adhered ash can be properly removed at an early stage while economic efficiency is ensured.

[0070]

The adhered ash assessment process is performed to include a condition based on experiences of the inventor, that is, a condition based on at least one of the main steam amount " $Q_s$ ", the gas differential pressure  $\Delta P_g$  inside the furnace, the rotation speed " $Q_r$ " of the induced draft fan 13, and the total combustion air amount " $Q_c$ ". In this manner, a state of the adhered ash accumulated in the pipe group 2 can be properly assessed.

[0071]

In the removal system 1, when the first assessment is obtained in the adhered ash assessment process, the recovery rate is calculated from the dirty heat transmittance " $K_d$ " and the clean heat transmittance " $K_c$ ", and when the recovery rate is equal to or greater than the recovery threshold value " $R$ ", the "consecutive activation" is performed on the soot blower 3. In this manner, the adhered ash can be removed at an early stage.

In addition, in the removal system 1, when the increasing speed of the recovery rate is high, the control device 4 automatically decreases the number of times of activation of the soot blower 3 in the "consecutive activation", and when the increasing speed of the recovery

rate is low, the control device 4 automatically increases the number of times of activation. Therefore, depending on the state of the adhered ash, the control device 4 controls the operation by properly increasing or decreasing the number of times of activation of the soot blower 3 in the "consecutive activation". Therefore, compared to a case where the number of times of activation is a fixed value, the control device 4 can effectively remove the adhered ash, and can ensure economic efficiency.

[0072]

According to the removal system 1, when the clean heat transmittance " $K_c$ " is equal to or greater than the first predetermined value  $\alpha_1$ , the control device 4 assesses that the heat conduction of the pipe group 2 is extremely satisfactory (the adhered ash is not accumulated or the accumulated amount of the adhered ash is extremely small), and resets the interval of "the one-time activation" to be longer. Therefore, an excessive activation of the soot blower 3 can be avoided, and as a result, the economic efficiency can be further ensured. On the other hand, when the recovery rate is equal to or greater than the recovery threshold value " $R$ ", the interval of the "one-time activation" subsequent to the completion of the "consecutive activation" is reset to be shorter. Therefore, even when the ash has such a property of strong adhesion that the

"consecutive activation" is required, the "one-time activation" is performed on the soot blower 3 at a short interval. Therefore, the adhered ash can be removed before the ash is thickly accumulated in the pipe group 2. Therefore, it is not necessary to frequently perform the "consecutive activation", and as a result, the economic efficiency can be further ensured.

[0073]

According to the removal system 1, the control device 4 does not activate the soot blower 3 while the backwashing of the bag filter serving as the dust removal device 11 is performed, and activates the soot blower 3 after waiting for the completion of the backwashing. Therefore, it is possible to avoid occurrence of a failure in the plant.

[0074]

The soot blower 3 may adopt a steam type or a shock pulse type. However, the steam type soot blower uses steam generated by heat exchange between the exhaust gas and the boiler. Therefore, the amount of steam supplied to a turbine for power generation by the boiler can decrease, and as a result, the amount of power generation in the plant can decrease. Therefore, when the amount of power generation in the plant is important, it is desirable to dispose the shock pulse type soot blower which does not use the steam.

[0075]

The soot blower 3 is usually installed on a wall surface of a duct forming a path of the exhaust gas. Therefore, when the soot blower 3 in Fig. 1 adopts the steam type, an expanding-contracting direction of an injection nozzle of the soot blower 3 is a direction on a plane including the X-axis and orthogonal to the Y-axis, and the steam is injected in the Y-axis direction from the injection nozzle.

On the other hand, when the soot blower 3 is of a shock pulse type, the injection direction of the shock pulse is a direction on a plane including the X-axis and orthogonal to the Y-axis.

Therefore, in a case of the removal system 1 including the shock pulse type soot blower 3, when shock pulses are emitted toward the wall surface between the pass 3 and the pass 2 in Fig. 1, the wall surface is vibrated. Accordingly, not only the adhered ash of the pipe group 2 but also the ash adhering to the wall surface can be removed.

