PULSE ENERGIZATION ESP FOR FLYASH FROM FLUIDIZED-BED COMBUSTORS

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Abstract

The electrical resistivity of the flyash from fluidized-bed combustors is very high and the precipitation performance is very poor with conventional energization techniques. Sumitomo Heavy Industries, Ltd. has conducted laboratory and demonstration tests with Sumitomo's pulse energization system for this application in cooperation with the Electric Power Development Co., Ltd. Basic design data are obtained from the 50MW atmospheric fluidized-bed combustor demonstration plant at Wakamatsu Power Station, Electric Power Development Co., Ltd. Results of the tests show that pulse energization ESP achieves a much higher performance than the conventional method, and thus pulse energization will be applied to the first commercial 350MW AFBC installation in Japan. The electrical resistivity of AFBC flyash ranged from 10^{12} to 10^{13} Ω-cm for most coal brands; Chinese, Australian and Japanese. This is because limestone was added to the bed for desulfurization and the calcium composition in the ash became extremely high. Sumitomo's pulse energization precipitator achieved a much better precipitation performance than that of conventional energization; twice the modified migration velocity (ω_k) compared to that of the conventional direct current method which suffered from severe back corona.

Introduction

The severest problem for electric precipitators is that the performance drastically decreases when the resistivity of flyash is very high and back corona occurs on the collecting electrodes. In the recent past, a new energization technique was developed to prevent the occurrence of back corona and improve precipitation performance for high resistivity dust applications such as pulverized coal fired boiler flyash and cement kiln exhaust gas (1), (2). It can adjust corona current by variation of pulse repetition frequency to inhibit back corona, and attain uniform corona discharge.

Recently, atmospheric fluidized-bed combustion, which can reduce NO_X and SO_X emission, has received much attention from the point of global environmental protection. Limestone is added to the bed to reduce SO_X emission. However, the electrical resistivity of AFBC flyash is extremely high because it contains substantially more limestone powder than that of a pulverized coal fired boiler (3). Up to now, fabric filters have been commonly used for AFBC flue gas dedusting.

Tests for improving precipitability were conducted by adopting pulse energization techniques which were recently developed for high resistivity dusts. First, the basic characteristics of the pulse energizer were examined in comparison with intermittent and direct current energization by a pilot scale ESP at the Hiratsuka Laboratory of Sumitomo Heavy Industries, Ltd. Then, pulse ESP demonstration tests were conducted at the 50MW AFBC demonstration facility at Wakamatsu Power Station.

Results from these tests indicated that the size of the ESP using a pulse energization system for AFBC flyash can be about half of that required by the conventional energization technique.

Particle Characteristics

The size distribution, chemical composition and electrical resistivity of the flyash particles from Wakamatsu AFBC demonstration facilities were examined.

Size Distribution and Shape. The mass median diameter of flyash from a fluidized bed combustor in which flyash captured by a mechanical collector is re-circulated is several μm, finer than flyash from a pulverized coal fired furnace. However, the size is about the same if a mechanical collector is not used. The shape of the particles was examined with a scanning electron microscope (Figure 1). There is a difference in the burning mechanism and flame temperature between a pulverized coal furnace and a fluidized bed combustor. Therefore, particles generated in a fluidized bed combustor are irregularly-shaped whilst pulverized coal flyash is mostly spherical. This suggests that special consideration is necessary with regard to rapping performance to avoid unusual adhesion onto the collecting electrodes.

Chemical Composition. Limestone is added to the bed as a SO_2 sorbent in fluidized bed combustors and the CaO content of the flyash generated is higher than that of pulverized coal furnace flyash. The CaO content of fluidized bed combustor flyash was 10 to 30 % which is several times that of the usual pulverized coal furnace flyash. There was no significant difference in CaO content between dust collected at the inlet and outlet hoppers of the demonstration ESP. It was also found that flyash from fluidized bed combustors has a higher carbon-in-ash content than pulverized coal furnace flyash. A chemical analysis was made for more than 20 samples of flyash and the carbon content was found to vary substantially; from 6 to 27 %. The carbon-in-ash content is largely affected by the fuel type and burning conditions. The carbon content of dust collected at the inlet hopper was found to be higher than that of the outlet hopper of the demonstration ESP. The ratio of carbon content in the inlet dust to that in the outlet dusts for each coal brand was about 1 to 2. This means that unburned carbon is likely to be collected at the inlet section of the ESP because of its good precipitability.

