Proceedings, ICESP VII
Sep. 20-25, 1998, Kyongju, Korea

EFFECT OF THE PLATE SPACING AND DISCHARGE ELECTRODE SHAPE ON THE EFFICIENCY OF WIDE PLATE SPACING ELECTROSTATIC PRECIPITATOR

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ABSTRACT

Plate spacing, gas velocity and applied voltage are the key parameters that determine the size of an industrial electrostatic precipitator(ESP). To save construction cost and operation energy, in recent years, there has been increased interest in the use of wide-plate spacing ESP with pulse energization. We have built a pilot-scale wide-plate spacing ESP of 2.5MWe equivalent power designed to be easily displaced and to ensure preliminary performance data of short time investigations with different equipment configuration such as plate spacing, electrode shape, and electrical energization system. Aerodynamic particle sizer(APS) was used to measure the collection efficiency for various particle diameters. Also particle collection efficiency was continuously monitored with time by using an opacity meter. Electrical operating characteristics and collection efficiency were measured for various shapes of discharge electrodes. The collection plate spacing ranged from 300 to 550 mm. The velocity and temperature of gas were kept constant at 1.2 m/s and 120 ℃, respectively. Results of electrical characteristic and collection efficiency tests as a function of collection plate spacing, discharge electrode type, applied voltage, and particle diameter were obtained. Increasing the collection plate pitch and altering the corona electrode geometry was found to increase the collection efficiencies without increasing input power requirement.

INTRODUCTION

The wire-plate electrostatic precipitator is one of the most economical means for collecting dust from flue gases emitted from coal combustion power generation plants with capacity of hundreds of megawatts (Oglesy & Nichols, 1978; Robinson, 1971; White, 1963). The ESP can handle large amounts of gases without significant pressure drops. Mechanically the ESPs are simple and therefore rather easy to maintain. The basic transport process of particles in the ESPs is straightforward: electric charge is placed on particles that are driven toward collecting plates by an applied electrostatic field, ie, Coulomb attraction. The collection efficiency of the precipitators depends upon 1) the velocity distribution and turbulence level of the gas flow, 2) the strength and distribution of the electric field, 3) the size and change of particles, and 4) some physical nonidealities, such as electric wind, baffles, reentrainment, back corona, entrance effects, etc.(Mcdonald & Dean, 1982). Despite of a broad use and successful operation of the ESP, many questions regarding to gas flow, electric fields and mechanism of particle collection remain to be solved in order to improve the collection performance.

Recently the many researches are conducted to reduce the installed cost and to enhance the collection performance and reliability of ESP by widening plate spacing from 300 mm to as much as 560 mm without enlarging the ESP casing (Kohl & Meinders, 1993; Pajak, 1996; Rea & Bogani, 1993). Because the larger spacings require higher voltage levels, more durable and rigid discharge electrodes in place of wire electrodes are used, thereby eliminating wire failures, improving reliability, and reducing maintenance costs (Crynak, 1991; Gawreluk, 1987; Pontius et al., 1984). Proper discharge electrode geometry and plate spacing are recognized by many researchers to be a critical factor to design high performance wide plate spacing ESPs.

In this study, a pilot scale experimental study has been performed to find the electrical characteristic and collection efficiency as a function of collection plate spacing, discharge electrode type, applied voltage, and particle diameter in a wide plate spacing ESP with various experimental conditions.

EXPERIMENTAL SET-UP

The schematic diagram of the pilot plant is shown in Fig.1 and the specifications of main equipment of the pilot ESP are shown in Table 1. This is manufactured as a versatile unit that admits internal configuration changes to be able to test different plate spacing, electrode types, energization levels and types, rapping levels, etc.. The plant is equipped with an automatic control of the most important operating variables such as flow rate, gas velocities, and temperatures, and a data acquisition system that monitors and stores the state of units, gas flow, and electrical conditions of the ESP at all times. The distance between the collecting plates (1.95 m high and 2.915 m long) is adjustable from 300 mm to 700 mm. The four-plate spacings used in this study are 300, 400, 450, and 500 mm. As shown in Fig. 2, three types of discharge electrode, RT(retangular), ST(saw type), and TP(twisted pin and pipe) were used. The discharging electrode is located in the center position between the electrode plates. For the case of ST type, the discharge points are toward the collecting plate. The high voltage power supply (-100kV/20mA) is connected to the discharging electrode frame.

