Separation Science and Technology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713708471

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To cite this Article Siebenhofer, M.(1990) 'Aerosol Precipitation', Separation Science and Technology, 25: 13, 2171 — 2177
To link to this Article: DOI: 10.1080/01496399008050450
URL: http://dx.doi.org/10.1080/01496399008050450

SEPARATION SCIENCE AND TECHNOLOGY, 25(13-15), pp. 2171-2177 (1990)

AEROSOL PRECIPITATION

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ABSTRACT

The efficiency of a single-stage wet electroprecipitator was investigated. This separation process is based on ionization of the particles in the first step. The precipitation electrode is formed by the scrubbing liquid. The operating voltage is limited to 20 kV.

INTRODUCTION

Many industrial processes need gas purification during different steps. There are several chemical purification methods, but there are fewer methods for efficient removal of particles. There are problems with precipitation of aerosols from off-gas streams when the particle size is between 0.1 and 1 micrometer (1,2). These problems cannot be solved satisfactorily, when the chemical nature of the substances to be separated does not permit the application of dry electroprecipitators. These limitations can be caused by specific electrical conductivity or other physical properties of the substances to be separated. For example, it is still very difficult to precipitate aerosols of highly viscous hydrocarbons formed by adiabatic cooling or to precipitate aerosols of evaporable salts.

Most problems arise when it is not possible to remove the precipitate from the collecting electrode continuously, or when the particle discharges at the collecting electrode. Different types of ionization scrubbers have been developed to solve these problems (3,4). This paper presents the characteristics of a single-stage wet ionization precipitator.

EXPERIMENTAL AND ANALYTICAL SETUP

The investigations were carried out with a continuously washed film ionization scrubber. This type of scrubber consists of a series of plates mounted vertically in a shell. The plates support the liquid film. They are mounted in parallel, with a constant distance between the plates. The scrubbing liquid film forms the collecting electrode.

The corona forming discharge electrodes are installed between the plates. Tungsten wire with a diameter of 0.2 to 0.5 mm was used as discharge electrode material. It is advantageous but not necessary to saturate the off-gas with scrubbing liquid in a prequenching zone before it enters the ionization scrubber. This guarantees constant gas conductivity.

During this program, the particles were ionized by a high voltage DC discharge unit with a maximum anodic voltage of 20 kV. The precipitation efficiency was detected by a particle counter, type DEHA PM 28-DD. The gas used for investigation of the precipitator behavior was taken from a refractory drier. The aerosols were mainly MgO aerosols and high-boiling kerosene aerosols.

THEORETICAL FUNDAMENTALS

The precipitation efficiency of electroprecipitators is described by the Deutsch equation (5).

$$\eta = 1 - \exp\text{-}(wt/s) . \tag{1}$$

The residence time, t, and the distance, s, between the parallel plates are geometrical constructive properties. The migration velocity, w, is determined by the initial field strength, E_O, and the precipitation field strength, E_p, as shown by Eq. (2) (6,7).

$$w = E_O E_p / 2\pi\eta \tag{2}$$

with

$$E_O = 30d + 9\sqrt{d/r_O}$$

and

$$E_p = \sqrt{2i/K} .$$

The specific current, i, is calculated by

$$i = KU(U - U_O)b^2 \ln(4b/(r_O\pi) . \tag{3}$$

RESULTS

The precipitation efficiency is based on the electrical and geometrical properties of the precipitator. Both properties are characterized by the current-voltage behavior as shown in Fig. 1. Based on these results, an operation voltage of approximately 12 kV is appropriate, as the breakdown voltage was 21 kV.

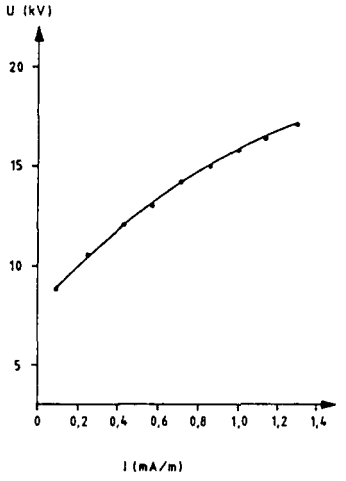

Fig. 1. Current-voltage properties of the investigated ionization scrubber ($s = 6$ cm, $r_O = 0.1$ cm).

Precipitation of particles with a mean size between 0.1 and 1 micrometer is difficult because within this region the mechanism of ionization shifts from ionization by collision to ionization by diffusion (8). Therefore, the particles from 0.3 to 0.5 micrometers were studied preferentially to characterize precipitation in this range.

Based on the Deutsch equation, the migration velocity of a particle is proportional to the field strength at the corona starting voltage and the collecting field strength. Figure 2 shows the experimentally obtained migration velocity compared with the theoretical values derived from Eq. (2) for different energy values.