Electrical Resistivity. Resistivity of the dust generated by the fluidized bed combustors was found to range from 10^7 to 8×10^{12} Ω–cm. The value of resistivity changed according to the hopper location; the dust resistivity of the inlet hopper was often lower than that of the outlet hopper because unburned carbon was selectively collected at the inlet section of the ESP. For this type of flyash, ESP performance is governed by the characteristics of the dust collected at the outlet section even if the overall dust resistivity is low. Therefore, the resistivity of the dust at the outlet must be estimated to evaluate ESP performance. Figure 2 shows the outlet dust resistivity for boiler startup and constant load. It can be seen that the resistivity is very high, in the range of 10^{12} to 10^{13} Ω – cm for most cases, although it differs with regard to boiler conditions and fuel type. It is well known that ESP performance will be very poor for this range of dust resistivity because severe back corona will occur if a conventional energization system is adopted.

Problems of Conventional Energization

In general, ESP performance using conventional energization is very good for flyash with resistivity less than around 5×10^{10} Ω–cm, however performance decreases as resistivity becomes higher because the electric field in the dust layer becomes too high and electrical breakdown occurs at some point on the collecting electrode surface. At higher resistivity than 10^{12} Ω–cm, severe back corona occurs at many points on the collecting electrodes and finally effective precipitation ceases at very high resistivity. This is because the positive ions produced by the electrical breakdown neutralize the negative ions and charged particles.

The resistivity of flyash from fluidized bed combustors is within the range of severe back corona occurrence, and thus precipitation performance is very poor. Therefore, the best solution for fluidized bed combustors has been to use fabric filters. The pulse energization system was tested to ensure that this system is also effective for fluidized bed combustor flyash precipitation.

Pulse ESP Performance

Pulse Energizer

Figure 3 shows a typical basic pulse energization circuit for commercial use (3). Sumitomo's pulse energizer achieves 100 µs pulsewidth using unique solid-state thyristor switching and L-C oscillation.

Pulse width. Today, pulse widths from nanoseconds to microseconds are developed for commercial use(4). As for the nanosecond pulse, the positive and negative ions that are generated in the active corona plasma are not likely to move away from the place that they are generated. There exist no corona quenching effects because the number of positive and negative ions are equal. Hence, the nanosecond pulse generator is applied more for chemical reactions to remove SO_X and NO_X than for dedusting. On the other hand, in the case of the microsecond pulser, the positive ions move towards the discharge electrodes and are neutralized so only negative ions exist. This space charge prevents corona plasma expansion towards the collecting electrodes, therefore uniform and intense corona discharges can be obtained. This suggests that the microsecond order pulse is the most effective for precipitation.

Principal Characteristics of the Sumitomo Pulse-Energizer. The basic circuit of the Sumitomo pulse-energizer is shown in Figure 4. This circuit works as follows;
The positive DC voltage source charges the coupling capacitor and the capacitance of the precipitator (series connected). When this condition is achieved, the thyristor closes the L-C oscillation loop, and one cycle of L-C oscillation is initiated. In the first half cycle of the oscillation, the oscillation current flows from the positive charged series connected capacitors to ground through the thyristor, and in the following half cycle, the oscillation current flows back from ground through the diode. This one cycle oscillation gives one single voltage pulse to the precipitator. Figure 5 shows the voltage and current waveforms at the points indicated in Figure 4. Pulse width is given by the equation : $2\pi\sqrt{LC}$, where L is the inductance of the resonant coil and C is the series composite capacitance of the coupling capacitor and the precipitator. This system has been patented and its features are as follows;

- The system does not use a pulse transformer as a storage capacitor in the L-C oscillation circuit. A thyristor switch is used to switch the high voltage L-C oscillation loop instead of using a gap switch, which is used in some other types of pulse energizer. Therefore, this system is much simpler and shows stable characteristics over a long period of operation.
- Pulse waveforms having a constant pulse width (100 µs) are featured with sufficiently rapid rise and decay.

