PERFORMANCE OF ESPS WITH SMALL SCAS IN SPRAY DRYER RETROFIT APPLICATIONS

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Abstract

This paper presents an analysis of data from the TVA 10 MW Spray Dryer/ESP Pilot Plant on the use of calcium chloride to improve the performance of ESPs operating downstream of spray dryers on medium- and high-sulfur coals. At the low levels of particle resistivity (10^7-10^8 ohm-cm) measured downstream of the spray dryer, an ESP can experience significant particle reentrainment which reduces the collection efficiency resulting in an increase in outlet emissions by a factor of five to ten at spray dryer conditions. This paper describes tests conducted to evaluate the effectiveness of calcium chloride addition for ESPs with specific collection areas (SCA) in the range of 200 to 400 ft^2/kacfm. Tests were performed with the pilot-ESP configured with 2, 3, and 4 sections energized.

The test program involved first characterizing the performance of the ESP at baseline spray dryer conditions with no calcium chloride addition. Following the baseline spray dryer operation, a second series of tests was conducted with calcium chloride added to the atomizer feed which resulted in elevated chloride concentrations in the spray dryer product solids. For the four and three field ESP configuration, the addition of calcium chloride reduced outlet emissions by greater than a factor of ten. The effect of chloride addition was also evident in the two field test as the emissions were reduced by a factor of seven. This improvement in collection could only be obtained at relatively low approach temperatures (e.g. 18 °F to 20 °F). The experimental data were analyzed by a computer ESP model to determine the mechanisms that produced the reduced emissions. The calcium chloride also greatly increased SO_2 removal from 92% at the baseline conditions with a 1.6 reagent ratio to 98% at a 1.3 reagent ratio with the chloride addition.

Introduction

This paper summarizes data from the TVA 10 MW Spray Dryer/ESP Pilot Plant Test Program that demonstrate the effectiveness of using chloride additives to improve ESP performance. This research was part of a five year program designed to obtain data on the retrofit application of spray dryer technology for utility boilers burning medium- to high-sulfur coal. The program was co-funded by the Tennessee Valley Authority, Electric Power Research Institute, and Ontario Hydro. The pilot plant program was designed to address questions which must be resolved prior to commercialization of the SD/ESP for high-sulfur coal applications. The successful completion of this program provided a parametric investigation of spray dryer performance variables, documented impacts of the spray dryer on the ESP, and generated data on process design, operational problems, and hardware requirements.

Results from the pilot plant have demonstrated that spray drying is an effective retrofit flue gas desulfurization (FGD) technology for existing coal-fired electric generating stations as SO_2 removals greater than 90% have been obtained for medium- and high-sulfur coals[1]. However, favorable economics for a spray dryer requires that the existing particulate control equipment be capable of collecting both the flyash and the injected sorbent. Since most of the plants that would be impacted by the 1990 Clean Air Act have electrostatic precipitators (ESPs), the performance of ESPs at spray dryer conditions is critical to the feasibility of the process.

This paper presents the most recent results which demonstrate that high efficiency ESP performance can be obtained at spray dryer conditions. Earlier results have been presented in several papers[1-4] which described the measurement and analysis of particle characteristics, spray dryer operating parameters, and ESP operating variables. It was concluded that particle reentrainment due to the low resistivity of the sorbent/flyash mixtures at low approach-to-saturation temperatures can have a significant impact on the collection efficiency of ESPs. This paper summarizes results from previous papers and presents recent results demonstrating the successful use of calcium chloride as an additive to improve the collection efficiency of an ESP downstream of a spray dryer, even for ESPs with relatively small specific collection areas (SCA). In addition to reducing the particulate emissions, chloride also significantly increases the removal of SO_2.

Description of the Facility

The Spray Dryer/ESP Pilot Plant, located at the TVA Shawnee Test Facility (now called the National Center for Emissions Research) near Paducah, Kentucky, extracts a slip stream from the Number 9 boiler. The flue gas is withdrawn downstream of the boiler air preheater and multiclone system at a nominal rate of 16.5 m^3/s (35,000 ft^3/min). The spray dryer vessel incorporates the side-exit design and uses a single rotary atomizer wheel. The atomizer wheel operates with a speed increasing gear box and variable speed control. The slurry delivery system consists of a fresh lime feed and a recycle system. Slurry from the recycle feed tank and the fresh lime slurry are prepared separately and mixed in the feed line to the atomizer.

The pilot ESP was designed to provide data that would be appropriate for scale up. Therefore, it was built with a plate height of 7 m (23 ft), which is in the same range as many existing full-scale units. The ESP has four electrical sections and eight gas flow passages. The corona electrodes are made of a stainless steel spiral wire mounted in a rigid frame configuration. Both the collecting and the discharge electrodes are rapped by falling hammers on a rotating shaft. The ESP design data are summarized in Table I.

Table 1. ESP Design Specifications.

Number of Sections	4
Number of Gas Passages	8
Plate spacing	25.4 cm (10 in.)
Plate Height	7 m (23 ft)
Plate Length	2.8 m (9.2 ft)
Plate Area/Section	314 m^2 (3,382 ft^2)
Corona Electrode	Spiral
Power Supplies	55 kV, 200 mA

Background on the Impact of Spray Drying on ESP Performance

Installation of a spray dryer upstream of an ESP produces many changes that will impact the operation and performance of the ESP. The primary effects of a spray dryer on a downstream ESP are due to the addition of large amounts of water and reacted and unreacted reagent to the flue gas which results in changes to the mass loading, particle resistivity, particle size distribution, and gas temperature.