Further, the precipitation efficiency is influenced by the ratio of the collecting area to the gas throughput. Experimental data on the influence of the gas velocity on the precipitation efficiency are shown in Fig. 3.

The total energy input during the evaluation of the velocity dependency was held constant at 32 Wh. Therefore, the specific energy input decreases with increasing gas velocity. The values of the specific energy input are listed in Table 1.

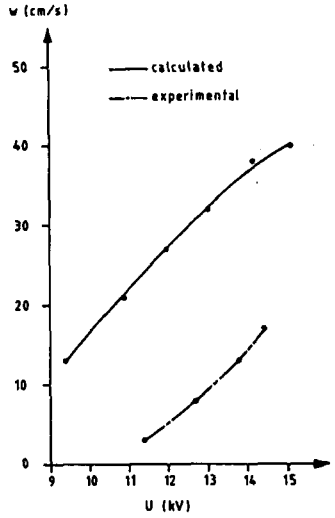

Fig. 2. Particle migration velocity, calculated from experimentally obtained precipitation data, compared with the theoretical migration velocity.

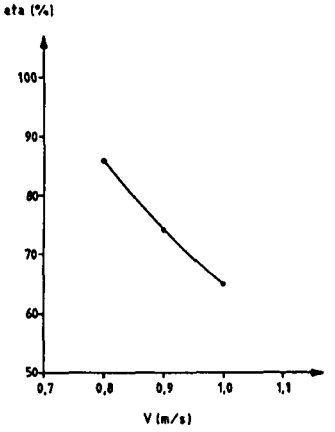

Fig. 3. Ratio of the precipitation efficiency to the gas velocity.

Table 1. Specific energy/input

v (m/s)	A/v (m^2s/m^3)	E (Wh/100 m^3)
0.7	21.0	72
0.8	18.4	63
0.9	16.3	56
1.0	14.7	50

The total power input influences the precipitation efficiency since it determines the collecting field strength based on Eq. (3). The precipitation of the particles between 0.3 and 0.5 micrometers shows the highest dependency on the energy input. Figure 4 relates the precipitation efficiency to the specific energy input. The separation of the 0.3 and 0.5 micrometer particles is compared with the precipitation efficiency of the 0.5 to 1.5 micrometer and the 1.5 to 3.0 micrometer particles.

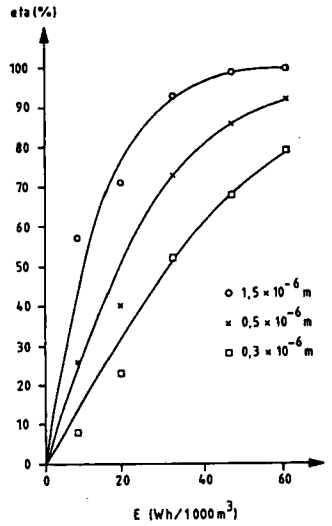

Fig. 4. Energy dependency of the precipitation efficiency.

When investigating the influence of energy on precipitation, the experimental data were worked out at a gas velocity of 0.74 m/s. Based on the total precipitation area, these data were achieved at a specific gas throughput of 9.9 m^2s/m^3.

DISCUSSION

Wet ionization precipitators, of course, do not have universal application. But they have some properties that give them advantages in some applications. These properties are:

1. No particle entrainment; the precipitate is continuously removed from the collecting electrode by the scrubbing liquid.

2. Rapping of the collection electrodes is not necessary; therefore, the construction is simplified.

3. Constant electrical resistivity; the off-gas is usually saturated with the scrubbing liquid before it enters the precipitator.

4. Applications are possible for the precipitation of particles even with high electric conductivity, such as soot.

Good precipitation efficiencies can be achieved at low ratios of the specific precipitation area. In comparison with dry electroprecipitators, this is a major advantage. The efficiencies of dry precipitators are limited by particle entrainment during rapping. This causes a need for additional precipitation area, from 40 to 70 m^2s/m^3. A specific precipitation area for wet ionization precipitators of approximately 20 m^2s/m^3 should solve many particle precipitation problems sufficiently.

SYMBOLS

A	precipitation area (m^2)
b	distance of discharge electrode to the collecting electrode (cm)
d	gas normalization factor ($d = T_Op/Tp_O$)
η	precipitation efficiency (%), or dynamic viscosity [Eq. (2), Poise]
E	specific energy input (Wh/1000 m^3)
E_O	electric field strength at corona starting
E_p	precipitation field strength
i, I	specific current (A/m)
K	ion mobility (cm^2/Vs)
r_O	radius of the discharge electrode (cm)
s	distance between collecting plates (cm)
t	residence time (s)
U	operating voltage (kV)
U_O	operating voltage at corona starting
v	gas velocity (m/s)
w	particle migration velocity (cm/s)

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