- The energy used to charge up the precipitator capacitance to peak pulse voltage is recovered as part of the stored energy of the coupling capacitor during L-C oscillation. Therefore this system is called an energy recovery type pulse energizer, as it achieves energy saving.

- The system is equipped with a base voltage generater and a pulse energizer. Therefore base voltage, pulse voltage and pulse repetition frequency can be controlled independently to their optimum values under every operational condition of the precipitator according to change of fuel and boiler loading.

Now, pulse energization is often compared with intermittent energization, which has been utilized widely. Figure 6 shows a comparison of these waveforms. The waveforms of intermittent energization are very different from those of pulse energization and are regarded as a variation of periodically controlled DC energization. Intermittent energization is utilized to reduce power consumption rather than to improve precipitation performance.

Pulse-ESP Performance

At first, laboratory tests were conducted at Hiratsuka laboratory to confirm that pulse energization is also effective for AFBC flyash. The precipitation performance with direct current, intermittent current and pulse energization were examined. Then the pulse-ESP demonstration test was performed at the 50MW AFBC demonstration facility at Wakamatsu power station. based on the laboratory test results.

Figure 7 shows the comparison of migration velocity for the laboratory ESP for direct current, intermittent current and pulse energization. Only the inlet gas temperature was changed to change the ash resistivity and to make other factors that affect ESP performance uniform for the same coal brand. In the case of direct current and intermittent energization, the value of migration velocity tends to decrease drastically as the temperature goes up. However, the precipitation performance with the pulse energization system did not change substantially throughout the temperature range and showed a quite high efficiency. The efficiency was expressed by the modified migration velocity; ω_K.

$$\frac{C_o}{C_i} = e^{-(\omega_k A / Q)^k}$$

where C_i : Inlet dust loading
C_o : Outlet dust loading
ω_K : Modified migration velocity
A : Collecting area
Q : Gas flow rate
k : constant

The performance enhancement is expressed by the factor H_k which is the ratio of migration velocity of pulse energization vs that of conventional direct current energization.

$$H_k = \omega_K(\text{pulse}) / \omega_K(\text{DC})$$

where $\omega_K(\text{pulse})$: migration velocity for pulse energized case
$\omega_K(\text{DC})$: migration velocity for DC energized case

From Figure 7 it can be seen that the value of H_k ranges from 1.4 to 2.0 , i.e., the size of the ESP using pulse energization would be only two-thirds to half of that using conventional DC energization. Though, in the case of intermittent energization, the migration velocity varied largely and in some cases ω_K was less than that of DC energization. The maximum value of the enhancement factor for intermittent energization was about 1.2. Therefore pulse energization is the most effective for the fluidized bed combustor flyash considering that the composition and the resistivity of the dust could be varied widely.

At Wakamatu power station, the precipitator performance was tested using pulse energization and conventional direct current energization by introducing actual AFBC gas from the AFBC demonstration facility. Figure 8 shows typical test results. The performance enhancement factor; H_k was in the range of 1.4 to 3.0. The value of H_k increased as ash resistivity became higher and the precipitation performance for AFBC flyash was greatly improved with pulse energization. This is because the performance of DC energization decreased markedly as the resistivity became higher, whilst that of pulse energization did not change a great deal. During the test with conventional DC energization, severe back corona was observed. Evidently, this means that pulse energization prevents back corona even in the severest conditions.

