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論　文

Sodium Conditioning Tests to Combat the Time Dependent Performance Degradation in Hot Side ESP

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This paper concludes the series of four papers that describe a research program that was conducted to find a solution to the time dependent performance degradation in certain hot side electrostatic precipitators. This paper describes a detailed field test to evaluate the addition of sodium bearing compounds to the coal prior to combustion to eliminate the formation of a high resistivity fly ash layer by the electrically induced migration of sodium carrier ions out of a thin residual layer on the collection electrodes. The result of this research is positive in that the mechanism for the formation of high resistivity was identified and sodium injection effectively eliminated the formation of this layer.

1. Introduction

Laboratory studies of the development of high resistivity limited performance in hot side ESP's have identified the cause for this degradation as sodium depletion within a residual dust layer on the collection electrodes.[2] From these data, an hypothesis was developed for a solution to this problem in full scale units. If a fly ash layer with increased sodium is deposited on the surface of the depleted layer, a sodium concentration gradient would be formed. At an operating temperature around 300°C, the thermally induced diffusion of sodium across this gradient is expected. This diffusion flow is in a direction opposite to that of migration of sodium ions in the electrical transport. These two competing transport mechanisms will come to equilibrium after a period of time. This equilibrium condition is expected to occur with a sufficient number of sodium ions adjacent to the collection electrode to avoid the formation of a high resistivity layer.

This concept was first tested at the Lansing Smith Station of Gulf Power near Panama City, Florida, U.S.A. It has been utilized subsequently at other stations. The Lansing Smith tests were the most comprehensive tests conducted of this concept. This research project, funded jointly by the Particulate Technology Branch of the U.S. Environmental Protection Agency, The Electric Power Research Institute and the Southern Company Services, was designed to evaluate this concept in detail. The results of the Lansing Smith tests are summarized in this paper.

A series of four tests was planned for this program. First, a test with a freshly washed precipitator to determine the performance of the precipitator with no degradation (baseline 1) was made. Next, a test with the ESP significantly degraded to assure that a high resistivity layer had formed was conducted (baseline 2). Following this, sodium injection was started and continued until the performance of the precipitator had stabilized. At that time the first conditioning test was conducted (conditioning 1). Finally, a test with an increased amount of sodium was made to investigate how an increased injection rate would influence the ESP performance.

This paper reports the results of these tests, and represents the last one of the four series reports.[1-3]

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2. Facility and Method of Test

At the beginning of the research project at Lansing Smith Station, the electrostatic precipitator was washed clean. After washing, the voltage vs. current curves exhibited normal characteristics without evidence of back corona. Selected voltage vs. current curves are shown in Fig. 1. At this time, the total useful power into the precipitator was about 310 kW. The design parameters for the Lansing Smith precipitator are given in Table 1. The general layout of the electrical sections is given in Fig. 2.

The power station was operated in a normal manner for a period of about 42 days. The total power and the outlet emissions were recorded as functions of time. The emissions had increased from about 0.01 pounds per million BTU (lb/10^6 BTU) at a power level of 310 kW when clean to 0.2 lb/10^6 BTU at 50 kW after these 42 days. After the degradation with time, the voltage vs. current curves had significantly deteriorated. Figure 3 indicates the degree of electrical degradation that had occurred.

The naturally occurring sodium in the fly ash during this period of degradation was about 0.3% by weight, when reported as sodium oxide. The electrical degradation was noted after only three days of operation. During the three days, the total power level had dropped from 310 kW to 275 kW with a concurrent increase in outlet emissions from 0.01 to 0.02 lb/10^6 BTU. After the 42 days of degradation the sodium addition tests were initiated.