The pilot system consists of a particle feeder, a two-fields ESP, and a measurement system. Throughout the experiment, coal fly ash particles of a polydisperse size distribution produced by the screw feeder and swirl generator were used to provide a dust loading of 0.5-10 g/m^3 at the inlet of the precipitator. The typical size distribution of the coal fly ash particles, used in this experiment, was in the range from 0.1 to 20 micron. Particulate chemical characteristics were not variables in this program and the resistivity was about $6\times10^{12}\,\Omega$-cm. The velocity and temperature of gas were measured by pitot tube and K-type thermocouple, respectively. All experiments were carried out at 120℃ gas temperature an atmospheric pressure. A mean gas velocity of 1.2 m/s is maintained through the ESP. In this experiment, the particle mass loading at ESP inlet was kept constant at 5g/m^3.

The most important measurements made during the test program were particle size and concentration. The particle concentration and size distribution before and after the precipitator are measured using

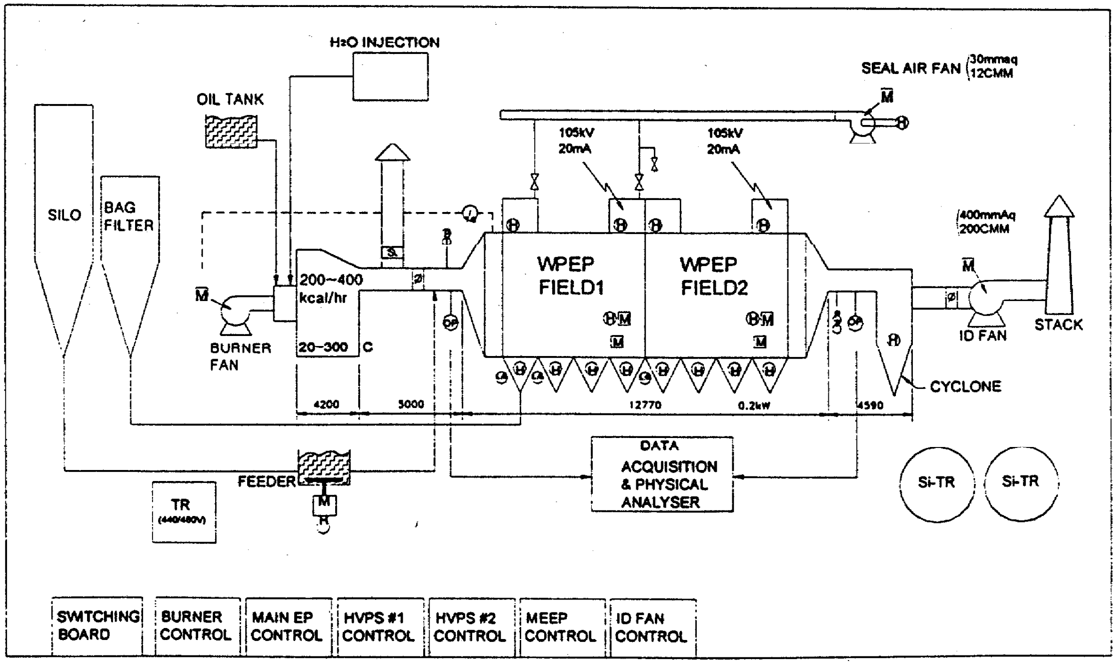

Fig. 1 Schematic diagram of the pilot wide spacing ESP

Table 1 Specification of the pilot ESP

Description	Specification
Type	Dry, Horizontal Gas Flow
Plate Height	1,950 mm
Plate Spacing	300 - 700 mm
Number of Fields	2
Number of Gas Passages	1 - 2
Plate Length(1 Field)	2,915 mm
Nominal Flow Rate	180 m^3/min
Nominal Gas Velocity	1.2 m/s
Nominal Gas Temperature	120℃
Discharge Electrode Voltage	- 105 kV
Discharge Electrode Current	20 mA

