

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: **90304406.3**

(51) Int. Cl.⁵: **F23J 15/00**

(22) Date of filing: **24.04.90**

(30) Priority: **26.04.89 GB 8909548**

(43) Date of publication of application:
31.10.90 Bulletin 90/44

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

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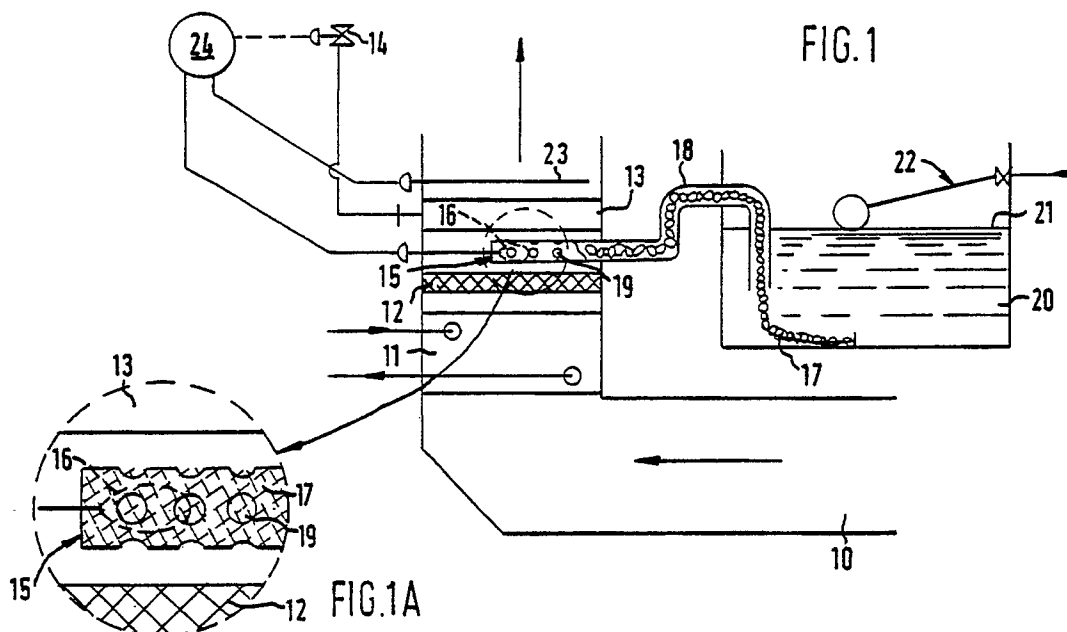
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(54) Conditioning of flue gases.

(57) In a heat recovery installation for the flue gases for example from a boiler, the flue gas is reheated to above the dew point by a heat exchanger 13 following the cooling of the gas to below the dew point thereof and the extraction of at least some of the condensate. The reheating is controlled by determining the wet bulb temperature 16,17 of the flue gas

before reheating and the dry bulb temperature 23 after reheating, the determined temperature being supplied to a differential temperature controller 24 which controls the setting of a flow valve 14, to regulate the flow of heated heat exchange medium through the heat exchanger.



CONDITIONING OF FLUE GASES

This invention relates both to means to control and to methods of controlling the condition of a flue gas, following the cooling thereof to release latent heat of condensation therefrom. The invention further relates to a flue gas heat recovery installation incorporating flue gas conditioning means.

Much industrial boiler plant has been converted to gas firing and this has given the opportunity of greatly improving the boiler efficiency. This is because natural gas is not polluted with sulphur, unlike coal and oil, and so the products of combustion can be cooled to low temperatures to recover the latent heat of condensation of the vapour in the flue gas, without giving rise to acid condensate problems.

Combusted natural gas produces flue gas which contains significant quantities of water vapour, with approximately 10% of the gross calorific value of the purchased gas locked-in as latent heat. The condensing temperature of this vapour is dependent upon the moisture content and excess amount of the ingested air used for combustion, but may be about 56 °C at typical boiler conditions.