[0076]

#### [5. Modification Example]

Hereinafter, a modification example of the removal system 1 having a plurality of the soot blowers 3 will be described. In Fig. 1, a first modification example is an example of using soot blowers indicated by a dotted line

and represented by a reference numeral 3' and a reference numeral 3". As illustrated in Figs. 4A to 4C, a second modification example is an example in which the number of pipe groups 2 disposed in the pass 3 in Fig. 1 is larger than that in Fig. 1. As illustrated in Fig. 5, a third modification example is an example in which a boiler structure of the plant has a tail end type. As illustrated in Fig. 6, a fourth modification example is an example in which the boiler structure of the plant has a two-drum type boiler.

In the following description, the same reference numerals will be assigned to the same elements as those in the above-described removal system 1 in Fig. 1, and repeated description will be omitted. In addition, in Figs. 5 and 6, the control device 4 illustrated in Fig. 1 and a signal line (thin solid line) input to the control device 4 or output from the control device 4 are omitted in the illustration.

[0077]

#### [5-1. First Modification Example]

In Fig. 1, although the removal system 1 in which only one soot blower 3 is disposed has been described as the embodiment, it is possible to provide a removal system 1' in which the plurality of soot blowers 3 are disposed, depending on the number of pipe groups 2 or the design of

the plant.

In general, the soot blower 3 effectively removes the adhered ash of the pipe group 2 disposed in the vicinity of the soot blower 3. Therefore, in the configuration of the removal system 1, the adhered ash of the two pipe groups 2 (pipe group 2 configured to respectively include the superheater pipes 22a and 22b) close to the soot blower 3a is effectively removed. However, the pipe group 2 configured to include the superheater pipes 22c located at the most downstream side is disposed at a position separated from the soot blower 3a. Therefore, there is a possibility that the adhered ash of the pipe group 2 (22c) may be insufficiently removed.

[0078]

Therefore, as indicated by a dotted line in Fig. 1, in the removal system 1', in addition to the soot blower 3a, a soot blower 3' is separately disposed at a position of a back flow of the pipe group 2 (22c) (next to the pipe group 2 (22c) and directly above in the Y-axis direction). In this manner, the adhered ash of the pipe group 2 (22c) can be effectively removed.

In this case, when the soot blower separately disposed from the soot blower 3a is the shock pulse type soot blower, instead of the soot blower indicated by the reference numeral 3' or together with the soot blower indicated by

the reference numeral 3', the soot blower may be disposed at a position indicated by a reference numeral 3". The soot blower 3" indicated by a broken line in Fig. 1 represents a soot blower installed in the vicinity of the wall surface of the ceiling of the pass 3. When the soot blower 3" is disposed to emit the shock pulses downward in the Y-axis direction, not only the adhered ash of the pipe group 2 (22c) but also the adhered ash of the pipe group 2 (22b) disposed on an upstream side thereof can be more effectively removed.

[0079]

Even when a plurality of soot blowers 3, 3', and 3" are disposed in the removal system 1', the control device 4 performs the process in Fig. 2 on each soot blower, in the same manner as the above-described configuration in which only one soot blower 3 is disposed.

However, in the process in Step S13, the control device 4 activates the soot blowers 3, 3', and 3" one by one in order by shifting respective activation timing, in accordance with the disposition of the respective soot blowers 3, 3', and 3". That is, the control device 4 does not activate the plurality of soot blowers 3, 3', and 3" at the same time.

When a plurality of steam type soot blowers are disposed and activated at the same time, the amount of steam supplied from the boiler to the turbine significantly

decreases. Therefore, the amount of power generation significantly decreases, and stable power transmission is difficult. In addition, when a plurality of shock pulse type soot blowers are disposed and activated at the same time, a pressure inside the furnace or a pressure inside the duct significantly increases, thereby causing a possibility that a failure may occur in the plant.

Therefore, in the removal system 1', the soot blowers 3 are sequentially activated by shifting the activation timings.

An order in which the control device 4 sequentially activates the plurality of soot blowers 3 is the same as that of the second modification example illustrated in Figs. 4A to 4C (to be described later), and thus, description thereof will be omitted.

