Full-Scale Evaluation of a Multi-Pollutant Reduction Technology: SO_2, Hg, and NOx
Mobotec USA, Inc.
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Abstract

Furnace sorbent injection using limestone and trona was examined in combination with the ROFA™ and ROTAMIX™ Mobotec USA system installed on Unit 5 at the Cape Fear Generating Station to examine sustainable SO_2 and mercury reductions at low capital and operating cost. Stable SO_2 reductions of 69% were achieved with Trona and 64% with limestone. Mercury reductions of 89% were achieved with limestone and 67% with Trona. Summarized test results as provided by URS are presented in Table 1. Trona provided better SO_2, HCl, NOx, and particulate matter reductions, while limestone provided better mercury reductions.

Mixing created by the ROFA and ROTAMIX system create optimal conditions to achieve maximum multi-pollutant reduction by providing ample turbulence and residence time within the specific temperature window. ROFA and ROTAMIX, because of the inherent turbulent mixing, improves the efficiency of sulfur capture and reduces the stoichiometric amount of sorbent needed to reduce sulfur and mercury emissions.

Slagging in the superheater section was found to be a major operational concern. Furnace sorbent injection in combination with ROFA and ROTAMIX Mobotec Systems can be continually operated with SO_2 and mercury reductions greater than 65% without back end humidification with improved soot blowing and carefully engineered injection schemes.

Table 1. Multi-Pollutant Test Results as Received by URS Engineering

Pollutant	Limestone	Trona
SO_2	64%	69%
SO_3	90%	90%
HCL	0%	75%
Mercury	89%	67%
NOx	4%	11%
PM	18%	80%

Objective

The objective of evaluating furnace sorbent injection (FSI) at the Cape Fear Generating Station was to demonstrate a cost efficient way to reduce SO_2 and mercury with the advantage of the turbulent mixing created by the ROFA™ and ROTAMIX™ system. The project goal was to achieve greater than a 60% reduction in SO_2 emissions with the use of trona and/or limestone.

Background

FSI was evaluated because of its potential to reduce SO_2, Hg, and HCl air emissions on a low cost per kilowatt basis. The advantages of FSI are primarily the simplicity of the process and its low capital cost. Past FSI demonstrations in the U.S. have produced a range of 25-75% SO_2 reduction. However, FSI coupled with ROFA (rotating opposed fire air) has produced a 90% SO_2 reduction at a 78 MW and 150 MW unit in Sweden. ROFA creates excellent turbulence and mixing in the furnace which improves FSI's ability to capture sulfur. The ROFA system is currently installed at Cape Fear Units 5 & 6.

In furnace sorbent injection, sorbents are injected directly into the furnace. Upon exposure to high gas temperatures (greater than 1600ºF), the sorbent rapidly decomposes to form highly reactive particles in suspension which capture SO_2. The reacted sorbent and any unreacted sorbent are then carried out of the furnace with the flue gas. In many systems, the flue gas is humidified downstream of the air preheater which enhances reagent utilization and conditions the flue gas for improved particulate removal. All solids entrained in the flue gas (reacted sorbent products, unreacted sorbent, and fly ash) are collected in the particulate control devices, the electrostatic precipitator or baghouse.

ROFA and ROTAMIX systems have been successfully installed in 17 boilers in Sweden and 5 boilers in the USA. Mobotec USA is currently installing ROFA and Rotamix systems on 14 additional boilers in the USA, 8 of which will be started up in 2003. These boilers range in size from 44 MW to 570 MW and are t-fired, wall-fired, or opposed-fired. ROFA and ROTAMIX systems work with the majority of fuel types and firing conventions.