In the Specification of our co-pending European Patent Application No. 89311489.2 (not yet published), we have described methods and apparatus for recovering that latent heat of condensation from the flue gas of, for example, a boiler installation. The disclosures in the Specification of our said prior Application No. 89311489.2 are deemed incorporated herein by this reference.

When recovering latent heat from a flue gas by lowering the temperature of that gas to below the dew point thereof, it is in general necessary thereafter to raise the gas temperature above the dew point in order that a dry gas may be discharged to an exhaust duct (stack). Though it may be possible to emit to atmosphere a wet flue gas if a condensing economiser is employed, the measures which then have to be taken (for example, providing a suitable lining to the exhaust stack) often are too costly to be justified. On the other hand, reheating the gas reduces the overall thermal efficiency of the latent heat recovery process and so it is desirable that the temperature to which the flue gas is reheated is just above the dew point for that gas under the particular operating conditions prevailing.

The quantity of energy required for reheating the flue gas (i.e. the "conditioning" of the gas) following the cooling thereof depends upon the type, design and materials of the flue gas stack, the design of the condenser unit, and the ambient conditions. It is desirable that the actual condition of the gas on leaving the condensing unit is accurately established so that only sufficient energy

is added to the gas to render it suitable for admission to the stack. Desirably therefore both the flue gas temperature and humidity are determined - and this must be done at a high level of moisture content, in the environment of a boiler flue. From the temperature and humidity, the flue gas dew point temperature can be determined with reference to a psychometric chart, but complex equipment is required for this, including some kind of computational unit to perform the required continuous calculation. Moreover, having regard to the hostile environment, such equipment is prone to low reliability. It is an aim of the present invention to provide both means to control and a method of controlling the condition of a flue gas, which are both simple and reliable and yet which allow sufficient reheating of the flue gas to ensure that a dry flue gas is discharged to the exhaust stack.

According to one aspect of the present invention, there is provided means to control the condition of flue gas following the cooling thereof to release latent heat of condensation, which means includes: reheating means to reheat the cooled flue gas, characterised in that a first temperature sensor is disposed in the flue gas path prior to that gas entering the reheating means, which first temperature sensor comprises a temperature sensing element providing an electrical output indicative of sensed temperature, an absorbent material at least partially surrounding the temperature sensing element and means to supply liquid to the absorbent material at a rate at least as great as the evaporation rate of the liquid from that material; in that a second temperature sensor is disposed in the flue gas path to sense the temperature of the gas leaving the reheating means which second temperature sensor comprises a temperature sensing element providing an electrical output indicative of sensed temperature; and in that there is provided heat control means operating on the outputs of the first and second temperature sensing elements and controlling the heat quantity imparted to the flue gas by the reheating means.

It will be appreciated that in the present invention, the first temperature sensor serves as a "wet bulb" temperature sensor, acting on the flue gas prior to that gas being reheated; and the second temperature sensor serves as a "dry bulb" temperature sensor, acting on that gas following the reheating thereof. The wet bulb temperature approximates to the actual dew point of the flue gas prior to the reheating thereof but yields a higher temperature than the actual dew point temperature; the consequence is that slightly more heat will be added to the gas than need be. This arrangement

is however inherently "safe", in that dry gas will always be discharged to the exhaust stack. In this invention, there is a closed control loop, completed by monitoring the actual temperature of the reheated gas and comparing that with the intended temperature derived from the wet bulb temperature, in order that the precise heat quantity imparted to the gas may be adjusted to give the required final flue gas temperature.

The temperature sensing element of the first temperature sensor preferably comprises a platinum resistance bulb or a thermocouple. The absorbent material advantageously is in the form of a wick which surrounds the temperature sensing element, the wick being continuously wetted by appropriate water supply means. For example, the wick may be lead into the flue gas duct within a tube connected to a water supply vessel in which a constant pre-determined head of water is maintained. The tube may thus form a liquid seal in conjunction with the wick, to prevent leakage of the gas out of the flue gas duct. The water within the tank may be fed from an outside source, or the condensate obtained from the flue gas cooling step may be employed.