[0080]

#### [5-2. Second Modification Example]

In removal systems 1A to 1C of the second modification example illustrated in Figs. 4A to 4C, the number of pipe groups 2, the number of soot blowers 3, and the disposition of the outlet steam temperature measuring device 24b are different from those of the removal system 1. In the second modification example, the plurality of pipe groups 2 and the plurality of soot blowers 3 are disposed in the Y-axis direction, that is, in the vertical direction. Fig. 4A

illustrates the removal system 1A in which four pipe groups 2 configured to include the superheater pipe 22 are disposed in the pass 3 in Fig. 1. Fig. 4B illustrates the removal system 1B in which five pipe groups 2 configured to include the superheater pipe 22 are disposed in the pass 3 in Fig. 1. Fig. 4C illustrates the removal system 1C in which six pipe groups 2 configured to include the superheater pipe 22 are disposed in the pass 3 in Fig. 1.

In the second modification example, as in the first modification example, the control device 4 also performs the process in Fig. 2 on each of the plurality of soot blowers.

[0081]

In the removal system 1A illustrated in Fig. 4A, in addition to the configuration in Fig. 1, a pipe group 2 configured to include a superheater pipe 22d is disposed downstream (upward in the Y-axis direction) of and adjacent to the pipe group 2 configured to include the superheater pipe 22c. In addition, a soot blower 3b is disposed between the pipe group 2 configured to include the superheater pipe 22c and the pipe group 2 configured to include the superheater pipe 22d.

In the removal system 1C illustrated in Fig. 4C, in addition to the configuration illustrated in Fig. 4A, a pipe group 2 configured to include a superheater pipe 22e is

disposed adjacently downstream of the pipe group 2 configured to include the superheater pipe 22d. Furthermore a pipe group 2 configured to include a superheater pipe 22f is disposed downstream (upward in the Y-axis direction) of and adjacent to the pipe group 2 configured to include the superheater pipe 22e. In addition, a soot blower 3d is disposed between the pipe group 2 configured to include the superheater pipe 22e and the pipe group 2 configured to include the superheater pipe 22f.

As illustrated in Figs. 4A and 4C, when the number of the pipe groups 2 (here, the pipe groups 2 configured to include the superheater pipe 22) from which the adhered ash is removed by the soot blower 3 is two or more and an even number, the soot blower 3 is not disposed in all of the target pipe groups 2. In view of cost effectiveness in removing the adhered ash, a set of units including two pipe groups 2 in order from the upstream pipe group 2 is configured in the target pipe groups 2, and one soot blower 3 is disposed in one unit. Therefore, the number of the plurality of soot blowers 3 to be disposed is half the number of the target pipe groups 2.

[0082]

On the other hand, in the removal system 1B illustrated in Fig. 4B, unlike Fig. 4C, in the removal system 1B, only the pipe group 2 configured to include the superheater pipe

22e is added to the configuration in Fig. 4A, and this pipe group 2 is disposed adjacent to the downstream (upward in the Y-axis direction) of the pipe group 2 configured to include the superheater pipes 22d. Therefore, in Fig. 4B, the number of the pipe groups 2 (pipe groups 2 configured to include the superheater pipe 22) from which the adhered ash is removed by the soot blower 3 is two or more and an odd number. In this case, the pipe group 2 in which the above-described "unit" cannot be prepared is formed. In Fig. 4B, the above-described "unit" cannot be prepared for the pipe group 2 configured to include the superheater pipes 22e.

However, when the adhered ash of the pipe group 2 configured to include the superheater pipes 22e cannot be ignored, the soot blower 3c is disposed downstream of the pipe group 2.

[0083]

In the above-described second modification example, the pipe groups 2 serving as the removal target of the adhered ash are aligned and disposed in the vertical direction (Y-axis direction). The outlet steam temperature measuring device 24b is disposed inside the superheater pipe 22 forming the pipe group 2 located on the most downstream side.

