Studies of an Electrostatic Air Cleaning System

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Introduction

The influence of the electrostatic forces on airborne particles have been known for centuries. These early discoveries have been summarized in several publications including the classical book "Electrostatic Precipitation" by White (1) and many others (e.g. 2, 3, 4). The utilization of the electrostatic force led to the development of electrostatic precipitator (ESP) which has been used for pollution control purposes since the beginning of this century. An excellent historical review about the development of electrostatic gas cleaning has been presented by White (1).

When cleaning air from aerosol particles, electrostatic precipitator is a tempting alternative to mechanical filtration. This is mainly due to the relatively high removal efficiency and the low flow resistance of the ESP. Besides power plant applications ESP's are used in many other industrial applications. The same method is also used in smaller scale devices to clean air in office rooms, homes and restaurants. During the past decades several modifications of ESP's have been developed.

This study focuses on an electrostatic air cleaning system developed by Ion Blast, Helsinki, Finland. The construction of this system is very simple and it has some similarities with the "wire in tube" electrostatic precipitator. However, instead of thin corona wire, a special corona electrode system is used to produce the necessary electric field and the unipolar air ionization. A typical feature of the Ion Blast system is the large diameter of collection tube - diameters up to 1200 mm have been used in some installations. The large diameter requires that the corona voltage must be high. Ion Blast systems have been operated at the voltages up to 150 kV.

The purpose of this study was to determine how the basic operational parameters, such as flow velocity, corona current and voltage, influence the performance of the Ion Blast system. Besides this, the aim was to clarify how the simple electrostatic theory could be applied when approximating the collection efficiency of Ion Blast system in different operation conditions.

Principle of the Air Cleaning System

The principle of the electrostatic air cleaning system is illustrated in Figure 1 (a). This system resembles the simple wire in tube electrostatic precipitator, Figure 1 (b). The corona electrode of the Ion Blast system consists of a metal tube to which electrode rings have been mounted. Each ring is equipped with several needle electrodes from which a corona current and an ionic wind is directed towards grounded collection tube.

The essential factors affecting the performance of the electrostatic air cleaning system are
stable corona discharge
strong electric field
high ion concentration

These factors have a strong influence on the charging of airborne particles and the electrostatic collection of charged particles on the grounded collection surface. It has been noticed that the electrical properties of the Ion Blast system can be estimated by using the basic theory developed for wire in tube electrostatic precipitator.

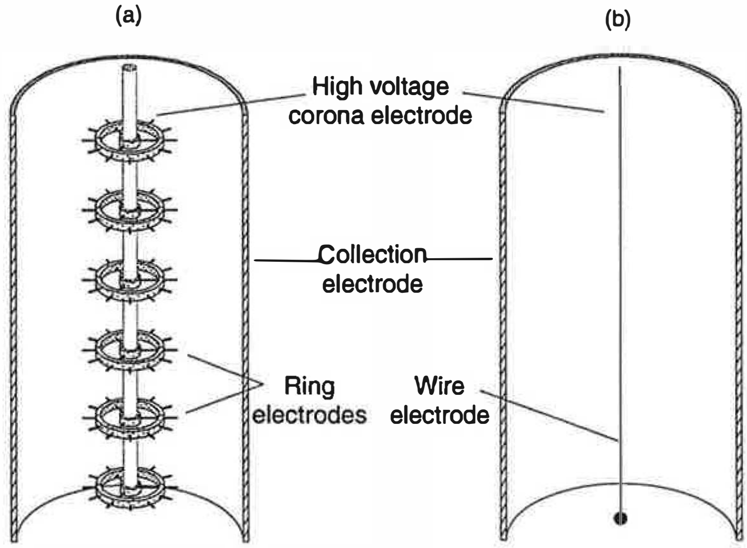

Figure 1. Principle of the electrostatic air cleaning system.