aerodynamic particle sizer (APS, TSI Inc. Model 3310). The APS is capable of measuring not only the total concentration by the particle size distribution over thirty different classes at the size range from 0.5 to 30.0㎛. The particle collection efficiencies were estimated by the APS data at upstream and downstream of the ESP. The average of three consecutive inlet and outlet samples is used to obtain the collection efficiency.

RESULTS AND DISCUSSIONS

Electrical Characteristics

The simplest of the electrical characteristics of ESPs is the voltage-current (V-1) curve. The V-I curves for the single channel of first field of the pilot wide plate spacing ESP are plotted in from Fig. 3 to 4. Fig. 3 shows the summarized V-I characteristics for various collecting plate spacings under the gas load condition. From the results of Fig. 3, two things can be explained. One is that the narrower spacings

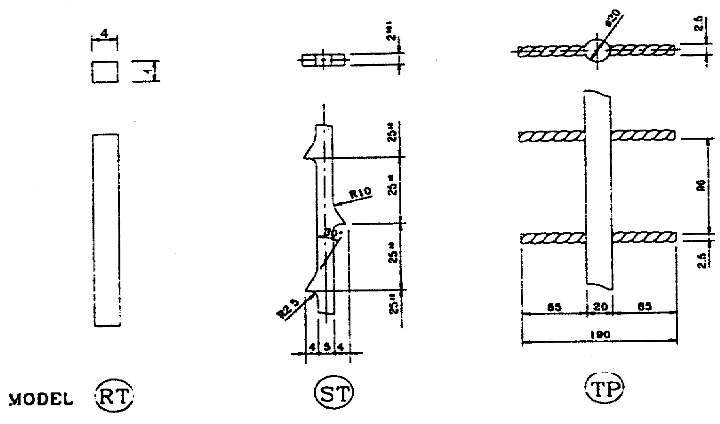

Fig. 2 Drawing of discharge electrodes

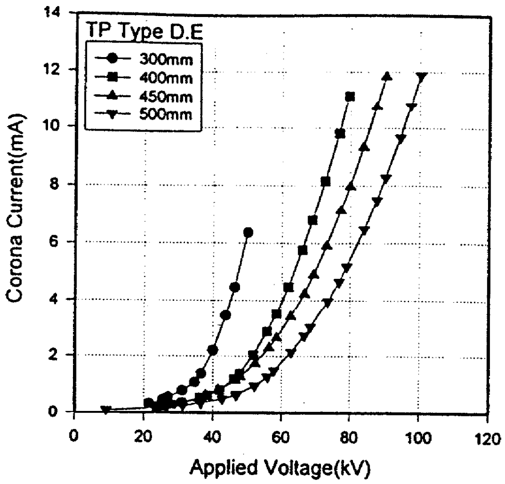

Fig. 3 V-I Curves for various plate spacings

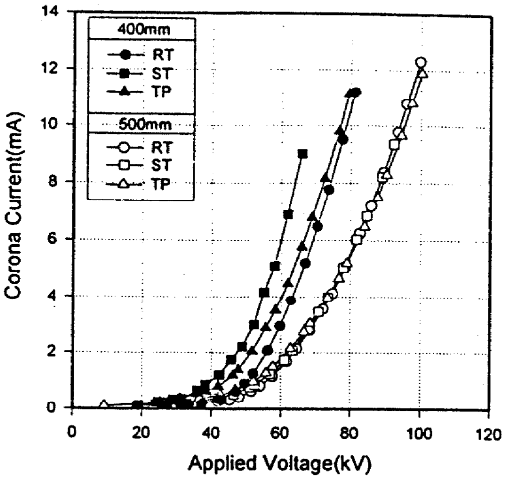

Fig. 4 V-I curves for various discharge electrodes at different plate spacing

