

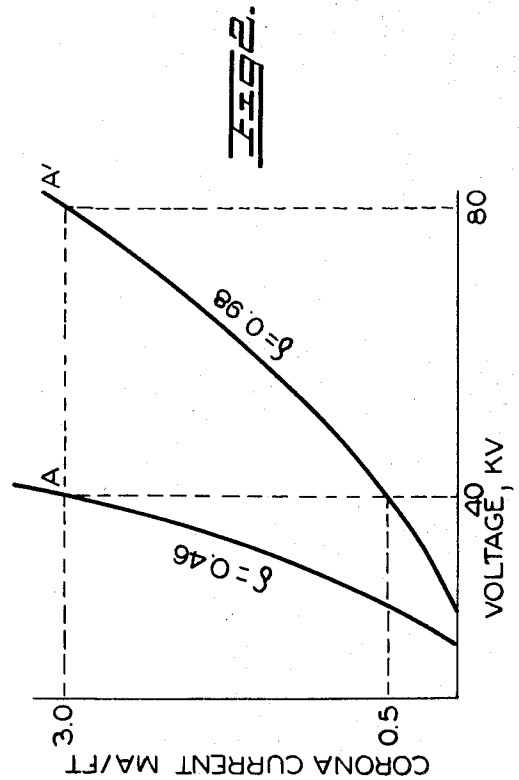
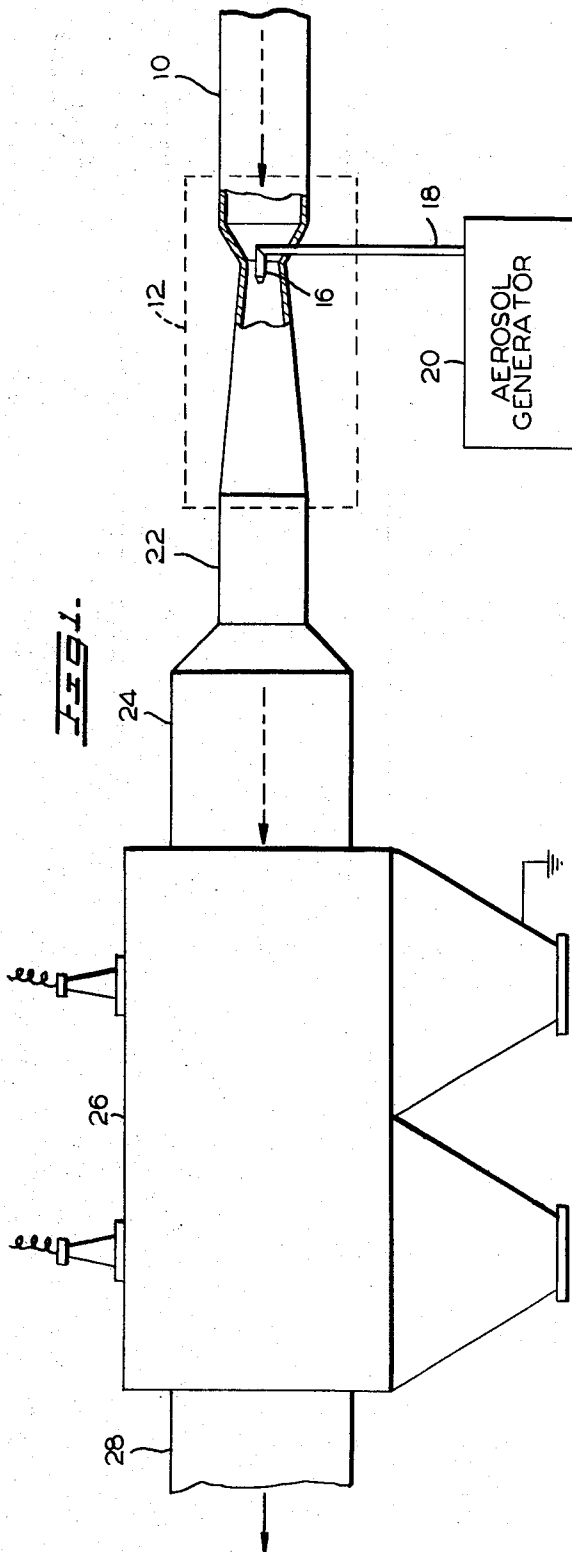
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LOW PRESSURE ELECTROSTATIC PRECIPITATOR