Special consideration required for AFBC flyash

The value of the electrical resistivity of AFBC flyash is extremely high, up to 10^{12} or 10^{13} Ω-cm. As mentioned previously, severe back corona will occur and performance will decrease drastically with conventional energization for AFBC flyash. Therefore, the most important and inevitable choice is to adopt the pulse energization system in order to prevent back corona. The electrical resistivity changes greatly because the value of carbon-in ash for AFBC flyash changes largely with coal type and burning conditions. It is essential to estimate the minimum value of predicted carbon-in-ash to decide the SCA required for actual application. Because of the angular shape of the particles, special consideration must be given to the rapping procedure to avoid unusual dust adhesion onto the electrodes.

Application of Pulse ESP for the First Commercial 350MW AFBC

In accordance with the results of the demonstration tests at Wakamatsu power station, the decision was made to adopt a pulse-energization ESP for the first commercial 350MW AFBC at Takehara power station #2, Electric Power Development Co., Ltd. The principal specifications of the ESP are as follows;

Gas flow rate	:	1,056,700	m^3N/h
Gas temperature	:	140	°C
Collecting efficiency	:	99.14	%

The size of the designed pulse ESP is about one half of that which would be required for conventional energization.

Conclusion

Up to now, the precipitability of AFBC flyash has been considered to be very poor because of high ash resistivity. Through laboratory and demonstration tests, the effectiveness of the new technique of energization was confirmed, e.g., the Sumitomo pulse energization ESP achieved outstanding performance.

This paper summarizes;

- AFBC flyash characteristics as regards size, shape, dust resistivity and the problems of conventional energization.
- Principal characteristics of the Sumitomo pulse energizer
- Pulse-ESP performance
- Application of pulse ESP for the first commercial 350MW AFBC

References

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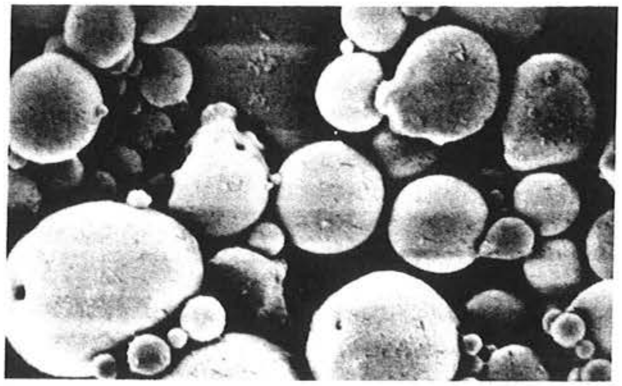
3. Ralph F. Altman. "Electrostatic precipitation of dust from fluidized-bed combustors and furnace solbent injection processes" Proc. 4th Int. Conf. on Electrostatic Precipitation, Beijing, China (September 1990)
4. Herbert J. Hall. "History of pulse energization in electrostatic precipitation" Journal of Electrostatics. 25, p. 1 (1990)

Flyash from fluidized bed combustor
Plant : Fluidized bed combustor demonstration facility
Fuel : Chinese coal



Flyash from pulverized coal furnace
Plant : 500MW coal fired boiler
Fuel : Australian coal