The injection of sorbent into the flue gas stream increases the particulate loading by 5 to 10 gr/acf. The amount of the increase depends on several factors including the amount of fresh sorbent and recycle required to achieve the desired level of SO_2 removal. If the ESP efficiency is not increased at spray dryer conditions, the increase in ESP inlet loading will result in an increase in emissions at the ESP outlet. Therefore, neglecting any other factors that may be detrimental to the performance of the ESP, the ESP must perform at a higher efficiency with dry scrubbing in order to maintain the same baseline emission levels.

The cooling of the flue gas stream that occurs as part of the spray drying process provides several beneficial effects that should enhance the collection efficiency of the ESP. The reduced temperature of the flue gas reduces the flow rate of gas being treated by the ESP, which increases the specific collection area (SCA) of the ESP which should result in improved collection efficiency. The reduced flow rate also decreases the gas velocity in the ESP which could lead to reduced non-ideal effects such as sneakage and reentrainment and result in reduced particle emissions. The lower temperature also reduces the viscosity of the flue gas by about 20%. The drag forces that resist the migration of charged particles to the plates are directly proportional to the viscosity, so a reduced viscosity should improve collection efficiency.

The lower flue gas temperatures also produce reduced particle resistivity levels of 10^8-10^9 ohm-cm, and increased spark-over voltages due to the higher gas density, resulting in improved electrical characteristics of the ESP. Tests at TVA have shown that the electric field strength increased at spray dryer conditions by 20% to 30% compared to baseline, flyash-only conditions[3]. Similar improvements have been observed at other dry scrubbing installations[5,6]. In addition to the beneficial effects listed above, the particle size of the sorbent is relatively large (i.e. mass median diameter ≈ 15 μm) and should be easy to collect.

Review of Previous Results

Several series of tests were conducted to measure the collection efficiency of the ESP under both baseline and spray dryer conditions. For each test program, ESP performance was first measured at baseline (flyash only) conditions with the ESP inlet temperature maintained at 320 °F. ESP performance was then measured at spray dryer conditions with the spray dryer operated under constant conditions. The inlet temperature to the spray dryer was maintained at 320 °F. The reagent ratio was set at a value of 1.3 moles of calcium in the fresh lime slurry per mole of SO_2 in the spray dryer inlet flue gas. A slurry of recycle material at 35 wt% solids was fed along with the fresh lime slurry to control the spray dryer outlet temperature. The recycle slurry feed rate was set to provide an 18 °F to 20 °F approach-to-adiabatic saturation which corresponds to an ESP inlet temperature of about 145 °F. The spray dryer flow conditions were designed to duplicate the baseline tests. However, the reduced gas flow rate at the spray dryer outlet due to the cooling of the gas in the spray dryer resulted in lower velocities and higher values of SCA than in the baseline tests.

Results from these tests, which are described in detail in other papers[2-4], show that, in spite of the improvement in most ESP operating parameters and the large size of the sorbent particles, the collection efficiency did not improve at spray dryer conditions. Therefore, the large increase in mass at the ESP inlet results in a similar increase in outlet emissions. A similar set of experiments was performed at the EPRI High Sulfur Test Center (HSTC)[3], and the relative effect of the spray dryer conditions was nearly identical to that observed at TVA. At both pilot plants, the collection efficiency did not improve at spray dryer conditions, resulting in a large increase in outlet emissions.

The implications of these results will depend upon the specific regulations that must be addressed by the retrofit technologies. If the regulation for a plant is based only upon meeting a set opacity (20%) and emission level such as 0.1 lb/MBtu, then the results suggest that a spray dryer has potential as a retrofit technology for those plants with larger (e.g., >300-400 ft^2/kacfm) ESPs. However, if the permit for the facility requires that the particulate emissions be maintained at pre-spray-dryer levels, then these results indicate that the spray dryer may not be a suitable retrofit technology unless a method for reducing particulate emissions is found.

Addition of Chloride for Improved ESP Performance

Laboratory and pilot-scale research have demonstrated that chlorides in the atomizer feed slurry affects the absorption rate of SO_2[7]. This effect is due to the formation of calcium chloride, a deliquescent salt which increases the slurry droplet drying times and increases the affinity of the spray-dried sorbent particles to hold moisture. These effects improve SO_2 absorption by extending the time for drying of the droplet and thereby increasing the time available for reaction during the reactive wet phase, and by making the subsequent spray-dried sorbent particles more reactive towards the remaining flue gas SO_2.

In addition to enhancing SO_2 removal, chloride content has also been found to be an important parameter for ESP performance[3,4,8,9]. In-situ resistivity measurements documented that the addition of chloride reduced the resistivity by an order of magnitude or more at the low approach temperatures. Since a decrease in particle resistivity would cause greater reentrainment, the higher chloride levels should produce a decrease in collection efficiency. However, for approach temperatures less than 18 °F to 20 °F, the collection efficiency actually increased.

The improved collection efficiency must be due to some other effect of the chloride such as an increase in particle cohesion due to increased residual moisture levels. Particle cohesion plays an important role in reentrainment. If cohesion is high, the particles will tend to stick together on the collector plate making reentrainment more difficult. Cohesion will also lead to increased agglomeration of particles. This will improve the recollection of particles and increase their likelihood of falling into the hopper. Therefore, any mechanism capable of increasing the cohesive characteristics of particles should improve the collection efficiency of the ESP. The effect of chloride may be due to an increase in the binding force holding the slurry particle together rather than making the outside of the particle stickier. The analysis of the particle size distribution at the inlet and outlet of the pilot ESP indicates that the slurry particles break up in the ESP and generate smaller particles. If the chloride tends to increase the binding of the agglomerates that make up each slurry particle and prevent the breakup in the ESP, then improved ESP performance would result.