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## LOW PRESSURE ELECTROSTATIC PRECIPITATOR

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3 Claims

### ABSTRACT OF THE DISCLOSURE

A method of operating an electrostatic precipitator to clean low density gas streams. The sparking potential of the gas stream to be cleaned is determined, a corona quenching aerosol is added to increase the sparking potential of the stream as it is passed through a precipitator for electrostatic cleaning.

### BACKGROUND OF THE INVENTION

This invention relates generally to cleaning of low density gases resulting from low pressures and/or high temperature operation and more particularly to a new and improved method of cleaning such gases by electrostatic precipitation.

Electrostatic precipitators have found wide use in industry for cleaning gases, particularly in operations where a minimum pressure drop in the gas stream is desired. Such operations have, however, been heretofore limited to gases at substantially atmospheric density due to reduced efficiency of the electrostatic process at low gas densities.

It is important, in particular situations, to clean low density gases with a minimum pressure drop through the cleaning operation. In such gases, the electrical impedance of the gas is low and the current density at which sparking in an electrostatic precipitator will occur is encountered at a relatively low voltage. The maximum field strength for the precipitator, upon which the precipitation rate and efficiency are critically dependent, is therefore limited, and precipitation cleaning of such gases has, heretofore, been considered impractical.

### SUMMARY OF THE INVENTION

This invention overcomes the disadvantages of the prior art by providing means for operating an electrostatic precipitator on low density, aerosol bearing gases in such a manner as to provide efficient, effective removal of the aerosol therefrom. This is accomplished by increasing the aerosol space charge in the gas to be cleaned by adding a secondary or corona quenching aerosol thus providing greater electrical impedance in the gases and thereby allowing imposition of greater precipitator operating field strengths at equivalent current densities.

The invention also provides a method for elevating the sparking voltage in an electrostatic precipitator operating on low density gases by increasing the electrical impedance of the gas to be cleaned through an increase in the concentration of aerosol present in the gas being treated.

In a preferred embodiment, the invention provides means for operating an electrical precipitator to remove solids or liquid aerosols from a gas stream flowing at density ratios relative to air at NTP not greater than about 0.5. The sparking potential of the gas stream to be cleaned is determined and a corona quenching or secondary aerosol is added to the gas stream, prior to precipitation, in an amount to increase the sparking potential of the gas stream at least about 100% and allow higher operating voltages and precipitation rates.

These and other objects and advantages of the invention

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will become better understood to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a recipitator and aerosol generator apparatus adapted to clean low density gases in accordance with the invention; and

FIG. 2 shows current-voltage curves for typical electrode geometry at two air densities relative to standard conditions.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1, a feed duct 10 conducts a stream of gas to be cleaned to a mixing zone 12 comprising a venturi 14 having a nozzle 16 concentrically disposed therein. The nozzle 16 is communicative, through a tube 18 with an aerosol generator 20 of any type known in the art. The mixed gases flow from the mixing zone 12, through a duct 22 and expansion chamber 24 into an electrical precipitator 26 for operation thereon by the precipitator as is known in the art. The treated clean gases are then exhausted from the precipitator through an exhaust duct 28.

The precipitator 26 may be any of the conventional electrostatic types known in the art. Such precipitators utilize a corona discharge to charge aerosol present in the gas stream flowing therethrough. Subsequently, the charged aerosol is precipitated from the stream as it passes through or between oppositely charged collection tubes, plates, or other surfaces.