When a certain soot blower 3 is activated to remove

the adhered ash, two situations are considered in the movement of the removed adhered ash as follows. [1] a case where the adhered ash falls downward in the vertical direction due to gravity, and [2] a case where the flow of the exhaust gas is strong and the adhered ash moves toward downstream by riding on the flow of the exhaust gas.

Therefore, in a case of [1], when the "one-time activation" or the "consecutive activation" is performed on the soot blower 3, the control device 4 activates the soot blowers 3 by shifting the timings in order from the soot blower 3 disposed on the most downstream side toward the soot blower 3 disposed upstream. That is, in a case in Fig. 4A, the soot blower 3a is activated after the soot blower 3b is activated. In addition, in a case in Fig. 4B, the soot blower 3b is activated after the soot blower 3c is activated, and the soot blower 3a is activated after the soot blower 3b is activated. Similarly, in a case in Fig. 4C, the soot blower 3b is activated after the soot blower 3d is activated, and the soot blower 3a is activated after the soot blower 3b is activated.

The respective soot blowers 3 are activated in this order. Accordingly, even when the adhered ash removed by the soot blower 3 in a certain pipe group 2 falls downward due to gravity and re-adheres to another pipe group disposed upstream, the adhered ash including the re-adhered ash can

be reliably removed.

On the other hand, in a case of [2], when the "one-time activation" or the "consecutive activation" is performed on the soot blower 3, the control device 4 activates the soot blowers 3 by shifting the timings in order from the soot blower 3 disposed on the most upstream side toward the soot blower 3 disposed downstream. That is, in a case in Fig. 4A, the soot blower 3b is activated after the soot blower 3a is activated. In addition, in a case in Fig. 4B, the soot blower 3b is activated after the soot blower 3a is activated, and the soot blower 3c is activated after the soot blower 3b is activated. Similarly, in a case in Fig. 4C, the soot blower 3b is activated after the soot blower 3a is activated, and the soot blower 3d is activated after the soot blower 3b is activated.

The respective soot blowers 3 are activated in this order. Accordingly, even when the adhered ash removed by the soot blower 3 in a certain pipe group 2 moves downstream by riding on the flow of the exhaust gas and re-adheres to another pipe group disposed downstream, the adhered ash including the re-adhered ash can be reliably removed.

[0084]

In the second modification example, the configurations corresponding to a first pipe group, a second pipe group, a third pipe group, a fourth pipe group, a first soot blower,

and a second soot blower in claim 6 of the present application are as follows.

That is, in Figs. 4A and 4B, the pipe group 2 configured to include the superheater pipe 22a corresponds to the first pipe group, the pipe group 2 configured to include the superheater pipe 22b corresponds to the second pipe group, the pipe group 2 configured to include the superheater pipe 22c corresponds to the third pipe group, and the pipe group 2 configured to include the superheater pipe 22d corresponds to the fourth pipe group. In addition, the soot blower 3a corresponds to the first soot blower, and the soot blower 3b corresponds to the second soot blower. In Fig. 4C, in addition to the same cases as in Figs. 4A and 4B, in some cases, the pipe group 2 configured to include the superheater pipes 22c may correspond to the first pipe group, the pipe group 2 configured to include the superheater pipes 22d may correspond to the second pipe group, the pipe group 2 configured to include the superheater pipe 22e may correspond to the third pipe group, the pipe group 2 configured to include the superheater pipe 22f may correspond to the fourth pipe group, the soot blower 3b may correspond to the first soot blower, and the soot blower 3d may correspond to the second soot blower.

[0085]

[5-3. Third Modification Example]

Next, a third modification example will be described with reference to Fig. 5.

In a removal system 1D of the third modification example, an exhaust gas flow path extending in the horizontal direction (X-axis direction) is added between the pass 3 in Fig. 1 and the economizer 9. The plurality of pipe groups 2 and soot blowers 3 are also disposed in the flow path in the horizontal direction. The boiler structure of the plant of the third modification example is called a tail end type. The outlet steam temperature measuring device 24b is disposed inside the superheater pipes 22f forming the pipe group 2 located on the most downstream side.