Figure 1. Particle shapes of flyash from FBC and pulverized coal furnace

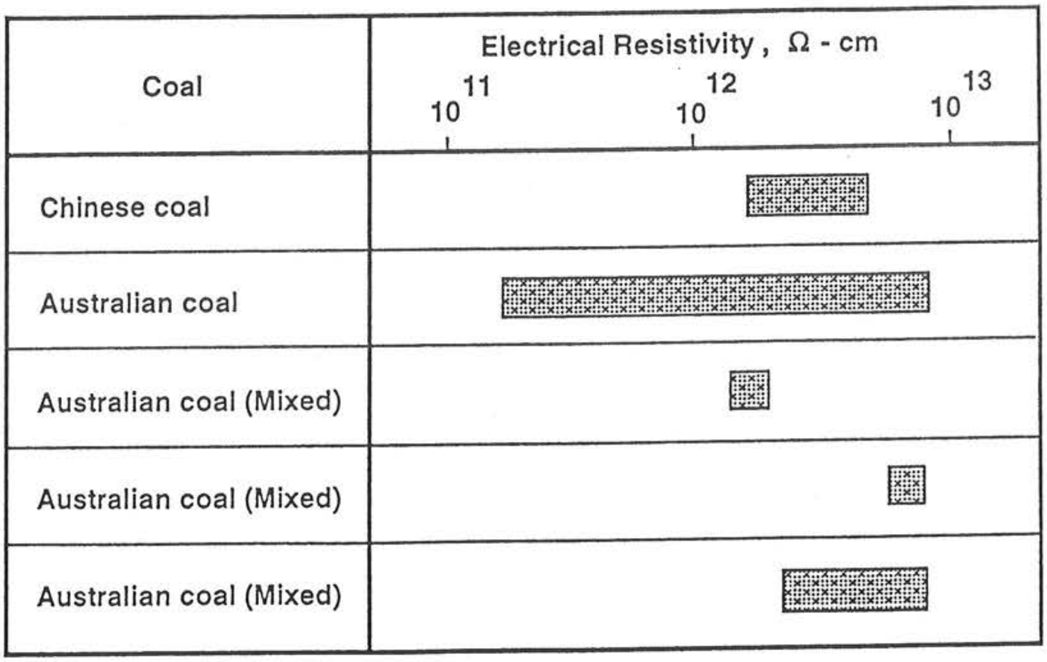
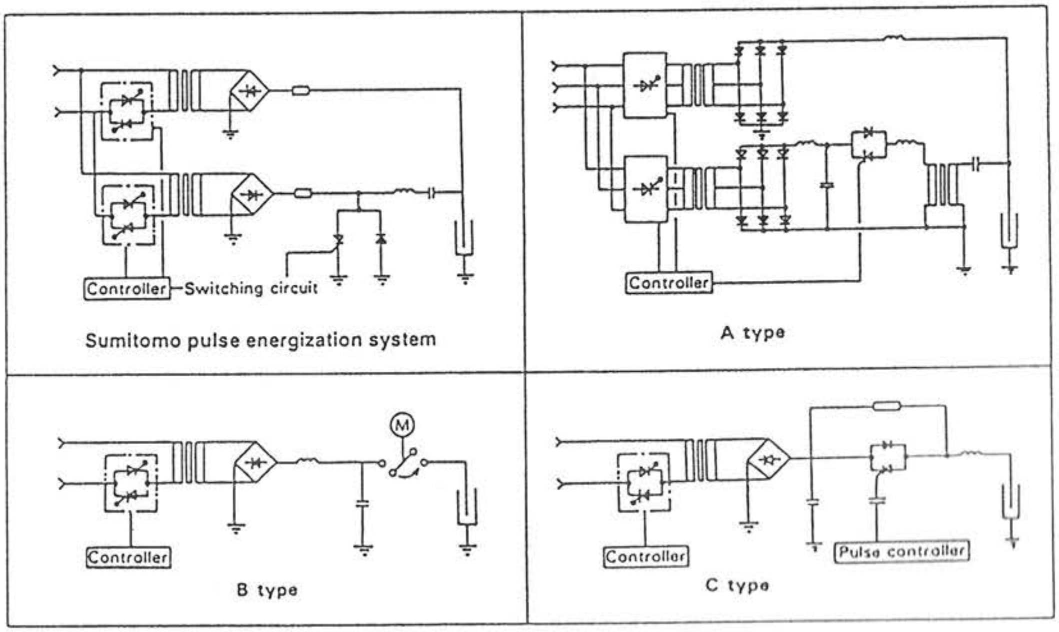