As was indicated above, electrostatic precipitator effectiveness depends upon the strength of the field in the precipitator. The maximum field strength possible is limited to the sparking voltage which, in turn, is a function of the electrical impedance of the gas. The electrical impedance of a given gas is determined primarily by its density up to temperatures of about 1500° F., with impedance decreasing with decreasing density. Low density gases thus have low electrical impedance. With gases substantially below atmospheric density, field strength has been limited to such low levels that it has been heretofore impractical to use the electrostatic precipitator for cleaning such gases.

In this invention, the electrical impedance or initial aerosol loading of the incoming, low density gases is first measured by any suitable means known in the art prior to entrance thereof into the mixing zone 12. A secondary aerosol is then added through the nozzle 16 in quantity and size sufficient to increase the sparking potential of the gases to a suitable level.

The following illustrative example will demonstrate, by order-of-magnitude calculation, the method of this patent. Let  $i_0$  (statamp/cm.) be the current per unit length in a wiretube precipitator before the introduction of the secondary aerosol, and  $i_1$  be the reduced current afterward. If  $i_1 \ll i_0$ , the greater part of the reduced current is carried by aerosol particles (rather than as free ions), and it is approximately true that the particle concentration  $C$  (particles/cm.<sup>3</sup>) is given by

$$C = \left(1 - \frac{i_1}{i_0}\right) \frac{\rho}{q} \quad (1)$$

where  $\rho$  (statcoul./cm.<sup>3</sup>) is the space-charge density and  $q$  (statcoul./particle) is the charge acquired by a single particle. The initial space charge density is

$$\rho = \frac{j_0}{k_E} \quad (2)$$

where  $j_0$  (statamp/cm.<sup>2</sup>) is the initial current density,  $k$  ((cm./sec.)/(statvolt/cm.)) the ion mobility, and  $E$

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(statvolt/cm.) the electric-field intensity. Particles charging by the ion-bombardment process obtain a charge

$$q = pEa^2 \tag{3}$$

where  $p$  (dimensionless) is a function of the particle's dielectric constant ( $1 < p < 3$ ) and  $a$  (cm.) is the particle radius. The field is given approximately by

$$E = \sqrt{2i/k} \tag{4}$$

In addition, the areal and linear current densities  $j_0$  and  $i_0$  respectively are related by

$$i_0 = 2\pi r j_0 \tag{5}$$

where  $r$  (cm.) is the distance from the axis at which  $j_0$  is measured. Using the foregoing expressions, Equation 1 may be rewritten

$$C = \left(1 - \frac{i_1}{i_0}\right) \frac{1}{4\pi r p a^2} \tag{6}$$

or in terms of the particulate mass per unit volume of gas  $C'$

$$C' = \left(1 - \frac{i_1}{i_0}\right) \frac{a \rho_p}{3r p} \text{ gm/cm}^3 = 4.37 \times 10^5 \left(1 - \frac{i_1}{i_0}\right) \frac{a \rho_p}{3r p} \text{ grain/ft.}^3 \tag{7}$$

where  $\rho_p$  (gm./cm.<sup>3</sup>) is the true particle density.

FIG. 2 shows measured current-voltage curves for a typical electrode geometry (0.094-in. diameter wire in a 6.06" diameter tube) at two air densities  $\delta$  relative to standard conditions, namely  $\delta=0.98$  and 0.46. At a voltage of 40 kv., the corona current in the former instance is 0.5 ma./ft., and in the latter 3.0 ma./ft. Points A and A' in FIG. 2 illustrate the points where sparking occurred. We seek to determine the particle concentration and size of the secondary aerosol which at  $\delta=0.46$  will reduce the initial current of 3 ma./ft. to 0.5 ma./ft. Since, to a first approximation sparkover at different gas densities (for a given gas and geometry) occurs at the same current density, and since the presence of heavy space charge effectively raises the corona-starting voltage, the secondary aerosol will serve, very roughly, to shift the current-voltage curve from that given for  $\delta=0.46$  to that for  $\delta=0.98$ . We introduce the following quantities into Equation 7:

