

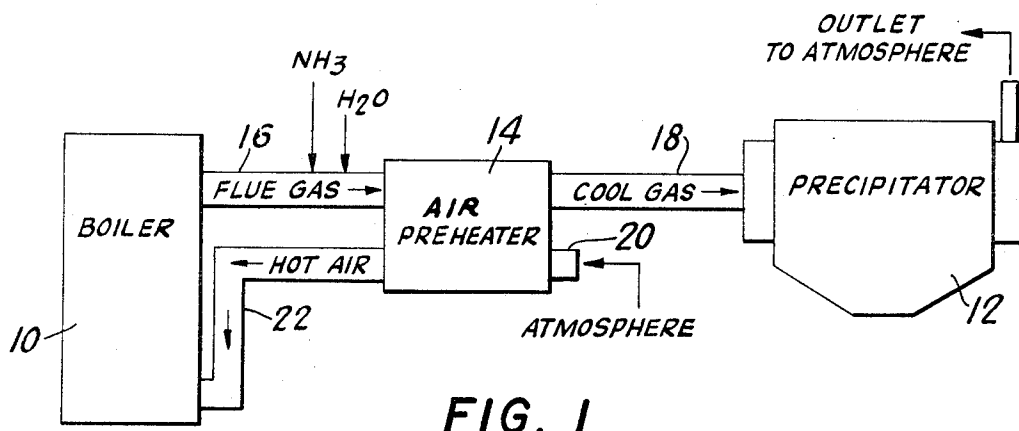
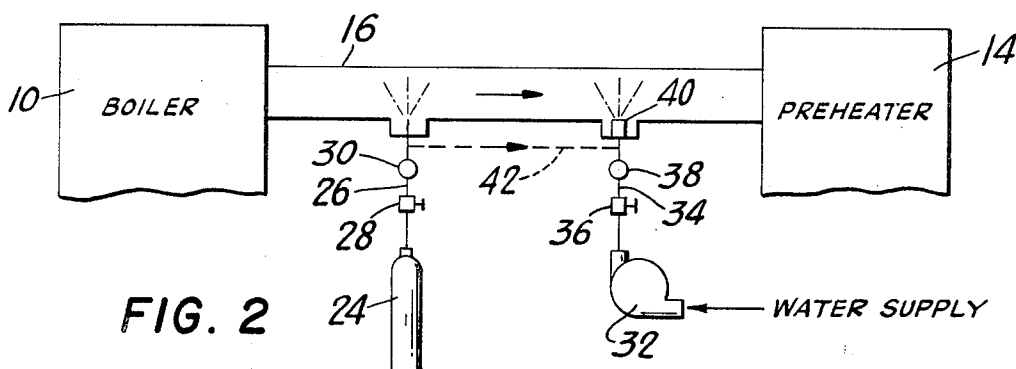
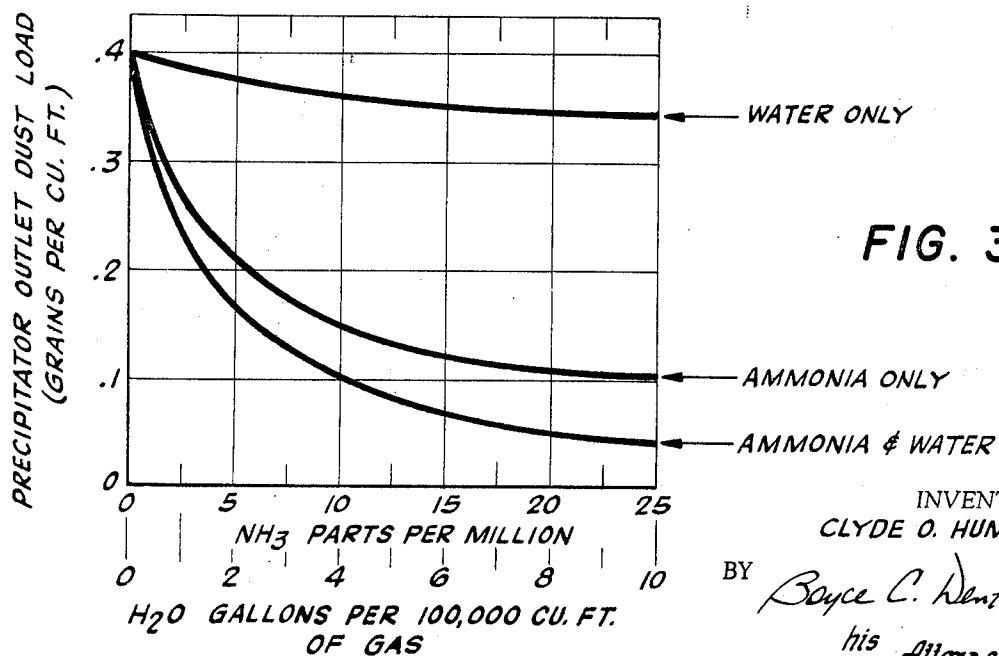
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METHOD FOR ELECTROSTATIC PRECIPITATION OF DUST PARTICLES