ROFA reduces NOx by improving the combustion in the boiler. The gas volume in the furnace is set in rotation via special asymmetrically placed air nozzles. The flue gases mix well with the added redirected air, creating increased turbulent mixing and rotation in the entire furnace. Turbulence improves temperature and species distributions and improves particle burnout in the upper furnace. Improved combustion and increased turbulence results in:

- Increased particle residence time
- More uniform temperature distribution
- Improved mixing of the fuel and oxygen
- Reduced CO and NOx
- Decrease in needed excess air

ROTAMIX is a second-generation SNCR and sorbent injection system. Depending on the design, sorbent, ammonia, or urea may be utilized in a Mobotec ROTAMIX System. ROFA prepares the way for the effective mixing of chemicals in the furnace. The result of rotating intermixing is that a more homogenous furnace temperature is obtained. The reducing chemicals can then be injected into the furnace, utilizing the ROFA air as a carrier, into areas where the temperature is most favourable for NOx, SO_2, Hg, and HCl reduction. The result is considerably reduced chemical consumption and lower chemical slippage. When coupled with ROFA and ROTAMIX, the efficiency of furnace sorbent injection improves. The Mobotec Systems becomes a multi pollutant reduction technology.

To evaluate the Mobotec System multi pollutant reduction technology, a team was formed in March 2002 which included personnel from Progress Energy, Mobotec USA, Wiley & Associates, URS, Chemical Lime, Solvay Minerals, and the Department of Energy. URS, an arbitrary third-party engineering, was firm brought in for quality assurance and to evaluate emission test results. An independent emissions monitoring company was used for an objective analysis of obtained results. Funding for the trial was supplied by Mobotec USA, Progress Energy, and the DOE.

Trona and limestone were chosen as test sorbents. In the furnace, the sorbent first undergoes calcination to form highly reactive oxides that readily react with the SO_2 in the combustion gas. Depending on the injected sorbent the reaction produces either sodium or calcium sulfate which is picked up by particulate control devices. The "popcorn-like" decomposition or calcination of the sorbent creates a large and reactive surface by bringing unreacted sodium or calcium carbonate to the particle surface for Hg, HC1, and SO_2 neutralization. Trona was supplied by Solvay Minerals and limestone was supplied by Chemical Lime.

Test Protocol and Design Basis

The sorbent injection trials were conducted on Unit 5 at the Cape Fear Generating Station located in Moncure, NC. Cape Fear is operated by Carolina Power and Light, a subsidiary of Progress Energy Carolinas. Mobotec installed ROFA in 2000 and Rotamix in 2002. The Cape Fear 5 unit conditions are:

- CE four corner fired unit
- 154 MWe generating capacity at gross
- Four levels of burners built in 1957
- No OFA or FGR systems installed previously
- No burner modifications

The multi pollutant reduction technology evaluation program at Cape Fear 5 was as follows:

- Injection of limestone to determine the effect on SO_2 and mercury reduction.
- Injection of trona to determine the effect on NOx, SO_2, HCl, and mercury reduction.

Sorbents were be injected into several locations, namely the existing ROFA and ROTAMIX ports at various molar stoichiometries. The test duration was scheduled for two 8 hour periods. The purpose of the first 8 hour test was to determine the best location and operational performance. The second 8 hour time period was allotted for the official test. Each sorbent was injected at a low sorbent to sulfur ratio to check safety and operational performance. Next a moderate sorbent to sulfur ratio was injected at different elevations to determine maximum SO_2 reduction. These initial trials were to last six to eight hours. If no safety or operational concerns were identified, then an official trial was conducted the next day. The official trial required an eight hour period beginning with the moderate ratio and increasing to a higher ratio. Test data was collected by URS

Corporation and the plants distributed control system. The test program for analysis included the following:

- Coal composition
- Sorbent particle size
- ESP: Mercury, (elemental/speciated), HCL, SO_3/SO_2
- Control room CEM data: NOx, SO_2, O_2, CO, CO_2, opacity

The following basic equipment was used for the trials:

1. The dry chemicals, or sorbents, were unloaded from the delivery trucks to a bulk storage tank.
2. From the bulk storage tank the dry chemicals were conveyed by air to a day tank.
3. From the day tank the dry chemicals were metered and then conveyed to various levels of the boiler.
4. The sorbents were injected into the boiler using the ROTAMIX high velocity air injection system.