In the configuration in Fig. 4C which is one of the second modification example, the third modification example adopts a configuration as follows. Including the soot blowers 3b and 3d, the pipe groups 2 from the pipe group 2 configured to include the superheater pipe 22c to the pipe group 2 configured to include the superheater pipe 22f are disposed in the horizontal direction without changing the order from the upstream side to the downstream side. In addition, here, it is considered that the pipe group 2 configured to include the superheater pipe 22b and the pipe group 2 configured to include the superheater pipe 22c are disposed adjacent to each other as in the second

modification example.

Therefore, in the third modification example, the plurality of pipe groups 2 sequentially disposed from the upstream side (downward in the Y-axis direction) to the downstream side (upward in the Y-axis direction) in the vertical direction, and the plurality of pipe groups 2 sequentially disposed in one direction (X-axis direction) in the horizontal direction are present.

In the third modification example, as in the first modification example and the second modification example, the control device 4 also performs the process in Fig. 2 on each of the plurality of soot blowers.

[0086]

Here, when focusing on the plurality of pipe groups 2 sequentially disposed in one direction (X-axis direction) in the horizontal direction, that is, the pipe group 2 configured to include the superheater pipe 22c, the pipe group 2 configured to include the superheater pipe 22d, the pipe group 2 configured to include the superheater pipe 22e, and the pipe group 2 configured to include the superheater pipe 22f in Fig. 5, when the soot blower 3b or 3d is activated to remove the adhered ash, there is a high possibility that the removed adhered ash may move toward downstream by riding on the flow of the exhaust gas.

Therefore, when the "one-time activation" or the

"consecutive activation" is performed on the soot blower 3, the control device 4 activates the soot blowers 3 by shifting the timings in order from the soot blower 3 disposed on the most upstream side toward the soot blower 3 disposed downstream. That is, the control device 4 activates the soot blower 3d after the soot blower 3d is activated.

The respective soot blowers 3 are activated in this order. Accordingly, even when the adhered ash removed by the soot blower 3 in a certain pipe group 2 moves downstream by riding on the flow of the exhaust gas and re-adheres to another pipe group disposed downstream, the adhered ash including the re-adhered ash can be reliably removed.

[0087]

In addition, in Fig. 5, when the plurality of pipe groups 2 disposed in the horizontal direction and the plurality of pipe groups 2 disposed in the vertical direction are comprehensively considered, there may be the case of [2] described in the second modification example. Therefore, when the control device 4 performs the "one-time activation" or the "consecutive activation" on the soot blower 3, the control device 4 activates the soot blowers 3 by shifting the timings in order from the soot blower 3 disposed on the most upstream side toward the soot blower 3 disposed downstream. That is, the control device 4

activates the soot blower 3b after activating the soot blower 3a, and activates the soot blower 3d after activating the soot blower 3b.

The respective soot blowers 3 are activated in this order. Accordingly, even when the adhered ash removed by the soot blower 3 in a certain pipe group 2 moves downstream by riding on the flow of the exhaust gas and re-adheres to another pipe group disposed downstream, the adhered ash including the re-adhered ash can be reliably removed.

[0088]

In the third modification example, the configurations corresponding to the first pipe group, the second pipe group, the third pipe group, the fourth pipe group, the first soot blower, and the second soot blower in claim 6 of the present application are as follows.

That is, when focusing on the plurality of pipe groups 2 disposed in the horizontal direction, the pipe group 2 configured to include the superheater pipes 22c corresponds to the first pipe group, the pipe group 2 configured to include the superheater pipes 22d corresponds to the second pipe group, the pipe group 2 configured to include the superheater pipe 22e corresponds to the third pipe group, the pipe group 2 configured to include the superheater pipe 22f corresponds to the fourth pipe group, the soot blower 3b corresponds to the first soot blower, and the soot blower

3d corresponds to the second soot blower.

In addition, when the plurality of pipe groups 2 disposed in the horizontal direction and the plurality of pipe groups 2 disposed in the vertical direction are comprehensively considered, in Fig. 5, the pipe group 2 configured to include the superheater pipe 22a corresponds to the first pipe group, the pipe group 2 configured to include the superheater pipe 22b corresponds to the second pipe group, the pipe group 2 configured to include the superheater pipe 22c corresponds to the third pipe group, the pipe group 2 configured to include the superheater pipe 22d corresponds to the fourth pipe group, the soot blower 3a corresponds to the first soot blower, and the soot blower 3b corresponds to the second soot blower.