Conveniently, the outputs of the first and second temperature sensors are fed to a differential temperature controller having an output which controls the energy input of the heating means, so as thereby to control the reheating of the cooled flue gas.

According to a second aspect of the present invention, there is provided a method of controlling the condition of a flue gas entering an exhaust duct following the cooling of the gas to release latent heat of condensation, in which method heat is added to the gas to raise the temperature of the cooled gas to above the dew point thereof, characterised in that the temperatures of the gas are sensed both before and after the reheating thereof, the temperature sensing before the addition of the heat being performed by a wet bulb temperature sensor, and the heat quantity added to the gas during the reheating being controlled dependent upon the sensed temperatures.

In the method of this invention, a closed loop control system is obtained in that an approximation of the dew point of the flue gas can be obtained from the wet bulb sensed temperature, and the required reheated temperature of the flue gas can be derived from this wet bulb sensed temperature. Heat is then added until the sensed dry bulb temperature (at the output of the gas reheating stage) is no lower than the required temperature as derived from the sensed wet bulb temperature. In this way, it can be assured that dry flue gas is always discharged to the exhaust stack. By way of example only, one specific embodiment of flue gas

conditioning means according to the present invention, and operating in accordance with the method thereof, will now be described in detail, reference being made to the accompanying drawings, in which:

Figure 1 diagrammatically shows the reheating stage of an economiser installation for a gas boiler; and

Figure 1A is a detailed view of an enlarged scale of the part of the installation ringed with a broken line in Figure 1.

A flue gas duct 10 carries flue gas to a condenser 11, wherein the temperature of the flue gas is reduced to below the dew point thereof, in order to allow recovery of the latent heat of condensation of the moisture in that flue gas. From the condenser 11, the flue gas is directed through a droplet extractor 12 and a reheater 13. After reheating, the flue gas is directed to a suitable exhaust stack (not shown).

The reheater 13 may comprise a conventional heat exchanger, supplied with hot water for example from a boiler installation fired by the gas combusted to produce the flue gas being treated. The hot water flow rate through the reheater 13 is controlled by an adjustable valve 14, so as to allow control of the energy input to the reheater 13.

Located in the duct between the droplet extractor 12 and the reheater 13 is a wet bulb temperature sensor 15. As best seen in Figure 1A, this comprises a platinum resistance bulb temperature sensing element 16 providing an electrical output indicative of the sensed temperature, the bulb being surrounded by a wick 17 contained within a pipe 18. The end portion of the pipe 18 in the region of the element 16 is perforated, as shown at 19.

The pipe 18 leads out of the duct 10 and into a tank 20, where the wick 17 is immersed in water contained within that tank. The water level 21 in the tank 20 is maintained constant by a ball valve assembly 22, such that the level 21 is slightly higher than the level of the temperature sensing element 16.

A second temperature sensing element 23, again comprising a platinum resistance bulb, is disposed on the outlet side of the reheater 13, to sense the actual temperature of the flue gas leaving the reheater 13. The electrical outputs of the first and second temperature sensing elements 16 and 23 are fed to a differential temperature controller 24, which provides an output controlling the adjustable valve 14.

In a typical system, a satisfactory condition for the flue gas to enter the exhaust stack may be that the flue gas temperature must be 25° C above the actual dew point. When such a typical system is operating under a full boiler load, the flue gas

temperature on leaving the condensing section 11 may be 80°C, with a moisture content of 70g/kg dry gas. The actual dew point under these conditions is 46.4°C (at atmospheric pressure), indicating that the flue gas temperature when discharged to the stack must be at least 71.4°C. If only the actual gas temperature is measured before reheating, the differential temperature controller will cause sufficient heat to be added to the gas to raise the temperature thereof to 105°C - a clear waste of energy. However, the wet bulb sensor element 16 would show a temperature of 49.5°C, so indicating a required stack temperature of 74.5°C: since the flue gas is already at 80°C, no heat is added by the reheater 13.

