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論　文

Laboratory Study on Time and Polarity Dependent Change in Fly Ash Resistivity at Hot Side ESP Temperature

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This paper reports the results of laboratory experiments to test the hypothesis of the formation of high resistivity in fly ash by the electrical depletion of the sodium carrier ions. Both laboratory resistivity cells and wire to plate corona systems were used in these investigations. The experiments showed that the resistivity of a fly ash layer could be increased by the sustained flow of current through the layer and further, that this process can be reversed with a polarity reversal on the corona system. These experiments fully supported the hypothesis of sodium depletion causing the development of high resistivity limited performance in a class of hot side ESP's.

1. Introduction

During an initial research project to define the cause of substandard performance in a group of hot side precipitators, we developed a hypothesis for the formation of a high resistivity residual layer on the collection electrodes caused by the depletion of the electrical carrier ions, principally sodium, in this layer, as reported in the first one[1] of the four series of reports.[1-3] We then tested this hypothesis in the laboratory in an attempt to identify the mechanisms for this development and to seek solutions for this problem. This paper reports the results obtained by this laboratory study, and represents the second of the above series of reports.

2. Test of Sodium Depletion Hypothesis Using Resistivity Cell

The hypothesis was first tested using an ASME*1 Power Test Code #28 resistivity cell (Fig. 1). A 3 mm layer of fly ash with an initial resistivity of about 1×10^9 $\Omega\cdot$cm was added to the cell. A voltage was impressed across the cell to yield a current density of about 100 nA/cm^2 (thirty volts). The current versus time was monitored for a period of 140 hours. The results of this experiment are shown in Fig. 2. This experiment was conducted in an air environment at a temperature of 350°C. This experiment provided evidence confirming the hypothesis of sodium depletion.

It was recognized that this experiment did not duplicate the electrical environment in an operating precipitator, in that no corona current was involved and that the ash layer remained in the cell. However, the increase in resistivity with time (indicated by the decrease in current at a constant voltage) was supportive of the hypothesis of carrier depletion. The sodium ions that were electrically transported from the positive electrode to the negative electrode[4] would lead to an increase in the resistivity of this remnant layer.

3. Test of Sodium Depletion Hypothesis Using Corona System

This hypothesis was further tested using a corona system to simulate electrostatic precipitator operation. The test consisted of an experiment where an ash layer was subjected to a continuous flow of corona current over a several day period to determine if a sodium carrier depletion such as was conjectured