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METHOD FOR ELECTROSTATIC PRECIPITATION OF DUST PARTICLES

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6 Claims

ABSTRACT OF THE DISCLOSURE

A method for the electrostatic precipitation of dust particles entrained in a gas stream which comprises adding predetermined amounts of ammonia and water into the particle-laden gas stream in a location preceding the precipitation apparatus where the gas is at an elevated temperature.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates generally to gas separation and more particularly to processes of gas separation involving electric fields and adding gases and vapors.

Description of the prior art

A conventional way of separating dust particles from a gas stream in which the particles are entrained is by the use of an electrostatic precipitator. This apparatus utilizes the corona discharge effect, i.e., the ionization of the particles by passing them through an ionization field established by a plurality of discharge electrode wires suspended in a parallel plane with a grounded collecting electrode plate. The ionized particles are attracted to the collector plate from which they may be removed by vibrating or rapping the plate. Examples of this type precipitator are found in Cummings' Pat. No. 3,109,720 and Pennington Pat. No. 3,030,753.

Dust particles have different characteristics depending upon their source. One characteristic is resistivity which is measured in ohm-centimeters. For example, where the source of particles is a coal-fired boiler, there is usually a predictable relationship between the type of coal burned and the resistivity of the particles. Typically, low sulphur coal, i.e. less than 1% sulphur, produces particles having high resistivity, i.e. 10^{-13} ohm-centimeters resistance; coal with 3-4% sulphur produces particles having 10^{-8} - 10^{-10} resistance; and, poorly combustible coal produces particles having 10^{-4} - 10^{-5} resistance.

It has been found that most efficient separation or precipitation of the particles occurs when their resistivity is about 10^{-8} ohm-centimeters. When the resistivity is higher than this, the precipitation process is encumbered because the particles tend to hold their charge; particles collected on the plate in a layer tend to remain negatively charged and particles subsequently charged in the gas stream are not attracted to the plate with a resultant loss of efficiency. Conversely, when the resistivity is lower than this, the low resistivity particles lose their charge rapidly upon contact with the collector plate thereby being difficult to retain thereon; re-entrainment then occurs with a resultant loss of efficiency. However, when the particles are of the preferred resistivity, a balance is achieved between the tendency to have either overcharged or undercharged particles with a resultant increase in precipitation efficiency. Thus, the problem which existed until now was to provide a means for reducing the resistivity of high-resistivity particles and increasing the resistivity of low-resistivity particles.

One approach taken to solve the problem is disclosed in Orne Pat. No. 3,284,990 which seems to imply that the

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acid content of the particles may be related to their resistivity. Orne found that the addition of phosphorus pentoxide (P_2O_5) to the particle-laden gas changed the acid level of the particles and apparently lowered their resistivity. However, this does not solve the problem of collecting low-resistivity particles.

SUMMARY

It has now been discovered that the electrostatic removal of the particles that are entrained in a gas stream can be improved by the addition of preselected amounts of ammonia and water into the particle-laden gas stream where the gas is at an elevated temperature. Specifically, optimum precipitation has been found to occur when ammonia is added in an amount of from 10 to 20 parts per million parts of gas and water is added in an amount of from 4-8 gallons per 100,000 cubic feet of gas and the gas temperature is above 400° F.