According to the removal system 1D of the third modification example, in addition to an advantageous effect obtained in the above-described embodiment, the adhered ash including the re-adhered ash can be reliably removed.

[0089]

[5-4. Fourth Modification Example]

Next, a fourth modification example will be described with reference to Fig. 6.

In the third modification example, a removal system 1E of the fourth modification example adopts a configuration as follows. The exhaust gas flow path extending in the

horizontal direction between the pass 3 and the economizer 9 is removed, and a two-drum type boiler including a steam drum 19 and a water drum 20 is installed between the pass 3 and the economizer 9. Since the flow path is removed, the pipe groups 2 (22c to 22f) and the soot blowers 3 (3b and 3d) which are disposed inside the flow path in the third modification example are also removed.

In addition, in the fourth modification example, the hanging pipe 21 and the soot blower 3a of the third modification example are removed, and the superheater pipes 22a and 22b are hung and disposed on the ceiling of the pass 3. Thereafter, the soot blower 3 (3e) is disposed adjacent to the superheater pipe 22a upstream of the superheater pipe 22a.

In addition, in Fig. 1, the pipe group 2 of the economizer 9 is not considered as the pipe group serving as the removal target of the adhered ash. However, in the fourth modification example, the plurality of pipe groups 2 of the economizer 9 are also the removal targets of the adhered ash. Therefore, the soot blower 3f is installed between the plurality of pipe groups 2 disposed in the vertical direction (Y-axis direction) inside the economizer 9, that is, the pipe group 2 configured to include a water pipe 23a and the pipe group 2 adjacent to the pipe group 2, disposed downstream thereof, configured to include a water

pipe 23b.

In this case, as described above, the "plurality of pipe groups 2" serving as the removal targets of the adhered ash are also disposed between the two pressure measuring devices 14a and 14b, and are also disposed the two gas temperature measuring devices 15a and 15b.

In Fig. 6, the pipe groups 2 serving as the removal targets of the adhered ash include the pipe group 2 having different types. That is, the pipe group 2 configured to include the superheater pipe 22, and the pipe group 2 configured to include the water pipe 23. Another pipe group 2 that acts as resistance to the flow of the exhaust gas is not disposed between the pipe group 2 configured to include the superheater pipe 22 (22b) and the pipe group 2 configured to include the water pipe 23 (23a).

Unlike Fig. 1, a temperature measuring device 15b for measuring the temperature of the exhaust gas in the "outlet" of the plurality of pipe groups 2 is disposed downstream of the pipe group 2 configured to include the water pipe 23b disposed on the most downstream side in the plurality of pipe groups 2 serving as the removal targets of the adhered ash. In Fig. 6, the temperature measuring device 15b is disposed at substantially the same position as that of the pressure measuring device 14b in Fig. 1. The outlet steam temperature measuring device 24b is disposed inside the

superheater pipe 22b located on the most downstream side in the superheater pipes 22.

In the fourth modification example, as in the first modification example to the third modification example, the control device 4 also performs the process in Fig. 2 on each of the plurality of soot blowers.

[0090]

In the fourth modification example, the control device 4 performs the "one-time activation" or the "consecutive activation" on the soot blower 3, the control device 4 activates the soot blowers 3 by shifting the timings in order from the soot blower 3 disposed on the most upstream side toward the soot blower 3 disposed downstream. That is, the control device 4 activates the soot blower 3f after activating the soot blower 3e.

The respective soot blowers 3 are activated in this order. Accordingly, even when the adhered ash removed by the soot blower 3 in the pipe group 2 disposed upstream moves downstream by riding on the flow of the exhaust gas and re-adheres to another pipe group disposed downstream, the adhered ash including the re-adhered ash can be reliably removed.

[0091]

In the fourth modification example, the configurations corresponding to the first pipe group, the second pipe group,

the third pipe group, the fourth pipe group, the first soot blower, and the second soot blower in claim 7 of the present application are as follows.