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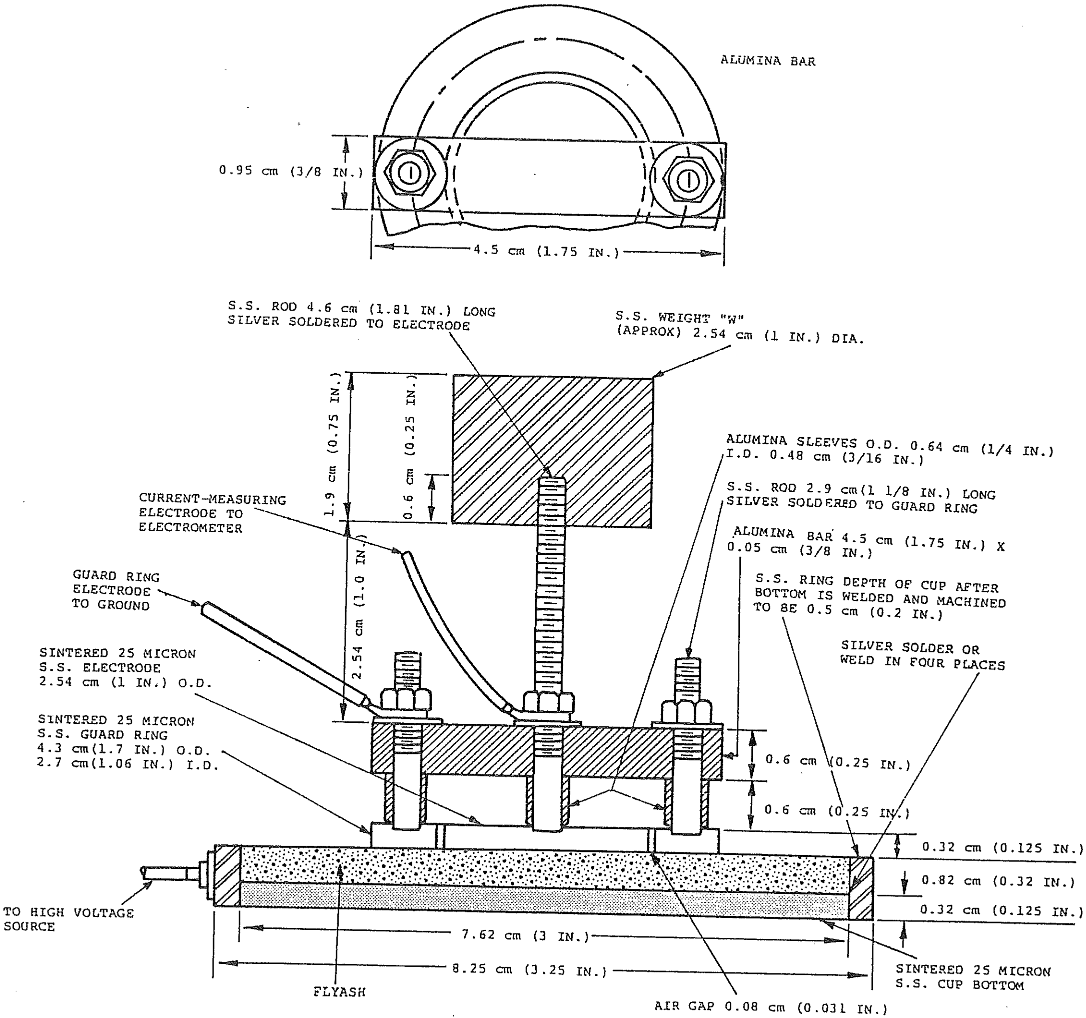

Fig. 1 ASME Power Test Code #28 resistivity cell.

Notes:
1. All electrode surfaces in the region of the ash layer shall be well rounded to eliminate high electrical field stresses. Electrode surfaces shall be flat.
2. Weight "*W*" sized to make pressure of upper electrode and guard ring equal 10 g/cm^2.
3. All threads No. 6-32.
4. All metal parts of stainless steel (S.S.) type 304 or equivalent.
5. All alumina parts >99.0% alumina (Al_2O_3).

above could be observed. A small wire-to-plate electrostatic precipitator as shown in Fig. 3 was constructed. The system was installed in an oven maintained at a temperature of 350°C. First, a clean plate voltage vs. current curve was obtained for the wire and plate precipitator. Then a 5 mm layer of fly ash (chemical analysis given in Table 1) was deposited on the plate. A voltage vs. current curve was then obtained for the system with the newly deposited layer. These voltage vs. current curves are shown together with the subsequent data in Fig. 4. The resistivity of this new layer was determined for the ratio of the electric field to the current density ($\rho = E/j$) to be 4.6×10^{11} $\Omega \cdot$cm.

This experiment was continued for a period of 192 hours with an average current density of 15 nA/cm^2. During this time, voltage vs. current curves were obtained. The electrical

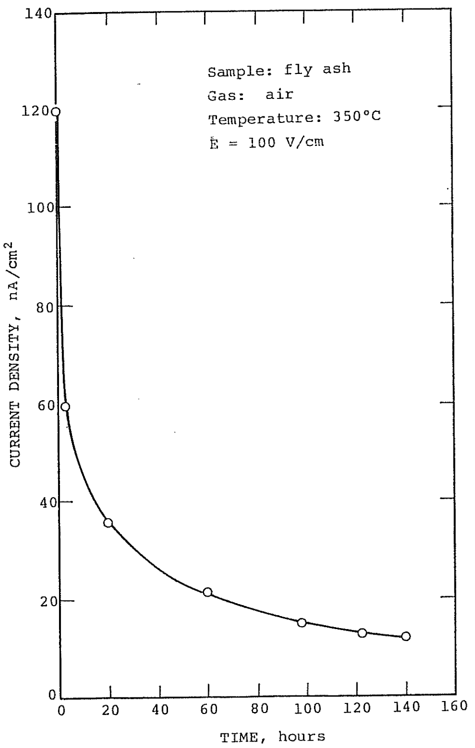

Fig. 2 Attenuation of current density with time of continuously applied direct current voltage (parallel plate resistivity test cell; see Fig. 1).

characteristics continued to shift to the right indicating an increase in the electrical resistivity of the ash layer. At the end of the test period a final voltage vs. current curve was obtained. This is shown as Curve B of Fig. 4.