The day tank was placed on ground level. The metering pumps and blowers used to convey the dry chemicals to the injection levels were located beneath the day tank on ground level. Four blowers, rotary valves, and screw feeders were used, one for each line going to the injection levels. PVC pipe was used to move the dry chemicals to the upper levels of the boiler. The installation was designed so that the dry chemicals could be injected into the boiler through the ROTAMIX system at four different levels; however, the actual injection of the dry chemicals was made into one or two levels. Each line was equipped with a series of valves to enable injection into various ROFA and ROTAMIX elevations. The PVC line was connected to the ROTAMIX system with flexible tubing. The sorbent injection lances projected through the associated box to the furnace. The ROFA air creates suction on the sorbent injection lances.

Safety and Equipment Concerns

Limestone and trona do not pose a serious safety concern. In case of boiler trip or emergency shutdown, a master fuel trip was run from the control to the feed screws to automatically shut down the sorbent feed system. All lines were checked prior to testing for leakage. All leakage was eliminated.

ESP efficiency typically decreases with the addition of sorbent to a furnace. Higher grain loading and increased solids resistivity both reduce the ability of an existing ESP to maintain its original outlet solids loading. Many older ESP's are designed for higher gas velocities and smaller specific collection areas than newer units and may have difficulty maintaining pre-retrofit particulate emission rates.

One solution to poor ESP collection efficiency to meet the standards for particulate control is to humidify the flue gas to temperatures approaching the gas adiabatic saturation temperature. The humidification system adds surface moisture to the unreacted sorbent, making it possible for additional SO_2 to be absorbed onto the sorbent particle surface. The collected unreacted sorbent may also be recycled to the feed tank.

Concerns raised during the project review meetings addressed convection pass fouling and opacity issues. Convection pass fouling prompted a major concern due to the increased solids loading, Unit 5's economizer design, and the tight gas passages in the air heater. It was decided to closely monitor economizer and air heater parameters during the trial. In addition, additional instrument were installed to monitor air heater differential pressure. In retrospect, better soot blowing and visual furnace inspections should have occurred during testing.

Test Procedure

The initial project start up date was significantly delayed due to equipment and design altercations. The original design of the conveyance system was poor such that significant blow back existed through the rotary valves and excessive line velocities and length resulted in high pressure drops.

On December 8th 2002, the sorbent injection trials commenced to determine the potential of furnace sorbent injection (FSI) to reduce SO_2, Hg, and HCl pollutants. Limestone and then Trona were injected at several furnace elevations using the existing Cape Fear Unit 5 ROFA and ROTAMIX boxes. The effluents were monitored during the test to determine the effectiveness of each sorbent. The ratio of sorbent to sulfur was established prior to testing and intentionally varied during the trials.

Limestone was initially setup and tested for approximately 8 hours to determine optimum injection location and check for any safety or operational issues. No issues were uncovered at this point. Limestone was then injected at a ratio of 2:1 (calcium to sulfur) simultaneously into furnace elevations 5-1/2 and 6 for a period of 6 hours. An official limestone injection trial was conducted on December 10th. Limestone was once again injected into the same two elevations for a period of 4 hours at a 2:1 ratio, and then 4 hours at a 3:1 ratio. Upon completion of this trial, the system was purged and prepared for the next sorbent injection trial.

On December 12th, Trona was injected at a 1:1 ratio (sodium to sulfur) into several locations, and then at a 2:1 ratio into elevations 5-1/2 and 6. An official Trona injection trial was conducted on Friday, December 13th. Trona was injected at elevations 5-1/2 and 6 first for a period of 4 hours at a 2:1 ratio, and then finally for 4 hours at a 3:1 ratio.

Tilts were held constant at 75% through the testing period. Excess O2 was held relatively constant between 3.7 and 4.1 %.

Discussion of Results

Both limestone and trona provide superior SO_2 and SO_3 reduction results. Trona provided a SO_2 reduction of 69% while limestone gave a reduction of 64%. For a summary of test results refer to Table 2. A detailed test summary as provided by URS is included in Appendix A. If back end humidification was incorporated into the furnace sorbent injection scheme, SO_2 capture would have increased and any unused sorbent may have be recycled back to the storage bin.