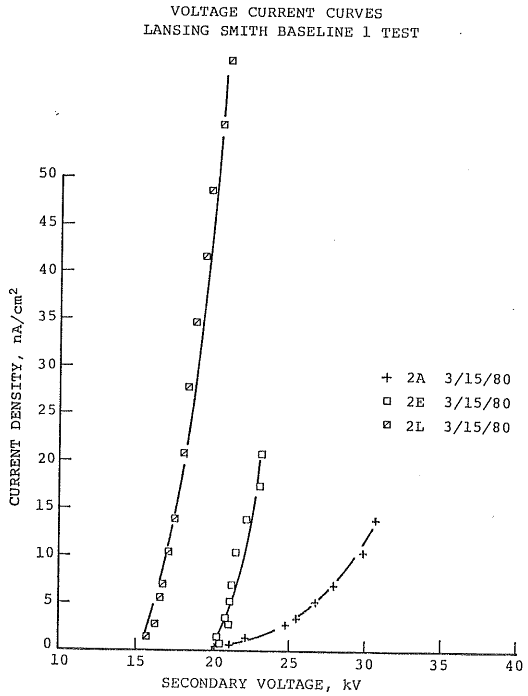


Fig. 1 Voltage vs. current curves (Three selected sections after washing).

Table 1 Lansing Smith Unit 2 precipitator design parameters.

	English units	Metric units
Plate height	36 ft	11 m
Effective plate length	30 ft	9.1 m
Total plate area	311,040 sq. ft	28,900 m²
Cross sectional area	3,888 sq. ft	361 m²
Maximum velocity	4.7 fps	1.4 m/s
Gas treatment time	6.4 s	
Gas temperature	680 °F	360°C
Depth to height ratio	.867	
Number of fields in service	5	
Number of cells wide	4	
Number of TR sets	12	
Number of isolatable sections	40	
Specific collection electrode area	283 sq. ft/kcfm	56 m²/m³/s
Number of isolatable sections per 100,000 cfm	3.62	
Number of rappers	120	
Collecting area/rapper	2,592 sq. ft	240 m²
Number of wire vibrators	40	

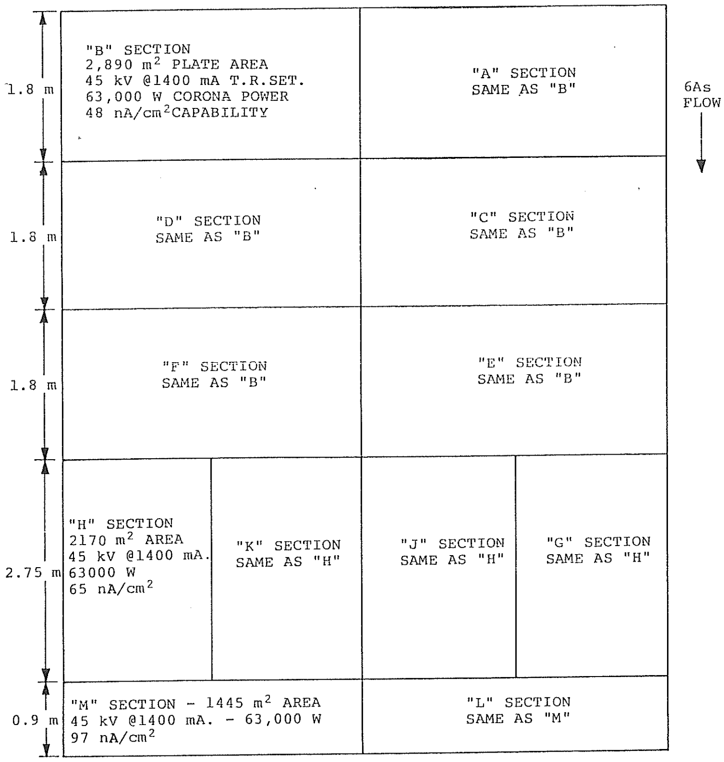


Fig. 2 Schematic of Lansing Smith Unit 2 precipitator TR arrangement (provided by Southern Company Services).