The reason for the improved collection efficiency is not clearly understood, but it appears that a synergistic relationship exists. For example, the addition of ammonia (NH_3) alone causes some improvement; and the addition of water (H_2O) alone causes some improvement. However, the addition of both ammonia and water causes an improvement greater than the sum of the individual improvements found for ammonia and water added individually to the gas.

It is possible that a surface phenomenon results from the invention. Ordinarily, fly-ash particles from a power plant, for example, include a minor amount of sulphur trioxide (SO_3). It is believed that the ammonia and water added to the gas stream reacts with the sulphur trioxide to form an ammonium bisulfate (NH_4HSO_4) film which envelopes the particles. It has been found that the greater amount of sulphur trioxide in the gas, the more water is needed to achieve the desired reaction. This, of course, would not affect the acid level of the particles or gas as Orne attempted to do. Apparently, the film itself has a resistivity near 10^{-8} ohm-centimeters, that is, near the desired resistivity for optimum collection efficiency. Since it is believed that the ionizing field responds only to the surface resistivity of the particles, it does not matter whether the particles originally had a high or low resistivity or a particular acid content. The surprising result is that both ammonia and water are essential to achieve the optimum collection efficiency, regardless of the cause of the phenomenon.

The temperature of the gas at the place where the ammonia is added has been found to affect the reaction. The exact temperature can be determined by one skilled in the art, depending upon the particular application. For example, in a power plant where fly-ash is present in the flue gas if the gas temperature is below 400° F., the ammonia and water apparently react with the sulphur trioxide to form ammonium sulfate $[(NH_4)_2SO_4]$ rather than ammonium bisulfate. The ammonium sulfate causes the particles to agglomerate as a sticky substance which cannot be easily removed from the collecting electrodes. Thus, the preferred gas temperature for addition of the ammonia and water can be determined by visual inspection for the existence of agglomerated, sticky particles.

Usually, the conditioned particles pass through an air preheater before entering the precipitator. This apparatus is even more adversely affected by sulfate-covered particles than the precipitator itself since it contains moving parts, seals, and the like which are affected by a build-up of particles. However, the gas leaving the pre-heater is not usually of a high enough temperature to cause a reaction for forming ammonium bisulfate.

The above and further objects and novel features of the invention will appear more fully from the following detailed description when the same is read in connection

with the accompanying drawings. It is to be expressly understood, however, that the drawings are not intended as a definition of the invention but are for the purpose of illustration only.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings wherein like parts are marked alike:

FIG. 1 is a schematic illustration of a boiler and precipitator system including an air pre-heater and showing the preferred location for injection of ammonia and water into the gas stream;

FIG. 2 schematically illustrates typical apparatus for injecting ammonia and water into the gas stream; and

FIG. 3 is a graph illustrating the effects of adding water only; adding ammonia only; and adding both ammonia and water to the gas stream.

DESCRIPTION OF THE PREFERRED EMBODIMENT

This invention contemplates the increasing of the efficiency of an electrostatic precipitator by adding selected quantities of ammonia and water to a particle-laden gas stream having an elevated temperature to condition the particles for subsequent precipitation within a conventional electrostatic precipitator.

Referring now to FIG. 1, an embodiment of the invention is illustrated as being incorporated in a power station which may include a coal-fired boiler 10 whose flue-gas is directed to an electrostatic precipitator 12 by way of ducts 16 and 18 through an air pre-heater 14 which transfers heat from the particle-laden exhaust flue-gas to the air supply for boiler 10.

Pre-heater 14 may be one of the several well-known types. A common type comprises a rotatable cylindrical shell which is filled with a labyrinth of metal grids. As the shell is rotated, a portion of the grids comes into alignment with ducts 16 and 18. The flue-gas is conducted into the shell and through the grids thereby heating the grids. As the shell continues to rotate, the heated grids are brought into alignment with air inlet 20 and connecting duct 22. Atmosphere drawn into inlet 20 flows through the heated grids and absorbs heat therefrom. The heated air passes into duct 22 which directs it into the combustion chamber of boiler 10. Appropriate seals and the like are provided so that the heater 14 may operate continuously.