Three series of tests were conducted to quantify the effect of chloride addition on ESP performance[9]. Each test series was performed using a different coal to cover a range of sulfur content, including both medium- and high-sulfur coals. All of the coals had low chloride contents (< 0.1%). Tests were performed at higher chloride levels by spiking the recycle slurry with calcium chloride. The chloride concentration in the recycle/waste solids was used to provide an indicator of the amount of chloride present. Samples of the recycle/waste solids were routinely analyzed and archived, so this was a convenient parameter to document the test conditions. Also there was evidence that it is the chloride level in the solids collected in the ESP (approximately the same as the recycle/waste solids), rather than the chloride level in the coal per se that is important in affecting ESP performance. For each test, the flow characteristics and ESP operating parameters were held approximately constant with the only change being the amount of calcium chloride that was added.

The first series of tests to characterize the impact of chloride addition on ESP performance was conducted during a period when a 2.7% sulfur coal was being burned in the boiler. Under baseline conditions, the ESP efficiency was approximately 99.4%. When the chloride level in the recycle/waste solids was increased to 3.4% by injecting calcium chloride into the feed stream, the ESP efficiency increased to 99.95%.

A second test program conducted to determine the effect of elevated chloride levels on ESP performance was performed on a 2.2% sulfur coal with a coal-chloride level of 0.01%. Prior to conducting these tests, modifications recommended by the manufacturer were made to the ESP and hopper baffles and the operating procedures for the hopper evacuation system were changed. Although the results are not directly comparable to any previous data, the trends observed are very similar to those found in the earlier tests. Operating at spray dryer conditions with no chloride addition (,0.1% Cl in the recycle/waste solids), the ESP removal was 99.84%. When the recycle slurry was spiked to produce a level of 0.6% Cl in the recycle/waste solids, there was no change in the ESP performance. This was not unexpected as earlier data had indicated that there was a threshold chloride level in the waste (1-2%) which must be exceeded before ESP performance improved. When the feed rate of calcium chloride was increased, resulting in a 2.6% chloride concentration in the recycle/waste solids, the ESP efficiency increased significantly to 99.97%. A maximum efficiency of 99.98% was obtained at a waste solids chloride level calculated to be 3.7%.

The final test program involved the investigation of the effects of chloride addition on spray dryer and ESP performance while burning a high-sulfur (4%) coal. The source of the flue gas for the spray dryer pilot unit is downstream of multiclones on the Unit 9 boiler. Therefore, the flyash loading at the spray dryer inlet is typically low, approximately 0.5 gr/acf. Also, the multiclones preferentially remove the larger flyash particles so the flyash size distribution at the spray dryer inlet is typically skewed towards smaller inlet particles. To provide a more characteristic flyash loading and size distribution during these tests, the hopper evacuation system for the multiclones was shut down and the multiclones were allowed to fill up with flyash. This increased the flyash loading at the inlet to the pilot ESP from a relatively low 0.5 gr/acf to a more typical coal-fired boiler flue gas level of 2.0 gr/acf. During the flyash-only testing, the average ESP efficiency was 99.87% which is typical of efficiency levels for well designed ESPs operating on high-sulfur coal. However, when the pilot plant was operated at spray dryer conditions with no chloride addition, the collection efficiency was nearly identical at 99.86%. When calcium chloride was injected into the spray dryer feed stream at a rate to produce a 2.15 wt% chloride level in the recycle/waste solids, the efficiency increased to 99.95%. This improvement is very similar to the effects measured for the medium-sulfur coals and demonstrates that ESP performance can be improved significantly by increasing particle cohesion to overcome particle reentrainment.

Figure 1 shows a comparison of the data from the high-sulfur coal tests with results for the two medium-sulfur coals. For all three coals, the addition of calcium chloride to the feed stream provided significant reductions in emissions from the ESP. Note in Figure 1 that the ESP efficiency values correlate well with the amount of chloride in the recycle/waste solids. It appears that the chloride level in the recycle/waste solids can be used as a parameter to define ESP performance independent of the coal being burned. The amount of chloride required to achieve a given level in the recycle/waste solids will be dependent on several factors, including the coal sulfur level, fresh lime reagent ratio, and flyash loading at the spray dryer inlet. For example, a recycle solids chloride level of 2 wt% might be achieved strictly from spray dryer removal of HCl produced by chloride in the coal for a medium-sulfur (2 to 2.5%), high-chloride (0.25 to 0.3 wt%) coal. For high-sulfur (e.g. 4%) coal, because of the additional amount of lime which must be added to obtain a similar reagent ratio, a substantial amount of calcium chloride may have to be added to the system to obtain a 2 wt% chloride level in the recycle/waste solids.