There are two basic approaches how to handle the particle collection in Ion Blast air cleaning system. The first approach is based on the assumption of laminar gas flow while the other assumes a turbulent flow. In this study it has been assumed that the turbulent flow approximation is more realistic than the laminar flow approximation. The collection efficiency in the case of turbulent flow ηT is given by

$$\eta_T = 1 - e^{-\frac{wA}{q}} = 1 - e^{-De} \qquad (1)$$

where w is the particle drift velocity in the electric field, A is the area of collection surface and q is the volumetric flow rate of the system. This equation which is called Deutsch equation has shown to be a useful tool for estimating the performance of electrostatic precipitators.

Experimental Setup

The properties of the Ion Blast system has been studied in laboratory by using several types of air cleaning chambers and high voltage electrodes. The principle of the measurement system is illustrated in Figure 2. This system includes a Ion Blast system equipped with an adjustable high voltage supply. The system also includes a supply air flow system which was used to create a controlled air flow through the air cleaning system. The supply air was cleaned with a HEPA filter and the air entry to the cleaning system was arranged either axially or tangentially.

The removal efficiency of the system was measured with PMS LAS X optical aerosol analyzer equipped with a sampling system which was used to extract air samples from upstream and downstream of the air cleaning system. The efficiency values were measured by using a polydisperse DEHS test aerosol. The effective operational size range of the measurement system was 0.12–5 μm. The main purpose of the laboratory studies was to clarify the relationships between the removal efficiency and the major operational parameters of the air cleaning system. Thus, the efficiency measurements were made at several flow rates and corona voltages.

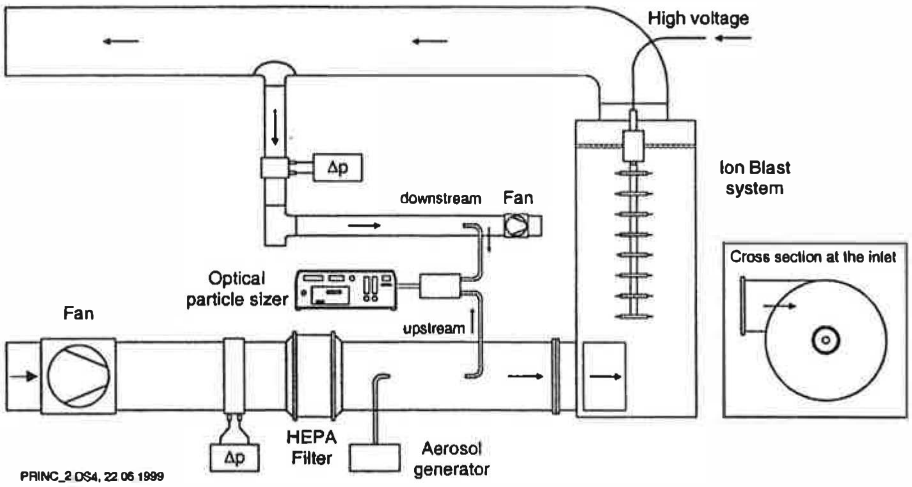

Figure 2. Principle of the measurement system.

Results

Figures 3–5 show some examples of efficiency curves measured with a typical Ion Blast laboratory test configuration. This system was built from standard ventilation duct (diameter 800 mm). The length of the corona electrode was 2000 mm and it included 11 ring electrodes the diameter of which were 240 mm. The flow rate was varied in the range of 0.25–0.75 m^3/s which correspond to the mean axial velocities of 0.5–1.5 m/s. In these measurements negative corona discharge was used. Corona voltage was 110 kV and the corresponding corona current 5 mA. The measured efficiency curves are in a reasonable agreement with the theoretical ones corresponding to laminar and turbulent air flows, i.e. experimental efficiency curves are between the curves corresponding to these cases.