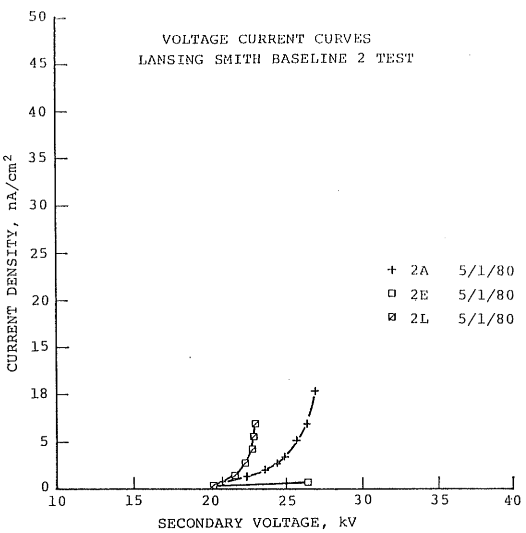


Fig. 3 Baseline 2, *V-I* curves (after 42 days).

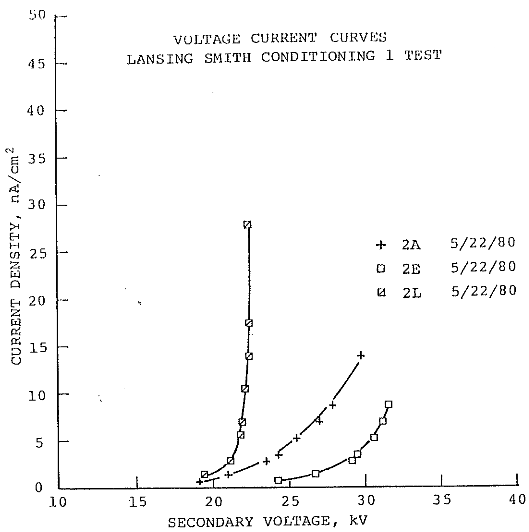


Fig. 4 Voltage vs. current curves after 22 days of conditioning with sodium sulfate. The total sodium content of the ash was 1.3% Na_2O.

The initial sodium experiment consisted of the addition of sodium sulfate to increase the sodium oxide in the fly ash by 1%, bringing the total quantity to 1.3% by weight. The sodium was added to the coal directly. A small spray nozzle was directed on the coal

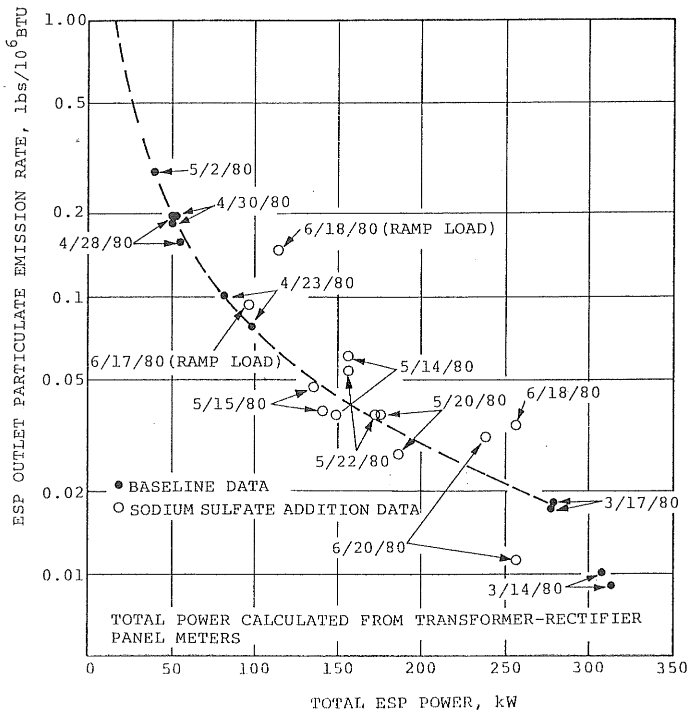


Fig. 5 Lansing Smith Unit 2 hot-side ESP, outlet emission vs. secondary power.