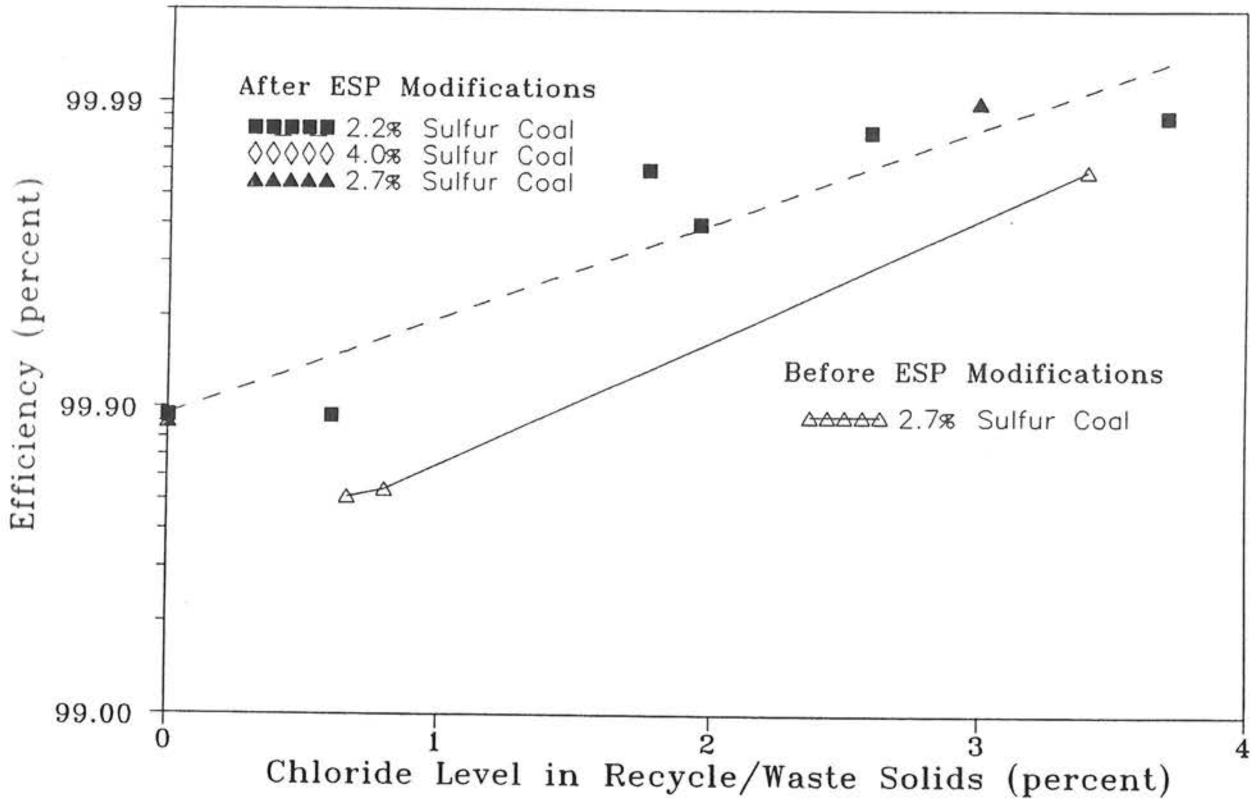

Figure 1. Effect of Chloride Addition on ESP Efficiency for Three Different Coals.

In all cases, the response of the ESP to chloride addition was not instantaneous, as it took as many as three days of continuous operation for the efficiency to reach steady-state conditions for the last test. This is most likely due to the time required for the high-chloride solids to make up a significant portion of the mass on the collector plates in the downstream sections of the ESP.

The addition of chloride to the recycle had a very strong effect on SO_2 removal. During operation on the low chloride coals with no chloride addition, the SO_2 removal in the spray dryer/ESP was less than 80% at a reagent ratio of 1.3. However, SO_2 removal increased to greater than 95% at the highest chloride levels tested. The response of the system to chloride addition is different for SO_2 removal than for ESP efficiency enhancement. Increases in SO_2 removal occur and at lower addition rates.

These results indicate how promising spray drying can be as a retrofit FGD technology. At a reagent ratio of 1.3, it was possible to obtain 96% SO_2 removal while maintaining particulate emissions at baseline (flyash only) levels.

These tests also confirmed that the addition of chloride is only effective for improving ESP performance at relatively low approach temperatures (e.g. 18 °F to 20 °F). This is probably due to the fact that the collection efficiency is improved by increased particle cohesion which requires high relative humidity to provide sufficient moisture in the solids. The data show that chloride still has an effect on SO_2 removal at the higher approach temperature, though.

Chloride Addition Data for ESPs with Reduced SCA

Since all of the earlier tests were conducted with a four field ESP, additional tests were conducted at the TVA Spray Dryer/ESP Pilot Plant to characterize the improvement in ESP performance that could be obtained by the addition of calcium chloride with the ESP configured with 2, 3, and 4 sections energized. For the 2 and 3 field tests, upstream sections were deenergized. This provided a variation in the specific collection area (SCA) of the ESP from 200 to 400 ft^2/kacfm.

The test program involved first characterizing the performance of the ESP at baseline spray dryer conditions with no calcium chloride addition. For these tests the spray dryer was operated with an inlet temperature of 320 °F, 18 °F approach temperature, and 1.6 reagent ratio. The 1.6 reagent ratio was chosen because it represents the level required to obtain greater than 90% SO_2 removal with no chloride addition. At these conditions, the performance of the ESP was measured for the three values of SCA.