The effective resistivity of the dust layer as determined from the voltage vs. current curve at the end of the negative corona test period was about 6×10^{12} Ω•cm. Therefore, during the 192 hour test period, for an average current density of 15 nA/cm^2, the effective resistivity of the 5 mm dust layer had increased from a value of 4.6×10^{11} Ω•cm to about 6×10^{12} Ω•cm. Concurrent with this increase in resistivity it is to be noted that Curve B is also indicative of the development of a back corona characteristic at an average current density of about 2 nA/cm^2. These data support the hypothesis of electrical carrier depletion in the dust layer.

If the depletion hypothesis were correct, then a polarity reversal of the corona system would be expected to move the electrical carriers back into the depleted zone causing a reversal in the resistivity characteristics previously observed. This was tested over somewhat shorter periods of time than was used in the degradation portion of the experiment.

For this period, the corona wire power supply was converted to a positive polarity.

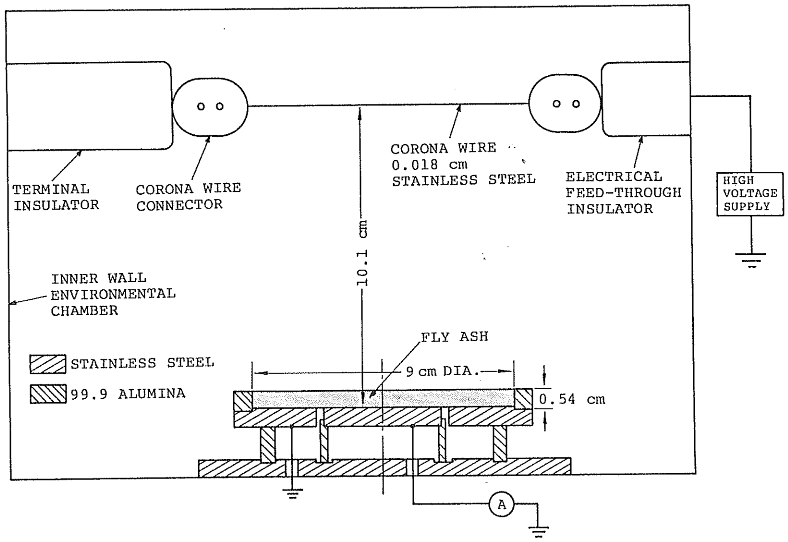

Fig. 3 Schematic and electrical circuit diagram for wire-plate corona discharge device.

Table 1 Fly ash chemical analysis.

Chemical	Per cent	Chemical	Per cent
Li_2O	0.02	Al_2O_3	23.7
Na_2O	0.29	SiO_2	51.9
K_2O	1.8	TiO_2	1.3
MgO	3.6	P_2O_5	0.39
CaO	8.6	SO_3	1.2
Fe_2O_3	5.9	Undetermined	1.3