- $i_0 = 3 \text{ ma./ft.} = 3 \times 10^5 \text{ statamp/cm.}$
- $i_1 = 0.5 \text{ ma./ft.} = 5 \times 10^4 \text{ statamp/cm.}$
- $a = 1 \text{ micron} = 10^{-4} \text{ cm.}$
- $\rho_p = 2 \text{ gm./cm.}^3$
- $p = 2$
- $r = 1.5 \text{ in. (average value of radius vector)} = 3.8 \text{ cm.}$

whence  
 $C' = 2.1 \text{ grains/ft.}^3$  of 2-micron particles

For particles less than a micron in size, Equation 3, whence Equation 7, are no longer applicable. Instead we have from Equation 1, 2, 4 and 5

$$C' = 4.37 \times 10^5 \left(1 - \frac{i_1}{i_0}\right) \frac{2a^3 d}{3r q} \sqrt{\frac{i_0}{2k}} \tag{8}$$

The charge  $q$  acquired by, say, a 0.2-micron particle by ion diffusion may be estimated at about 10 electronic charges or  $4.8 \times 10^{-9}$  statcoul. Taking  $k=1400$  (cm./sec.)/(statvolt/cm.) and  $a=0.1 \text{ micron} = 10^{-5} \text{ cm.}$ , we have

$$C' = 0.28 \text{ grain/ft.}^3 \text{ of 0.2-micron particles}$$

With the above parameters, the maximum corona voltage was on the order of 10 times greater than that possible without aerosol augmentation of the gas stream.

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The secondary aerosol may be of any type suitable for the purposes, however, an aerosol selected from the group consisting of metallic oxide fumes or a fine liquid fume such as oil, water vapor, glycol and the like in wet precipitator operations has been found to be preferable. In high temperature conditions the dry aerosol is preferred. Such aerosol is ideally of submicron size formed by condensation of the aerosol material from its vapor state.

In general the size of the particles added to the gas stream should not be greater than about .25 micron and preferably in the order of about .1 micron or smaller as shown by Equation 7.

What has been set forth above is intended as exemplary of a teaching in accordance with the invention to enable those skilled in the art in the practice thereof. It should therefore be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

It will be appreciated that suitable current or voltage, or spark sensing means may be utilized as the control means for the aerosol generator to insure optimum operation of the precipitator.

I claim:

1. A method of operating an electrostatic precipitator to remove initial aerosol from a gas stream wherein the density of the gas stream to be cleaned relative to air at NTP is not greater than about 0.5 comprising the steps of:
  - determining the sparking potential of the gas stream to be cleaned;
  - adding a corona quenching aerosol of a size not greater than about .25 micron to the gas stream to thereby increase the sparking potential of the gas stream; and
  - electrostatically precipitating said aerosols from said gas stream.
2. The method defined in claim 1 wherein the corona quenching aerosol is produced from a fine liquid fume selected from the group consisting of oil, a glycol, and water.
3. The method defined in claim 1 wherein the corona quenching aerosol is a fume produced from a metallic oxide.

References Cited

UNITED STATES PATENTS

1,022,012	4/1912	Whitney	317—262
1,331,225	2/1920	Wolcott	55—5
1,441,713	1/1923	Prosser	55—5
1,883,373	10/1932	Hedberg	55—5
1,909,825	5/1933	Hahn et al.	55—106X
2,356,717	8/1944	Williams	23—1
2,726,730	12/1955	MacKenzie	55—101X
2,746,563	5/1956	Harlow	23—175X
2,841,242	7/1958	Hall	23—174X
2,864,456	12/1958	Hall et al.	55—106X
1,883,372	10/1932	Hedberg	55—5
2,935,375	5/1960	Boucher	23—2
3,372,528	3/1968	Hoff	55—106
3,395,193	7/1968	Bruce et al.	260—679

FOREIGN PATENTS

559,532	2/1944	Great Britain	55—5
932,895	7/1963	Great Britain	55—134

DENNIS E. TALBERT, JR., Primary Examiner  
U.S. Cl. X.R.

5—10, 105, 106, 134