Following the baseline spray dryer operation, a second series of tests was conducted which involved the addition of calcium chloride to produce a level of 3% in the recycle/waste solids[9]. This level has been determined in the past to provide optimum spray dryer and ESP performance. The spray dryer operating conditions were identical to the baseline conditions except that the reagent ratio was reduced to 1.3 because the amount of fresh sorbent required to provide 90% SO_2 removal is significantly reduced at higher chloride levels. Three tests were then conducted to measure ESP performance with 2, 3, and 4 ESP fields energized.

The results of the ESP performance tests for baseline and calcium chloride addition conditions are summarized in Table 2. For the four and three field ESP configuration, the addition of calcium chloride reduced outlet emissions by greater than a factor of ten. The effect of the chloride was also evident in the two field test as the emissions were reduced by a factor of seven. Although not reported in Table 2, the calcium chloride also greatly increased SO_2 removal. During the baseline tests the average SO_2 removal was 92% at the 1.6 reagent ratio. However, the chloride addition increased the SO_2 removal to 98% at the 1.3 reagent ratio.

Because of the time constraints of the test program, flyash only ESP performance tests were not conducted which could be used to compare with the spray dryer/ESP tests. Therefore, it was necessary to look at previous flyash only tests to determine if a goal of zero emissions increase was obtainable.

Table 3 shows a summary of the flyash only ESP performance and the results obtained under spray dryer conditions with and without chloride addition. The data for the flyash only conditions represent average emission levels measured throughout the pilot program and include data from several different coals. The data are plotted in Figure 2. For all three sizes of ESPs, the performance of the ESP at spray dryer conditions with no chloride addition is unacceptable, as there are significant increases in emissions when compared to the flyash only case. For the 200 ft^2/kacfm SCA ESP the emissions exceed the 0.1 lb/MMBtu limit. However, when chloride is added, the emissions for all three ESP configurations are lower at spray dryer operating conditions than at flyash only conditions. For the four field case the particulate emissions at spray dryer conditions are a factor of seven lower than the average flyash only performance. With three fields in service, the spray dryer emissions are a factor of three lower than the minimum flyash emissions. For the two field case, the baseline flyash emissions are maintained but no additional decrease is obtained.

Table 2. Effect of Chloride Addition on ESP Performance at Spray Dryer Conditions for Peabody Coal; Medium Sulfur (2.7%), Low Chloride (0.03%).

Recycle $CaCl_2$ (%)	ESP Fields	ESP SCA (ft^2/kacfm)	Inlet Loading (gr/acf)	Outlet Loading (gr/acf)	ESP Efficiency (%)	Emission Rate (lb/MMBtu)
0	4	440	8.70	0.011	99.87	0.036
3.0	4	427	8.32	0.0006	99.99	0.002
0	3	329	8.63	0.0238	99.71	0.075
3.0	3	324	8.40	0.0019	99.98	0.006
0	2	217	8.49	0.0825	98.98	0.254
3.0	2	216	7.65	0.0106	99.86	0.036

Table 3. Outlet Emissions for Flyash Only and Spray Dryer Conditions

ESP Fields	**2**	**3**	**4**
SCA (ft^2/kacfm)	**200**	**300**	**400**
Flyash Only (lb/MMBtu)	0.037	0.022	0.014
Spray Dryer (lb/MMBtu) No Chloride Addition	0.254	0.075	0.036
Spray Dryer (lb/MMBtu) 3% $CaCl_2$ in Recycle	0.036	0.006	0.002