Figure 2. Electrical resistivity of FBC flyash for each coal brand



Sumitomo pulse energization system

A type

B type

C type

Figure 3. Typical pulse energization systems

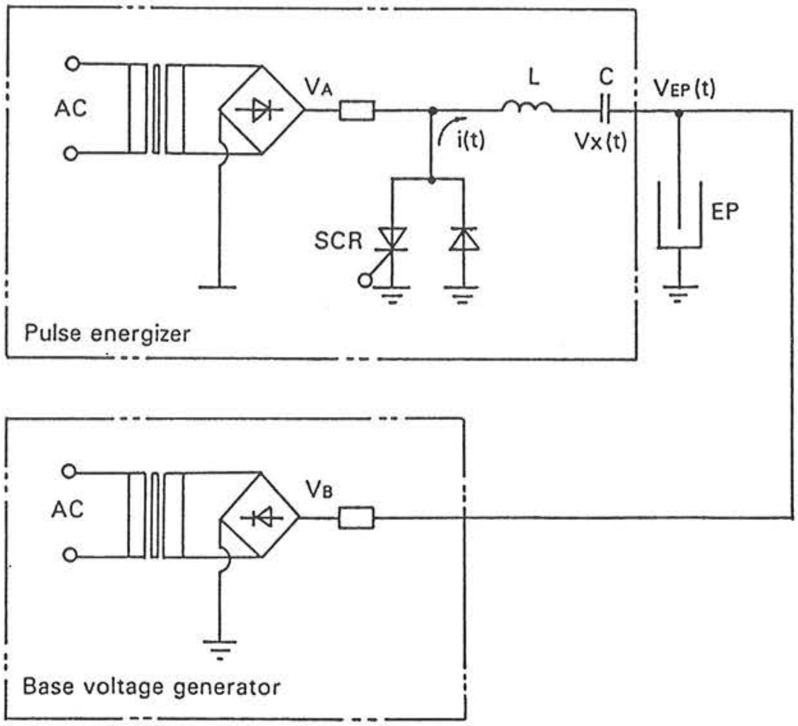