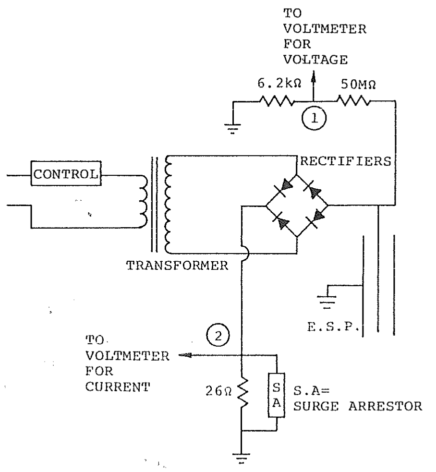
belt, followed immediately by a dry addition of sodium sulfate.

3. Results of Tests

The power levels increased within a few hours after the sodium conditioned coals reached the furnace.

This sodium addition was continued for 15 days to allow the power station precipitator to stabilize. The ESP power levels had increased to about 150 kW during this time with a decrease in outlet emissions to about 0.05 lb/10^6 BTU. The voltage vs. current curves were then recorded after seven additional days of operation. These data are shown in Fig. 4. The power level remained in the general vicinity of 200 kW with the outlet emissions of somewhat less than 0.05 lb/10^6 BTU.

Figure 5 summarizes the measurements conducted during this experiment. The outlet loadings were measured with the EPA Method 17 sampling train which consists of filters mounted together with an S-type Pitot tube and inserted directly into the precipitator outlet ducts. The power levels were obtained from calibrated voltage dividers connected to the corona wire feed system and the secondary



$$\text{SECONDARY VOLTAGE} = V_1 \times \frac{50\times10^6 + 6.2\times10^3}{6.2\times10^3} = 8.1 \times 10^3 V$$

$$\text{SECONDARY CURRENT} = \frac{V_2}{26}$$

Fig. 6 Circuits used to measure electrical operating characteristics of the electrostatic precipitator.

Table 2 Lansing Smith Unit 2 hot-side ESP performance.

Test	Efficiency (%)	Power (kW)[a]	SCA ($m^2/m^3/s$)	Na_2O (wt%)
Baseline 1	99.88	294	64.1	0.34
Baseline 2	98.21	47	61.9	0.34
Conditioning 1	99.64	157	63.7	1.2
Conditioning 2	99.71	258	65.1	2.1

a) Calculated from T-R panel meters.

current was determined by monitoring the current through the ground return resistor in the power supply. A schematic of this measurement system is shown in Fig. 6.

This experiment was continued for a period of about 3 months. During this time, the sodium sulfate feed rates were increased to determine whether this additive caused difficulties with the furnace. During this time, no detrimental effects, such as boiler fouling or other operational difficulties were encountered. In general, the higher the injection rate (up to about 2% Na_2O by weight) was the higher the power level and the lower the outlet emission.

At this point, the experiment was considered to be a success. The plant had operated for a period of four months with no detectable deterioration in performance. Prior to the addition of sodium sulfate, the plant was required to shut down for washing the precipitator at intervals between five and six weeks.

The results of this experiment supported the original hypothesis of sodium depletion leading to the development of a high resistivity residual layer of fly ash on the plates. The addition of sodium prevented the development of this high resistivity layer and allowed the power station to continue operation without the requirement for intermittent interruptions for washing. Table 2 summarizes the performance of the hot-side electrostatic precipitator during the experiment. Baseline 1 refers to the precipitator immediately after washing; baseline 2 is after the degradation period. Conditioning 1 and 2 refer to the two levels of sodium oxide increment tested.

4. Conclusion

This field test completed the research project to identify and correct the time dependent degradation in a class of hot side ESP's. The addition of sodium bearing compounds to the coal brought the performance of a degraded precipitator back to the design collection efficiency. This performance has been maintained for a period of 16 months with this sodium conditioning. Sodium injection has also been used successfully in other hot side installations exhibiting a similar time dependent degradation. Two of these stations are currently using sodium conditioning on a routine basis while another is blending high and low sodium coals.

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1) G.B. Nichols: Proc. Inst. Electrostat. Jpn., **5** (1981) 412

2) G.B. Nichols: *ibid.*, **5** (1981) 418

3) G.B. Nichols: *ibid.*, **5** (1981) 423