of collecting electrodes, the lower corona onset and spark-over voltages. The other is that, the narrower spacings of collecting electrodes, the higher the occurrence of corona current at the same voltage. For this reason, the narrower spacing between the discharge electrode and the collecting electrode plate leads to the strong electric potential near the corona wire and generates the corona current easily.

Fig. 4 shows typical V-I characteristics of three types of the discharge electrode at 400 mm and 500 mm spacing. As shown in this figure, for the case of 400 mm spacing, RT and TP type electrodes have a lower corona onset voltage than ST type. Because the ST type electrode has sharper edge toward to collecting electrode to produce the corona, the ST has a much steeper V-I curve, whereas the rigid discharge electrode of TP has a relatively flat V-I curve. However, we can see from this figure that the V-I characteristics of three discharge electrodes nearly become similar for 500 mm spacing.

Collection Efficiencies

The experimental results of ESP collection efficiency are shown in from Figs. 5 to 8. In the

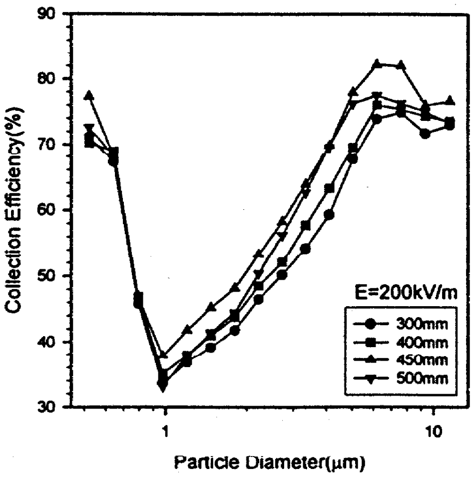

Fig. 5 Collection efficiency versus particle diameter for various plate spacings

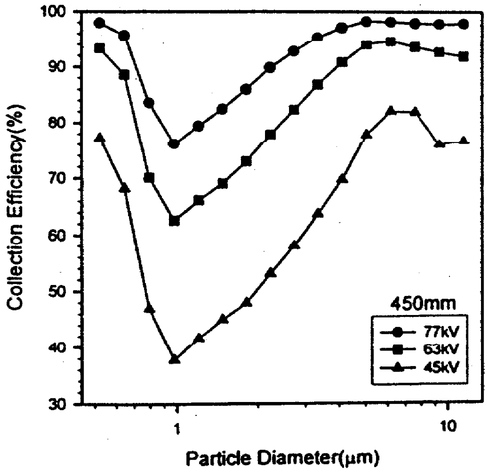

Fig. 6 Collection efficiency versus particle diameter for various applied voltages