Figure 4. Basic circuit of pulse energizer

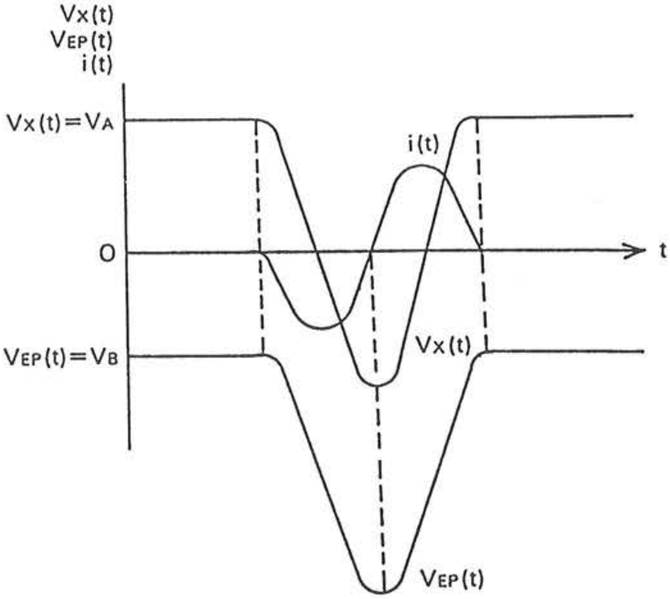


Figure 5. Voltage and current waveform of basic circuit

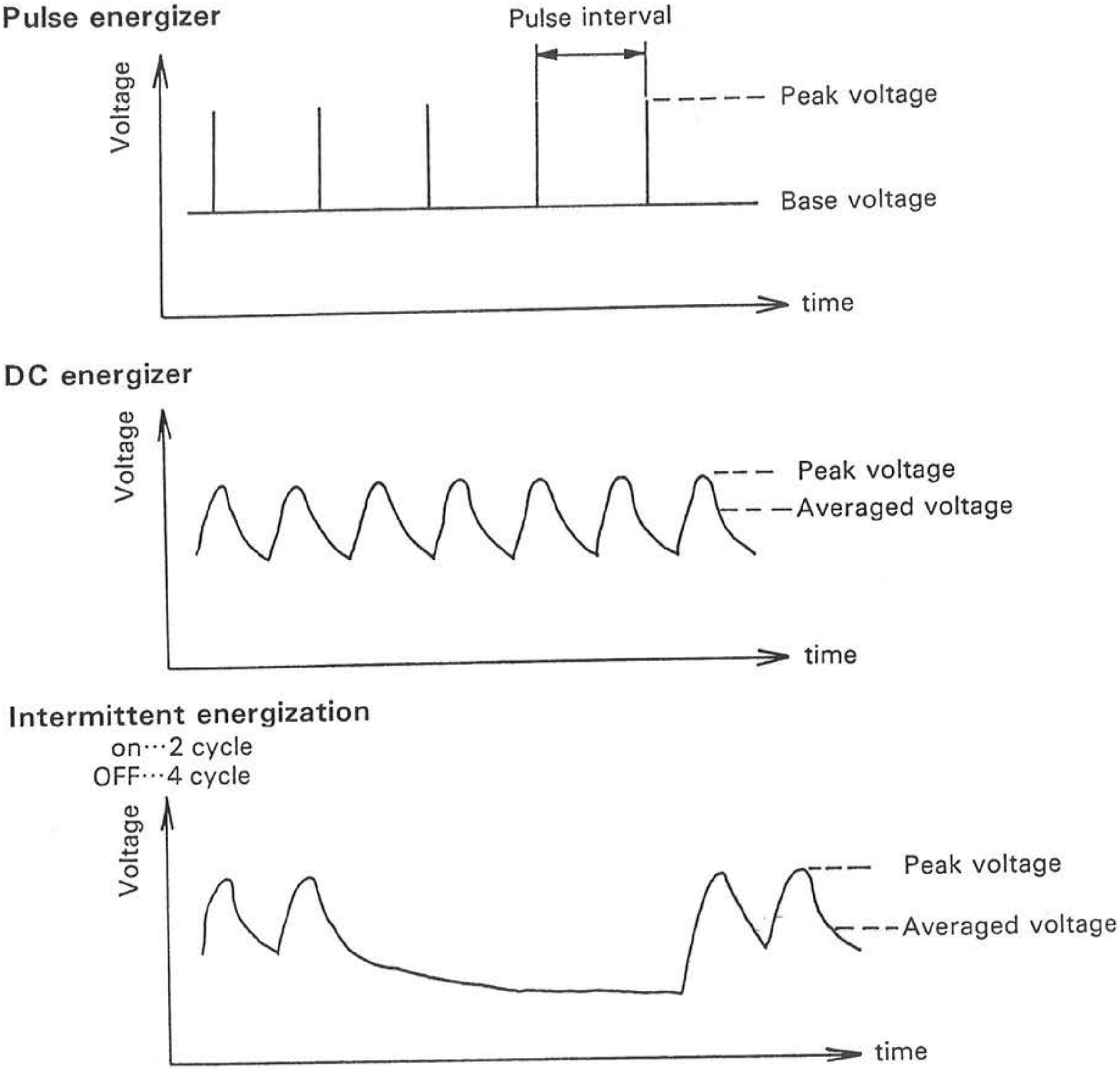
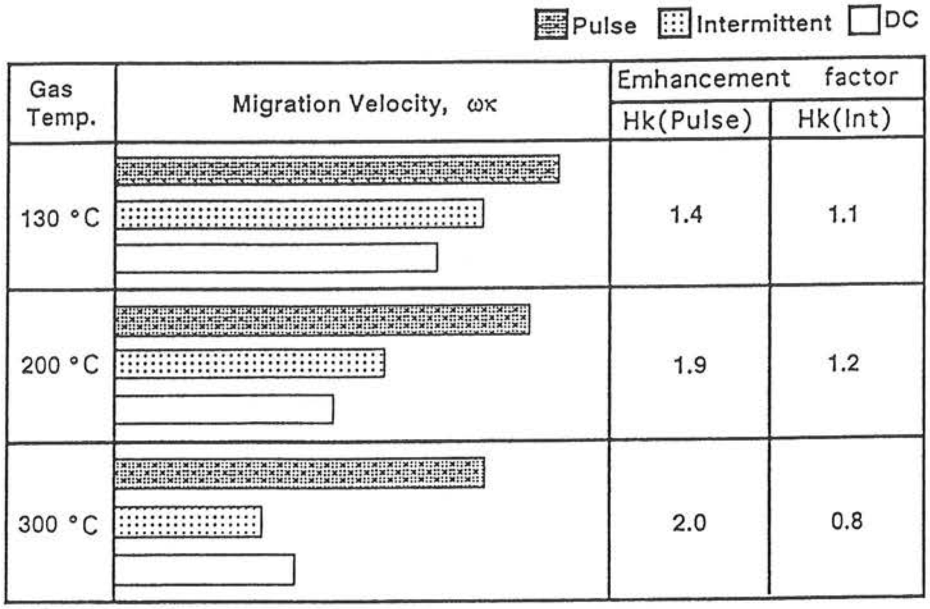