If now the boiler is operated at half load, the flue gas temperature on leaving the condensing section may typically be at 55°C with a 60 g/kg moisture content, so giving an actual dew point of 43.6°C. The minimum flue gas temperature on discharge to the stack must thus be 68.6°C. The wet bulb temperature sensor would give a reading of 45°C, so indicating a required flue gas temperature of 70°C. Sufficient heat is thus added to raise the gas temperature from 55 to 70°C. By contrast, if only actual gas temperature were measured before reheating, then there would be a reheat to 80°C, again wasting thermal energy.

Claims

1. Means to control the condition of flue gas following the cooling thereof to release latent heat of condensation, which means includes reheating means to reheat the cooled flue gas characterised in that a first temperature sensor (16,17) is disposed in the flue gas path prior to that gas entering the reheating means (13), which first temperature sensor comprise a temperature sensing element (16) providing an electrical output indicative of sensed temperature, absorbent material (17) at least partially surrounding the temperature sensing element (16), and means (18,20) to supply liquid to the absorbent material (17) at a rate at least as great as the evaporation rate of the liquid from that material; in that a second temperature sensor (23) is disposed in the flue gas path to sense the temperature of the gas leaving the reheating means (13) which second temperature sensor (23) comprises a temperature sensing element providing an electrical output indicative of sensed temperature; and in that there is provided heat control means (24,14) operating on the outputs of the first and second temperature sensing elements (16,23) and controlling the reheating quantity imparted to the flue gas by the heating means.

2. Condition control means according to Claim

1, characterised in that the temperature sensing element 16 of the first temperature sensor comprises a platinum resistance bulb or a thermocouple.

3. Condition control means according to Claim 1 or Claim 2, characterised in that the absorbent material (17) is in the form of a wick which surrounds the temperature sensing element (16), water supply means (18,20) being arranged to supply the wick (17) with water to maintain the continuous wetting thereof.

4. Condition control means according to Claim 3, characterised in that the water supply means includes a vessel in which a constant pre-determined head (21) of water is maintained, in combination with a tube (18) leading from the vessel to the temperature sensing element (16), said wick being located within the tube.

5. Condition control means according to any of Claims 1 to 4, characterised in that the heat control means includes a differential temperature controller (24) to which the outputs of the first and second temperature sensors (16,23) are fed, the differential temperature controller (24) having an output which controls the energy input of the reheating means (13), so as thereby to control the reheating of the cooled flue gas.

6. A method of controlling the condition of a flue gas entering an exhaust duct following the cooling of the gas to release latent heat of condensation, in which method heat is added to the gas to raise the temperature of the cooled gas to above the dew point thereof, characterised in that the temperatures of the gas are sensed both before (16,17) and after (23) the reheating thereof, the temperature sensing before the addition of the heat being performed by a wet bulb temperature sensor (16), and the heat quantity added to the gas during the reheating being controlled dependent upon the sensed temperatures.

7. A method according to Claim 5, characterised in that liquid is supplied to the wet bulb temperature sensor (16) at a rate at least as great as the evaporation rate of the liquid from the wet bulb temperature sensor.

8. A method according to Claim 6 or Claim 7, characterised in that the sensed temperatures determined both before (16) and after (23) reheating of the gas are supplied to a differential temperature controller (24), and the output of the differential temperature controller is used to control the quantity of heat added to the gas.

9. A method according to Claim 8, characterised in that the differential temperature controller (24) serves to control the setting of an adjustable valve (14) which regulates the flow of heated heat-exchange medium through a heat exchanger (13) through which the gas is passed following the

cooling thereof, to perform the reheating.

10. A flue gas heat recovery installation comprising gas cooling means (11) to lower the temperature of the flue gas to below the dew point thereof, and reheating means (13) to reheat the flue gas to above the dew point following removal of at least some of the condensate resulting from the cooling, characterised by the incorporation in the installation of means (16,17,23,24,14) to control the condition of the flue gas as claimed in any of Claims 1 to 5.

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FIG. 1A