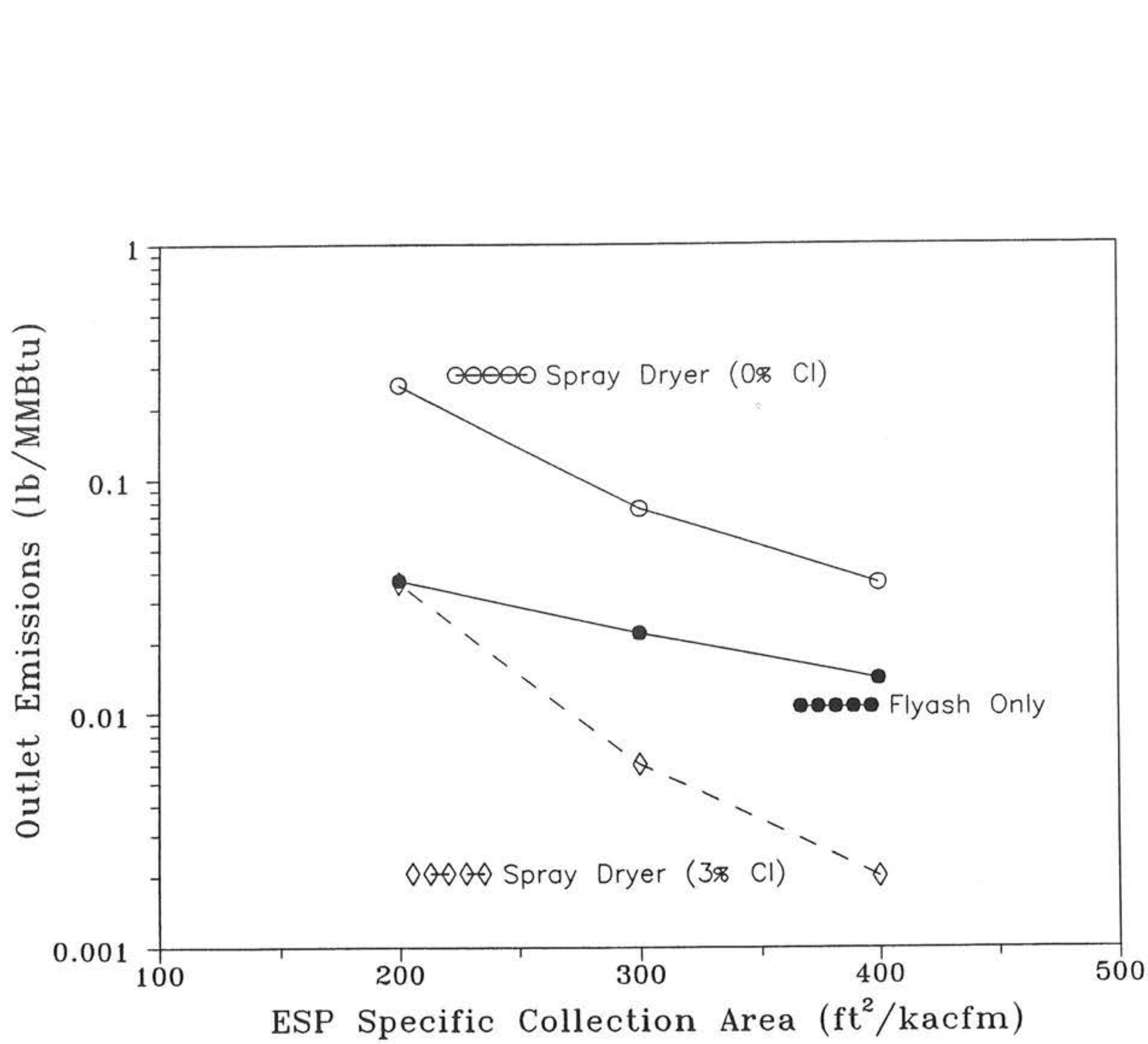

Figure 2. Effect of Chloride Addition on Outlet Emissions.

Modeling of ESP Performance

In order to better understand the mechanisms by which the chloride addition improves ESP performance, the experimental results were analyzed using the ADA ESP Computer Model[10]. Data on the geometry of the ESP are used in the model along with the actual electrical operating conditions measured during the tests. Impactor measurements made previously in the pilot plant program were used to characterize the particle size distribution of the spray dryer material. Several modeling runs were then made in which the factors for non-ideal effects (i.e. sneakage, gas flow distribution, non-rapping reentrainment) are varied until the predicted values are close to the actual measured values.

Table 4 presents a summary of the modeling results for the baseline and chloride additive conditions. Included in this table is the value of the non-rapping reentrainment factor that is required for the predicted performance to match the measured performance. This represents the percentage of the collected material that is reentrained after collection and must be recharged and recollected.

Table 4. Modeling of ESP Performance at Spray Dryer Conditions.

$CaCl_2$	ESP Fields	Non-Rapping Reentrainment Factor	Measured Efficiency	Calculated Efficiency with Rap	Calculated Efficiency No Rap
0	4	0.65	**99.87**	**99.86**	99.91
3%	4	0.01	**99.99**	99.99	**100**
0	3	0.44	**99.71**	**99.74**	99.86
3%	3	0.01	**99.98**	99.94	**99.98**
0	2	0.44	**98.98**	**99.05**	99.74
3%	2	0.01	**99.86**	99.34	**99.89**

As can be seen, with no chloride addition the predicted reentrainment factors are quite high. For the four field case, the model predicts that 65% of the material is reentrained upon collection. The predicted reentrainment drops to 44% for the two and three field cases. This shows that the material is easily reentrained and that reentrainment is a big factor in the fourth section of the ESP. This indicates that the higher the efficiency the greater the impact of non-ideal effects.

It has been concluded from previous analysis that the effect of chloride addition is due to an increased particle cohesion which reduces the potential for particle reentrainment. Therefore, the reentrainment factor for the chloride addition tests was reduced to 1% which is the lowest value acceptable by the model. However, for the two and three field test conditions, the measured performance was much greater than that predicted by the model even with non-rapping reentrainment essentially eliminated from the calculation. Therefore, the chloride must have an additional effect on the performance of the ESP beyond reducing reentrainment.

Since the chloride addition does not effect the operating voltage and current characteristics or the gas conditions such as viscosity, it cannot effect the charging and collecting characteristics of the ESP. The only way that the increased chloride levels can affect collection efficiency is by reducing the non-ideal effects. One would not expect that the chloride content of the particles would have any effect on the fluid dynamic properties of the flue gas, so it is unlikely that the non-ideal effects of sneakage or gas flow distribution would be impacted.

Therefore, the most likely effect of the chloride is that due to increase agglomeration of the cohesive particles, the emissions due to rapping reentrainment are reduced. This can be seen in the data presented in Table 4. The last column shows the predicted collection efficiencies before the rapping emissions are added. As can be seen for the two and three field case, the no-rap collection efficiency predictions are very close to the measured collection efficiencies which include rapping emissions. Therefore, it is concluded that the chloride addition provides a combined effect of eliminating non-rapping reentrainment and greatly reducing emissions due to rapping. Together these two effects can account for the amount of improvement in ESP performance that occurs with chloride addition.

The effect of chloride addition on rapping emissions can be seen dramatically in Figures 3 to 6, which are the ESP outlet opacity tracings for the two and three field tests. The Figures show that the addition of chloride lowers both the baseline opacity and the height of the rapping spikes. It is also obvious from the charts that it is not just the final field raps that are affected by the chloride addition. For example, with two fields energized and no chloride, it is impossible to separate the first field raps from the second field raps because they both approach 100%. However, when chloride is added, the raps for the two sections are very distinguishable. Although some of the final field raps still exceed 50%, the first field raps have been reduced to below 10%. These charts confirm the results of the modeling study.