The mercury reduction achieved for both trona and limestone was very promising. Limestone gave a mercury reduction of 89% while Trona gave a reduction of 67%. The accuracy of the particulate matter (PM) reduction is somewhat unclear due to upper furnace slagging; i.e. the percentage of PM captured by the slag was not determined.

Table 2: Multi-Pollutant Reduction test results.

Pollutant	Limestone	Trona
SO_2	64%	69%
SO_3	90%	90%
HCL	0%	75%
Mercury	89%	67%
NOx	4%	11%
PM	18%	80%

Another noteworthy result was the reduction in NOx obtained with the trona injection. The trona supplier maintains that trona will react with the NOx before it will react with the SO_2. Additional NOx reduction achieved with sorbent injection is an added benefit of the Mobotec USA multi pollutant reduction technology.

The duration of the limestone and trona tests are presented in Figure 3 and 4, respectively. It may be noted that the SO_2 reduction does not significantly change for increased molar feed ratios of 2:1 and 3:1, sorbent to sulfur. The stoichiometric feed rate comparison suggests the flue gas and sorbent were well mixed; ROFA and ROTAMIX decrease the amount of sorbent needed to achieve the desired SO_2 and Hg reductions.

The sorbent tests were conducted for a duration of eight hours at 75% load, 100 MWe. The sorbent tests where conducted at reduced load because of the limited amount of sorbent and Cape Fear 5 is a base load unit. The unit operates on load control for the majority of time and averages approximately 75% load. Opacity throughout testing did not significantly or notably change from a value of 11%. Coal data is presented in Table 3. Sorbent particle size is presented in Table 4.

Figure 3: Limestone Injection - 12/10/2002. Data collected through plant instrumentation.

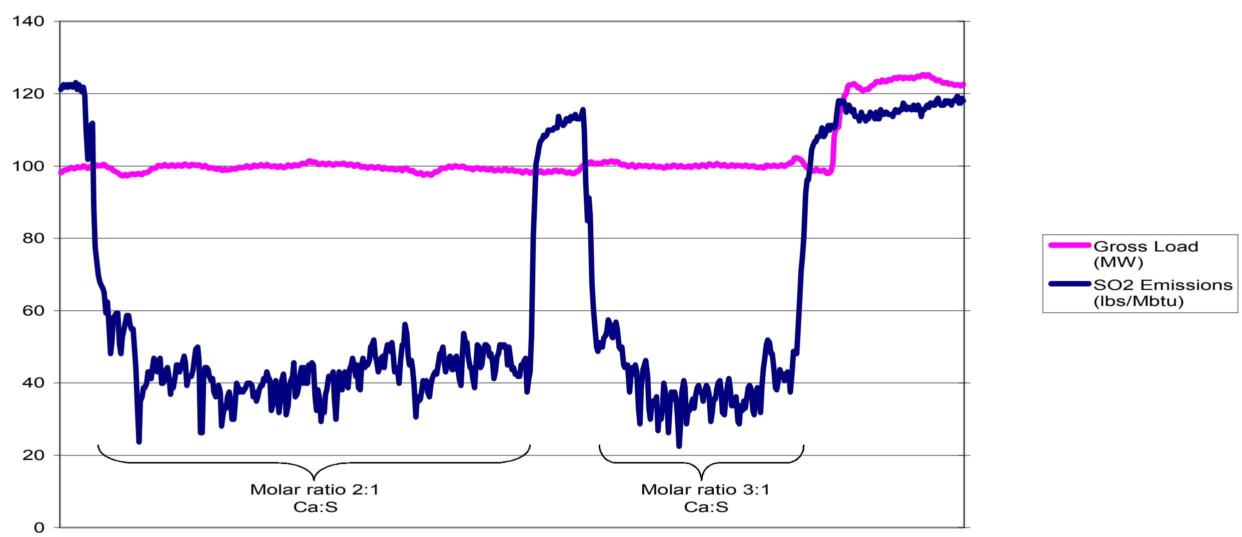

Figure 4: Trona Injection - 12/13/2002. Data collected through plant instrumentation.