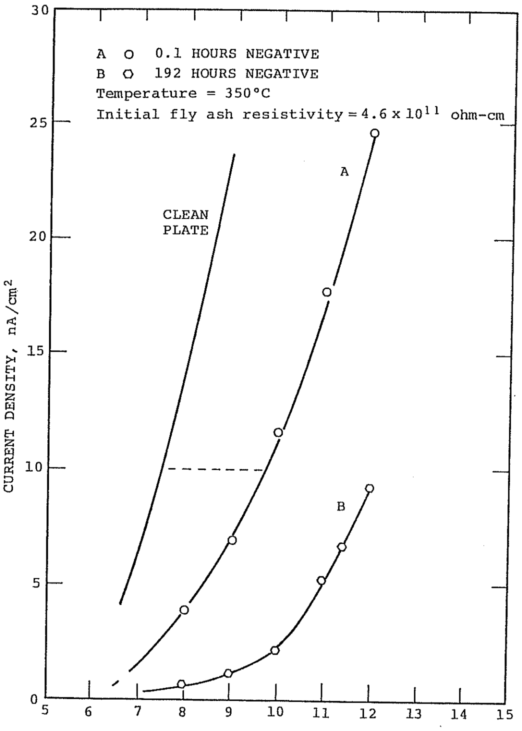

Fig. 4 Current density as a function of applied negative voltage (wire-plate corona discharge device; see Fig. 3; 15 nA/cm²).

The initial positive polarity voltage vs. current characteristics, along with subsequent data are shown in Fig. 5. Curve C represents the initial positive polarity voltage vs. current curve taken after a 192 hour period of negative corona at a current density of 15 nA/cm².

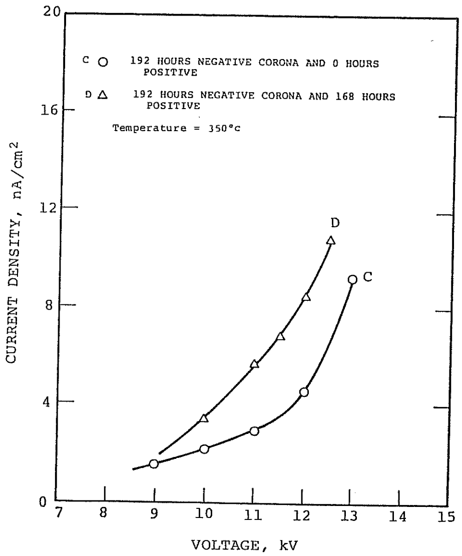

Fig. 5 Current density as a function of applied positive voltage (wire-plate corona discharge device; see Fig. 3; 15 nA/cm²).

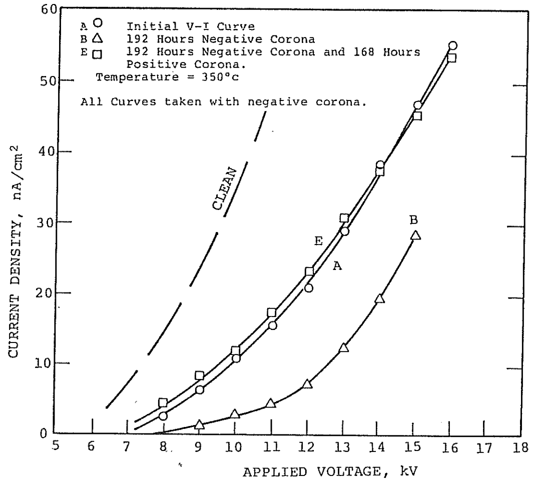

Fig. 6 Influence of corona polarity reversal on current density vs. voltage curves (wire-plate corona discharge device; see Fig. 3).

A positive polarity corona current of 15 nA/cm² was then passed through this dust layer for a period of 168 hours. The final voltage vs. current characteristics for positive polarity are shown as Curve D of Fig. 5. Note the significant reduction in resistivity indicated by the shift of the curve to the left.

At this time, the system was switched back to negative polarity to determine if the dust layer resistivity had been restored to its initial values. Figure 6 shows the clean plate negative characteristics; the initial characteristic with the dust layer (Curve A); the characteristic after 192 hours of negative corona at a current density of 15 nA/cm^2 (Curve B); the negative characteristic after the 192 hours of negative corona current followed by 168 hours of positive polarity corona current (Curve E). It is to be noted that the similarity between Curves A and E suggest that the ash resistivity had been essentially returned to the initial value.

4. Conclusion

These experiments provided sufficient evidence to support the hypothesis of the development of a high resistivity residual layer in the hot side precipitators that exhibited substandard performance. The parallel plate experiment clearly showed that the resistivity of a fly ash layer increased with time with current flow. The corona system verified these findings and further showed that a reversal in the direction of current flow would restore the resistivity to near its initial value. These experiments provided the basis for continued work in full scale installations for the final verification of the hypothesis.

References

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