The pre-heater at a power plant for example usually receives flue-gas having a temperature of about 650° F. The temperature of the relatively cool gas exiting into duct 18 is about 400° F. The ambient atmosphere entering inlet 20 will be heated to about 500° F. in preheater 14 and will exit into duct 22 at that temperature.

In accordance with this invention, the ammonia is injected into a gas stream having an elevated temperature. In the preferred embodiment, by way of example, the gas temperature is at least 400° F. and preferably over 450° F. Thus, the ammonia should be injected in duct 16 preceding pre-heater 14 since the gas is hottest at that point. Of course, it can be injected in duct 18 downstream from the preheater 14 provided the gas temperature is high enough. The water can also be injected downstream provided the gas temperature is high enough to vaporize it. An alternative is to inject steam into the gas although this is more expensive.

A suitable apparatus for injecting the ammonia and water into the gas stream is illustrated somewhat schematically in FIG. 2. A conventional bottle or tank of ammonia 24, which is gaseous in form upon exit from the tank, is connected to duct 16 by a conduit 26. A conventional throttle valve 28 and flow meter 30 are connected in conduit 26. Thus, the amount of ammonia injected into the gas stream can be controlled by valve 28 and monitored by meter 30.

The water is similarly injected into the gas stream adjacent the ammonia injection. If water under pressure is

not available, a conventional water pump 32 is connected to a water supply and its output is connected to duct 16 by a conduit 34. A throttle valve 36 and flow meter 38 are connected in conduit 34 to regulate and monitor the amount of water injected into the gas stream. Preferably, an ordinary water spray nozzle 40 is connected to the output end of conduit 34 to disperse the water in a fine spray inside the duct 16. If desired, a fog nozzle may be used in lieu of nozzle 40 to disperse the water as a fog.

Although FIG. 2 shows the ammonia and water injected at separate locations, it is possible to connect the ammonia conduit 26 to the water conduit 34, as shown by the dotted line 42, so that both are injected into the gas stream at one location.

The ammonia used should be anhydrous (NH_3) when injected as previously described. However, aqua ammonia (NH_4OH) can be used when it is impractical to provide a separate water supply. Care should be taken to provide the preferred proportions of ammonia and water in the aqua ammonia as previously mentioned.

The efficiency of an electrostatic precipitator can be determined by the amount of particles or dust load released to atmosphere from the precipitator outlet or stack. The dust load is usually measured in grains per cubic foot of gas. As illustrated in FIG. 3, a typical fly-ash precipitator may have an outlet dust load of 0.4 grain per cubic foot at normal temperature and pressure. With the addition of water alone to the particle-laden gas stream in duct 16, the dust load may be reduced to approximately 0.35 grain per cubic foot. The addition of anhydrous ammonia alone may reduce the dust load to nearly 0.12 grain per cubic foot. However, actual field installations have proven that the addition of both ammonia and water can reduce the dust loading below 0.05 grain per cubic foot. The curves on the graph of FIG. 3 show the outlet dust loading reduced as a function of the quantity of ammonia and water added. Ammonia added at the rate of 10–20 parts per million parts of gas, by volume as shown in FIG. 3, is equal to 1–2 cubic feet of ammonia per 100,000 cubic feet of gas at normal temperature when compared to the water added to the same amount of gas.

Operation

In operation, the boiler 10 is fired and the precipitator 12 energized. When the flue-gas leaving the boiler in duct 16 attains 400°–450° F., ammonia and water are injected into the gas stream by opening throttle valves 28 and 36. These valves are opened to the desired setting by reading the meters 30 and 38. Exactly what the desired setting will be is determined by the volume of gas flow through duct 16. Suitable meters (not shown) are provided to indicate the gas volume. The conditioned gas passes through the pre-heater and through duct 18 to the precipitator 12 where most of the dust particles are collected in the conventional manner. The air pre-heater, as mentioned, heats incoming atmosphere and supplies the pre-heated air through duct 22 to boiler 10 to aid in combustion of the fuel.