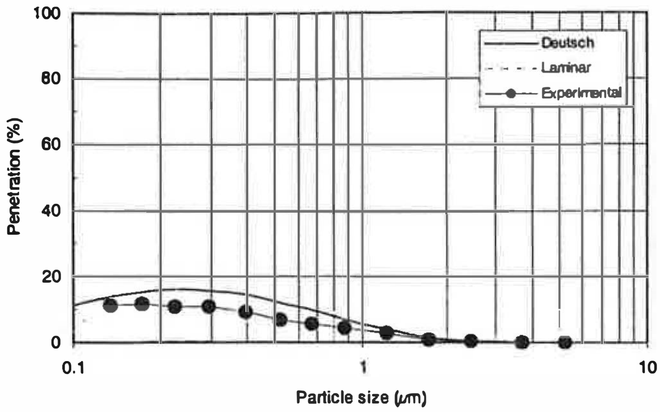

Figure 3. Efficiency as a function of particle size. Duct diameter 800 mm, electrode length 2000 mm, diameter of ring electrodes 240 mm, axial flow 0.25 m³/s, 110 kV, 5 mA.

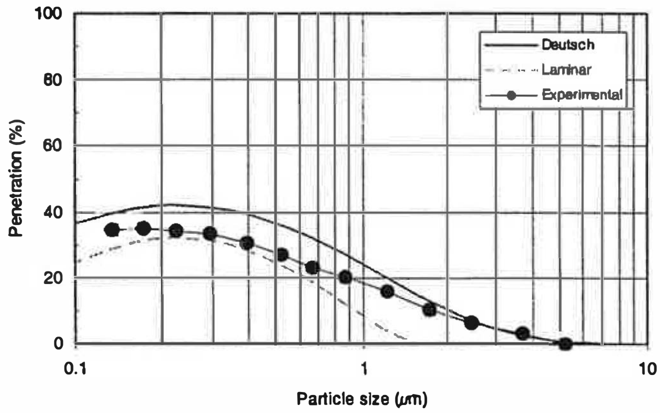

Figure 4. Efficiency as a function of particle size. Duct diameter 800 mm, electrode length 2000 mm, diameter of ring electrodes 240 mm, axial flow 0.5 m³/s, 110 kV, 5 mA.

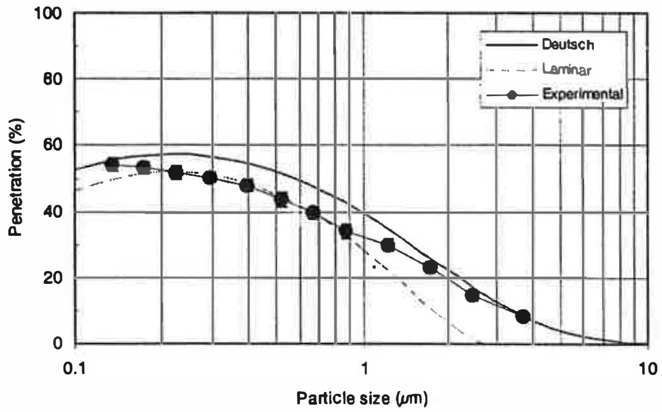

Figure 5. Efficiency as a function of particle size. Duct diameter 800 mm, electrode length 2000 mm, diameter of ring electrodes 240 mm, axial flow 0.75 m³/s, 110 kV, 5 mA.

Conclusions

A large number of efficiency measurements were made in laboratory to clarify the relationship between the system efficiency and various operation parameters such as corona voltage, corona current, flow velocity and the geometry of the air cleaning system. These studies show that the particle removal efficiency can be estimated at a reasonable accuracy with Deutsch equation which is based on complete mixing of air inside the system. The performance of the system in various operation conditions should, however, be tested by means of controlled long-term measurements.

According to the experimental results, effective removal of fine particles requires that the flow rate is reduced to a relatively low level. Feasibility of Ion Blast air cleaning system can be assumed to be better if high concentrations of coarse particles must be separated and the air cleaning system should not cause a large flow resistance.

References

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