Summary

These tests have demonstrated that with chloride addition it is possible to improve the performance of the ESP to maintain flyash only emission levels while operating downstream of a spray dryer. This is true even for relatively small SCA ESPs, such as 200 ft^2/kacfm. The chloride also provides for excellent SO_2 removal levels, 98% with a reagent ratio of 1.3. This combination of high SO_2 removal with no increase in particulate emissions demonstrates the viability of a spray dryer/ESP retrofit.

There are potential problems related to operating at high-chloride levels. The extended drying time required by the droplets will require a vessel with adequate flue gas residence time to prevent spray dryer plugging problems. Chloride in the waste may adversely affect solid byproduct disposal properties. This potential impact will have to be addressed in future studies. Also the materials used to fabricate the atomizer wheel will have to be selected to resist chloride corrosion. After failure of a stainless steel wheel, a titanium wheel was used as a replacement at the TVA pilot plant and no additional problems were encountered. However, all of the problems associated with high-chloride conditions can be overcome if the proper equipment and operating procedures are incorporated into the system.

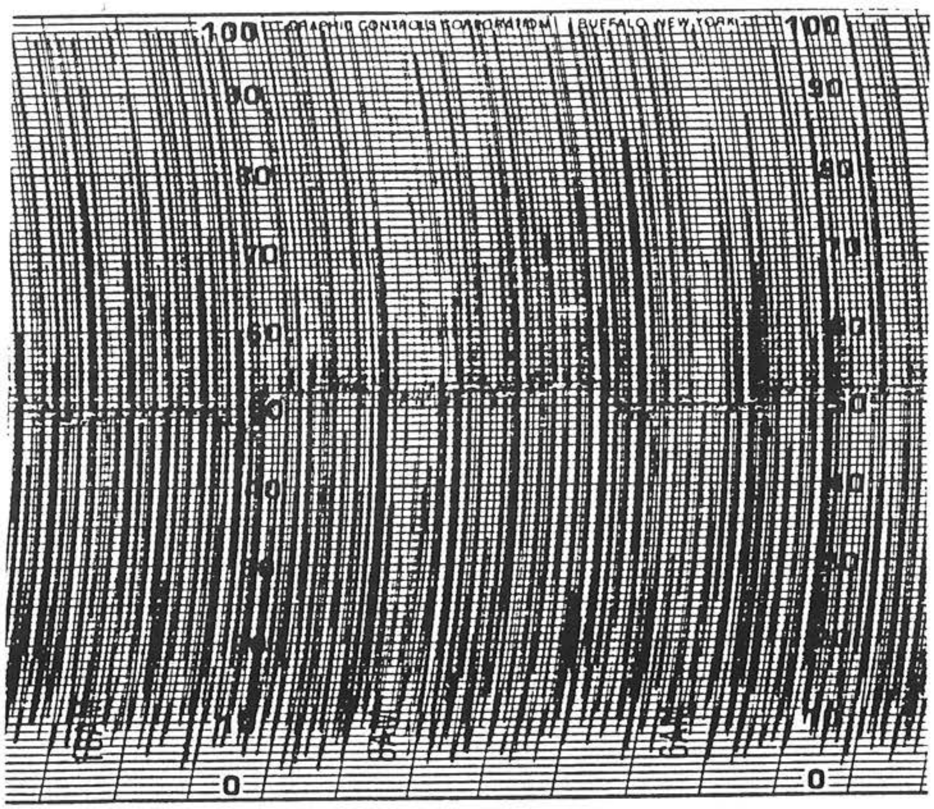

Figure 3. Opacity with Two Fields Energized with No Chloride Addition.

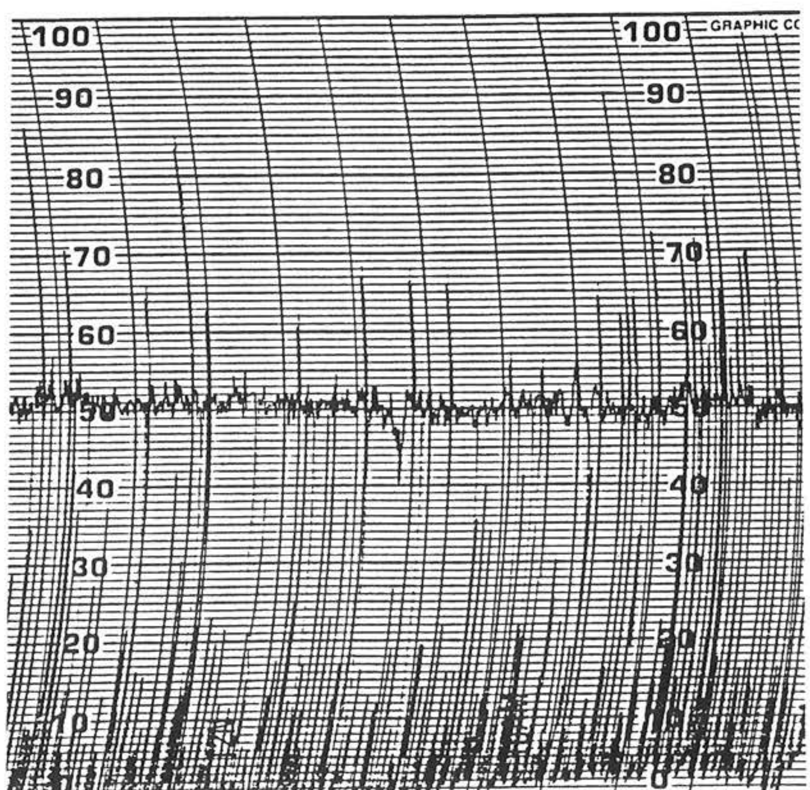

Figure 4. Opacity with Two Fields Energized and Chloride Addition.