That is, the pipe group 2 configured to include the superheater pipes 22a corresponds to the first pipe group, the pipe group 2 configured to include the superheater pipes 22b corresponds to the second pipe group, and the pipe group 2 configured to include the water pipe 23a corresponds to the third pipe group, the pipe group 2 configured to include the water pipe 23b corresponds to the fourth pipe group, the soot blower 3e corresponds to the first soot blower, and the soot blower 3f corresponds to the second soot blower.

According to the removal system 1E of the fourth modification example, in addition to an advantageous effect obtained in the above-described embodiment, the adhered ash including the re-adhered ash can be reliably removed.

[0092]

Hitherto, the embodiments and the modification examples of the present invention have been described. The technical scope of the present invention is not limited to the embodiments or the modification examples, and various changes can be made within the scope not departing from the concept of the present invention.

[Reference Signs List]

[0093]

1, 1', 1A to 1E: System for removing adhered ash from boiler pipe group (removal system)

2: Pipe group

3, 3', 3", 3a to 3f: Soot blower

4: Control device

5: Hopper

6: Feeder

7: Stoker

8: Ash chute

9: Economizer (type of pipe group)

10: Temperature reducing tower

11: Dust removal device (bag filter)

12: Chimney

13: Induced draft fan

14a, 14b: Pressure measuring device

15a, 15b: Gas temperature measuring device

16a, 16b: Gas flow rate measuring device

17: Desuperheater

18: Spray water amount measuring device

19: Steam drum

20: Water drum

21: Hanging pipe (screen pipe)

22a to 22f: Superheater pipe (superheater)

23a, 23b: Water pipe

24a, 24b: Steam temperature measuring device

25: Main steam amount measuring device  
26: Primary air supply device  
27: Secondary air supply device  
28: Combustion air amount measuring device  
"K": Heat transmittance  
"Kc": Clean heat transmittance  
"Kd": Dirty heat transmittance  
"Kc"/"Kd": Recovery rate  
 $\Delta p_g$ : Differential pressure  
"pgmin": Second threshold value  
"Qc": Total combustion air amount  
"qcmin": Fourth threshold value  
"Qr": Rotation speed of induced draft fan  
"qrmin": Third threshold value  
"Qs": Main steam amount  
"qsmin": First threshold value  
"R": Recovery threshold value  
 $\alpha_1$ : First prescribed value  
 $\alpha_2$ : Second prescribed value

## Claims

[Claim 1]

A system for removing adhered ash from a boiler pipe group, which removes adhered ash of a plurality of pipe groups of a boiler for recovering heat from an exhaust gas generated in a furnace, the system comprising:

a soot blower disposed between the plurality of pipe groups;

an induced draft fan disposed downstream of the plurality of pipe groups to induce the exhaust gas; and

a control device that controls activation of the soot blower,

wherein the control device

calculates heat transmittance of the boiler,

activates the soot blower only once at a predetermined interval, when the calculated heat transmittance is equal to or greater than a predetermined value, thereafter, performs a one-time activation on the soot blower again at the predetermined interval or at an interval different from the predetermined interval,

and performs an adhered ash assessment process of selectively assessing any one of first assessment and second assessment, when the calculated heat transmittance is smaller than the predetermined value,

performs a consecutive activation to consecutively activate the soot blower multiple times without setting the interval, when the first assessment is obtained in the adhered ash assessment process, and

performs the one-time activation when the second assessment is obtained in the adhered ash assessment process,

the adhered ash assessment process is performed to include at least one condition of a first condition that a main steam amount of the plurality of pipe groups is equal to or greater than a first threshold value, a second condition that a pressure difference between the exhaust gases in an inlet and an outlet of the plurality of pipe groups is equal to or greater than a second threshold value, a third condition that a rotation speed of the induced draft fan is equal to or greater than a third threshold value, and a fourth condition that a total combustion air amount supplied to the furnace is equal to or greater than a fourth threshold value,

when the adhered ash assessment process is performed based on only one condition of the four conditions, the first assessment is obtained when the one condition is satisfied, and the second assessment is obtained when the one condition is not satisfied, and

in a case where the adhered ash assessment process is performed to include any two, three, or four conditions of

the four conditions, the first assessment is obtained when all of the conditions including the two, three, or four conditions are satisfied together, and the second assessment is obtained when any one of the conditions including the two, three, or four conditions is not satisfied.