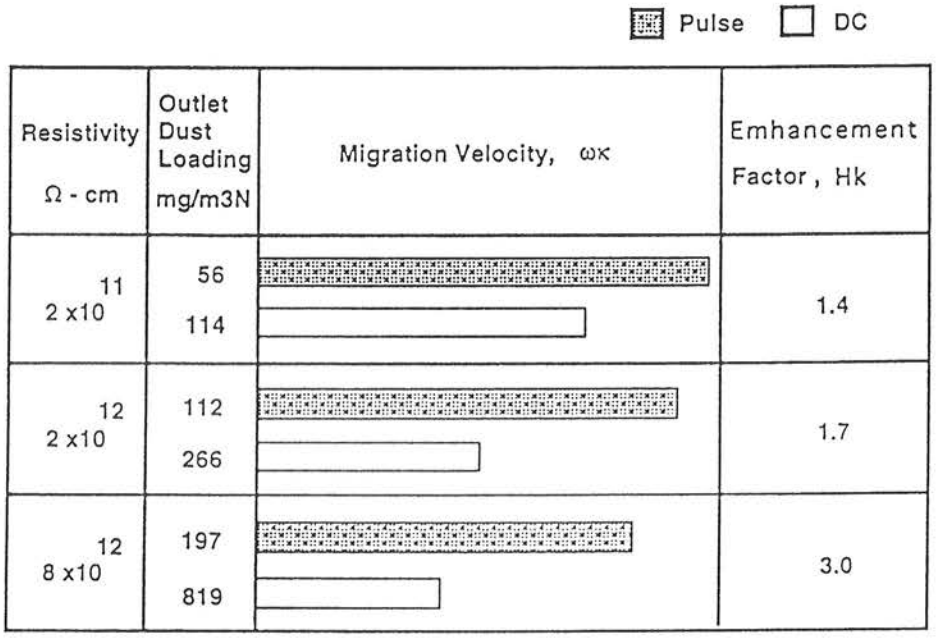
Figure 6. Comparison of ESP voltage waveforms



▨ Pulse ▦ Intermittent ☐ DC

Gas Temp.	Migration Velocity, ωκ	Emhancement factor	
		Hk(Pulse)	Hk(Int)
130 °C		1.4	1.1
200 °C		1.9	1.2
300 °C		2.0	0.8

Figure 7. Migration velocities by pulse energization and intermittent energization



▨ Pulse ☐ DC

Resistivity Ω - cm	Outlet Dust Loading mg/m3N	Migration Velocity, ωκ	Emhancement Factor , Hk
2×10^{11}	56 114		1.4
2×10^{12}	112 266		1.7
8×10^{12}	197 819		3.0

Figure 8. Enhancement factor, H_K by pulse energization