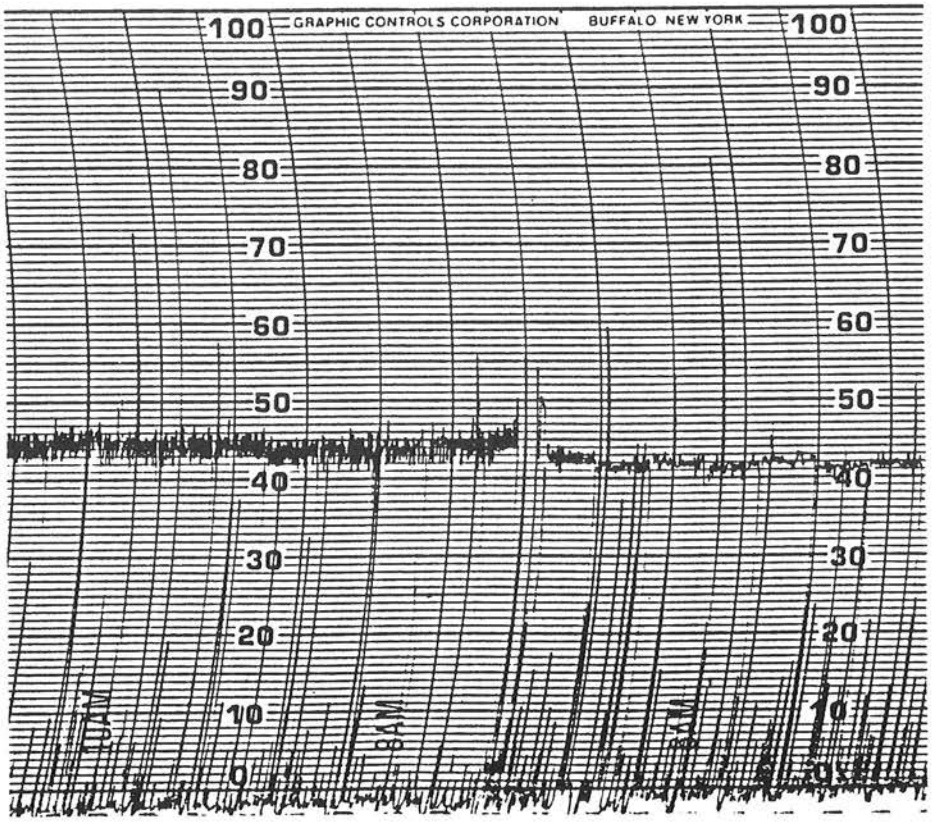

Figure 5. Opacity with Three Fields Energized with No Chloride Addition.

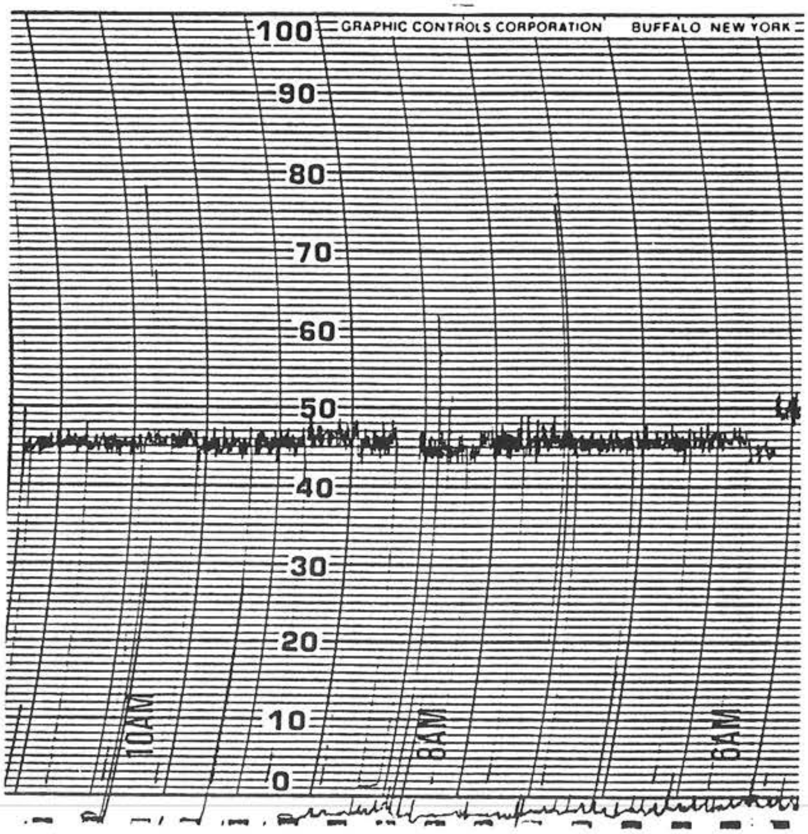

Figure 6. Opacity with Three Fields Energized and Chloride Addition.

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