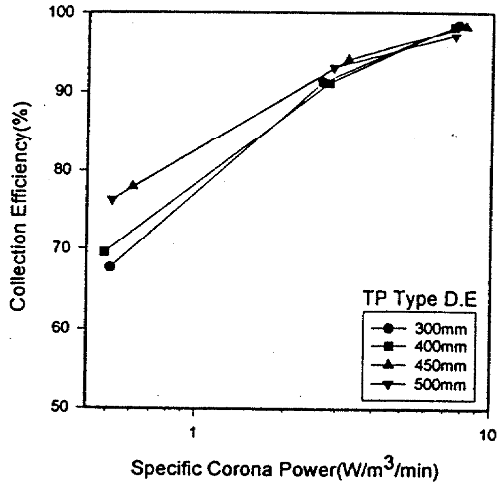

Fig. 7 Collection efficiency versus specific corona power for various spacings

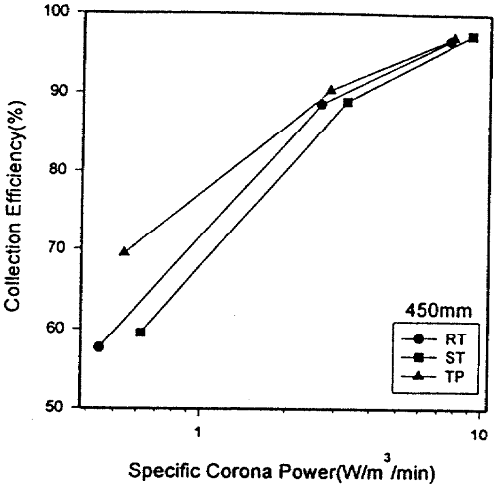

Fig. 8 Collection efficiency versus specific corona power for various discharge electrodes

experiments, the gas temperature is 120℃, the gas humidity is about 8.5 % in volume, the gas flow velocity is 1.2 m/s, and fly ash mass loading is 5 g/m³. First, the fly ash collection efficiency was measured under four different spacings at the same electric field condition of E=200 kV/m. Typical results for TP type discharge electrode are shown in Fig.5 for various particle diameters. Shown in Fig. 6 also are the collection efficiencies versus particle diameter for three different applied voltages of V=45, 63 and 77 kV with TP type discharge electrode at 450 mm plate spacing. As shown in Fig. 5, for a given dp and E, the difference of collection efficiencies between the plate spacings are not so much. However, the effect of V on the collection efficiency (Fig. 6) is prominent. For fixed dp, the collection efficiency is substantially increased with increasing V. The size dependent collection efficiency decreases with the particle size reaching a minimum at about the diameter of dp= 1μm, then increases with particle size.

One of the important checking parameters of an ESP performance involves the concept of specific corona power. Multiplying the mean voltage and current of operating precipitator section result in the corona power of ESP section. If the corona power(W) divided by the gas flow rate(m³/min), the result is the specific corona power in units of watts per m³/min. We obtained this relation by the measurement of ESP collection efficiency with three apply voltages for each plate spacing. Fig. 7 shows the collection efficiencies versus specific corona power for various spacings of plate distance with TP type discharge electrode for a case with particle diameter dp=5μm. As expected, ESP collection efficiency increases with increasing specific corona power. It can also be found from Fig. 7 that the higher collection efficiencies with wide plate spacing for a given corona energy are obtained which imply an appreciable energy savings in fixed costs by using the configuration of wide plate spacing. The data obtained in the tests (Figs. 5 and 7) show that the best collection efficiency are achieved for a plate spacing of 450 mm. Fig. 8 shows the effect of discharge electrode shape on the particle collection efficiency for single plate spacing of 450 mm. As shown in this figure, for the plate spacing of 450 mm, the best collection efficiency is achieved for the rigid TP type discharge electrode.

CONCLUSIONS

Useful data for the design and operation of wide plate spacing ESP have been developed by means of parametric tests to find the optimum combinations of plate spacing and discharge electrode shape that maximize the performance. The main conclusions of the present work clearly indicates that the significant increase of the precipitation efficiency can be obtained with a special design of discharge electrode and wide spacing of collecting electrode. If the wide plate spacing is optimized with discharge electrode configuration, it can give power saving and reduced emission. As a result of our pilot experiment, the best collection performance and energy saving are achieved at 450 mm spacing with TP type discharge electrode.

ACKNOWLEDGEMENTS

The Ministry of Environment of Korea has been supporting this research via the national G7 environmental engineering research program. KHIC(Korea Heavy Industries and Constructions Co.) are also gratefully acknowledged for their financial support.

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