[Claim 2]

The system for removing adhered ash from a boiler pipe group according to Claim 1,

wherein the control device

calculates a recovery rate, based on a dirty heat transmittance indicating a heat transmittance calculated before the soot blower is activated, and a clean heat transmittance indicating the heat transmittance calculated after the soot blower is activated, when the first assessment is obtained in the adhered ash assessment process,

performs the consecutive activation, when the recovery rate is equal to or greater than a recovery threshold value, and

performs the one-time activation, when the recovery rate is smaller than the recovery threshold value.

[Claim 3]

The system for removing adhered ash from a boiler pipe group according to Claim 2,

wherein when the clean heat transmittance is equal to or greater than the predetermined value, the control device resets the predetermined interval to be longer than a value set immediately before, and when the recovery rate is equal to or greater than the recovery threshold value, the control device resets the predetermined interval to be shorter than the value set immediately before.

[Claim 4]

The system for removing adhered ash from a boiler pipe group according to Claim 3,

wherein during the consecutive activation, when an increasing speed of the recovery rate is high, the control device decreases the number of times of activation in the consecutive activation, and when the increasing speed of the recovery rate is low, the control device increases the number of times of consecutive activation.

[Claim 5]

The system for removing adhered ash from a boiler pipe group according to Claim 4, further comprising:

a bag filter disposed downstream of the plurality of pipe groups to remove soot and dust of the exhaust gas,

wherein the control device does not activate the soot blower while backwashing of the bag filter is performed,

and activates the soot blower by waiting for completion of the backwashing.

[Claim 6]

The system for removing adhered ash from a boiler pipe group according to Claim 5,

wherein the plurality of pipe groups include

a first pipe group,

a second pipe group disposed adjacent to the first pipe group downstream of the first pipe group,

a third pipe group disposed adjacent to the second pipe group downstream of the second pipe group, and

a fourth pipe group disposed adjacent to the third pipe group downstream of the third pipe group,

the soot blower includes

a first soot blower disposed between the first pipe group and the second pipe group, and

a second soot blower disposed between the third pipe group and the fourth pipe group,

when the control device performs the one-time activation or the consecutive activation on the first soot blower and the second soot blower,

the control device

activates the first soot blower after activating the second soot blower or activates the second soot blower

after activating the first soot blower, in a case where the first pipe group to the fourth pipe group are sequentially disposed from a lower side to an upper side in a vertical direction,

          activates the second soot blower after activating the first soot blower, in a case where the first pipe group to the fourth pipe group are sequentially disposed in one direction in a horizontal direction, and

          activates the second soot blower after activating the first soot blower, in a case where the first pipe group and the second pipe group are sequentially disposed from the lower side to the upper side in the vertical direction, and the third pipe group and the fourth pipe group are sequentially disposed in one direction in the horizontal direction.

[Claim 7]

The system for removing adhered ash from a boiler pipe group according to Claim 5,

          wherein the plurality of pipe groups includes

          a first pipe group,

          a second pipe group disposed adjacent to the first pipe group downstream of the first pipe group,

          a third pipe group disposed downstream of the second pipe group, and

a fourth pipe group disposed adjacent to the third pipe group downstream of the third pipe group,

the soot blower includes

a first soot blower disposed adjacent to the first pipe group upstream of the first pipe group, and

a second soot blower disposed between the third pipe group and the fourth pipe group, and

when the control device performs the one-time activation or the consecutive activation on the first soot blower and the second soot blower, the control device activates the second soot blower after activating the first soot blower.

[Claim 8]

The system for removing adhered ash from a boiler pipe group according to any one of Claims 1 to 7,

wherein the soot blower is a pressure wave type soot blower that generates a pressure wave by exploding a gas.