If desired, automatic controls can be provided to open throttle valves 28 and 36 when the flue-gas reaches the desired operating temperature and to close them should the temperature fall below operating temperature. The automatic controls can be made to open the valves an amount to correspond to the volume of gas flowing in duct 16.

It is presently difficult to measure the amount of sulphur trioxide in the flue-gas. As means are developed to accurately measure this constituent, automatic controls can be used to vary the addition of ammonia and water in response to the amount of sulphur trioxide in the gas. In this manner, adequate ammonia and water can be injected to react with the sulphur trioxide to form sufficient ammonium bisulfate to envelop the dust particles.

In systems where the flue-gas does not contain sulphur trioxide, minor amounts may be added to the flue-gas to

equal the amount normally found when sulphur-bearing coal is burned. This amount is usually about 10-30 parts per million parts of gas. The addition can be accomplished in the same manner that ammonia is added. This will provide the necessary constituents for the formation of ammonium bisulfate with the beneficial effects previously set forth.

The foregoing has demonstrated that the addition of ammonia and water to flue-gas leaving a boiler increases the precipitability of dust particles in the gas when the additives are injected in selected amounts at the proper gas temperature.

Thus, the invention having been described in its best embodiment and mode of operation, that which is desired to be claimed by Letters Patent is:

1. Apparatus for conditioning particles entrained in a hot particle-laden gas, having a temperature of at least 400° F., flowing from a fuel combustion chamber to an electrostatic precipitator to improve the collection characteristics of said particles by said precipitator, comprising:

- an air pre-heater between said chamber and said precipitator for heating air in said pre-heater by said hot gas;
- said pre-heater including heat exchange surfaces for absorbing heat when exposed to said hot gas and for giving off the absorbed heat when exposed to air;
- a first duct connecting said pre-heater with said combustion chamber for directing said hot gas into said pre-heater;
- a second duct connecting said pre-heater with said precipitator for directing said particle-laden gas to an input in said precipitator;
- an inlet in said pre-heater for introducing air into said pre-heater;
- a third duct connecting said pre-heater with said combustion chamber for directing heated air from said pre-heater to said combustion chamber for aiding the combustion of said fuel;
- an ammonia injector connected to said first duct for injecting at least 1 cubic foot of ammonia into said hot particle-laden gas for each 100,000 cubic feet of gas flowing through said first duct;
- said ammonia injector including a supply of ammonia under pressure and a valve for regulating the amount of ammonia injected into said hot gas;
- a water injector connected to said first duct for injecting at least 4 gallons of water into said hot particle-laden gas for each 100,000 cubic feet of gas flowing through said first duct;
- said water injector including a supply of water under pressure and a valve for regulating the amount of water injected into said hot gas; thereby conditioning said particles for collection by said precipitator.

2. The apparatus of claim 1, and in addition:

controls responsive to the temperature and volume of said hot gas in said first duct for regulating the amounts of ammonia and water injected into said gas in said first duct.

3. The apparatus of claim 1, and in addition:

a sulphur trioxide injector connected to said first duct for injecting at least 1 cubic foot of sulphur trioxide into said hot particle-laden gas for each 100,000 cubic feet of gas flowing through said first duct; said sulphur trioxide injector including a supply of sulphur trioxide and a valve for regulating the amount of sulphur trioxide injected into said hot gas.

4. The apparatus of claim 1 wherein said water injector includes a spray nozzle for dispersing said water in a fine spray inside said first duct.

5. The apparatus of claim 1 wherein said air pre-heater includes a labyrinth metallic grid rotatable within a cylindrical shell with a first portion of said grid arranged for exposure to said hot gas flowing from said first duct into said pre-heater and a second portion of said grid arranged for simultaneous exposure to air entering said pre-heater from said inlet:

whereby, upon rotation of said grid, said first portion is exposed to said air and said second portion is exposed to said hot gas.

6. The apparatus of claim 1 wherein:

said hot particle-laden gas flowing in said first duct has a temperature of at least 650° F.;
said gas flowing from said pre-heater in said second duct has a temperature no more than 400° F.; and
said air flowing from said pre-heater in said third duct has a temperature of at least 500° F.

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