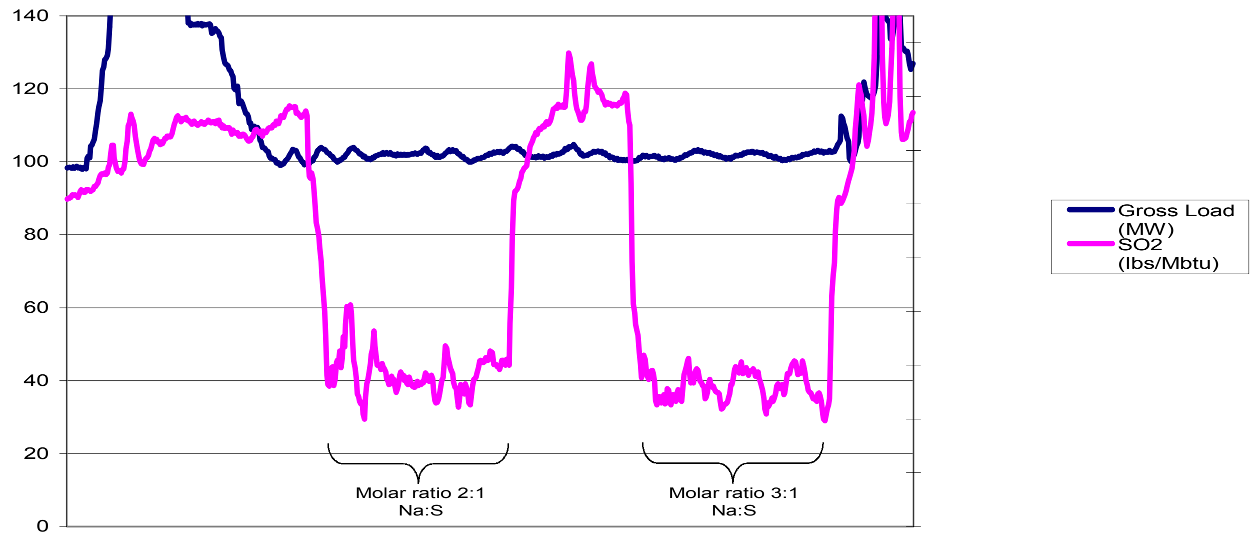

Table 3. Coal analysis.

	As Received	Dry Basis
% Moisture	1.65	-
% Carbon	70.19	71.37
% Hydrogen	4.67	4.75
% Nitrogen	1.41	1.43
% Sulfur	0.87	0.88
% Ash	12.64	12.85
% Oxygen	8.57	8.72
Sum	100	100

Table 4. Sorbent particle size as received by supplier.

	Limestone
% < 74 micron	92
% < 44 micron	80
	Trona
% < 70 micron	75
% < 28 micron	50
% < 6 micron	10

Upper Furnace Slagging

During the sorbents trials, excessive slagging occurred on the superheater tubes. Cape Fear 5 required a shut down to remove the slag with high pressure water and explosive blasting. It is theorized that the slagging was initiated by limestone and finished by trona. Cape Fear 5 does not have the soot blower capacity to handle sorbent injection.

Analysis of the slag indicates that the bottom layer adhered to the superheater tubes was primarily calcium or limestone. Depending on the sorbent concentration, it was determined limestone lowers the ash fusion temperature by approximately 500ºF. Trona lowers the ash fusion temperature by 300ºF. Although limestone has a lower ash fusion temperature than trona, trona sticks more tenaciously due to the nature of the chemical bond. Mobotec USA believes the slagging problem can be significantly decreased and properly dealt with by injecting the sorbent in a furnace location where the combustion gases are below the ash fusion temperature combined with a more frequent use of the soot blowers.

The sorbents were injected into furnace regions above the ash fusion temperature. Resulting, material, fly ash and sorbent, adhered tenaciously to the superheater pendant tubes and was not successfully removed by the plant air soot blower. Cape Fear 5 does not have the needed soot blowing capacity to deal with additional sorbent loading. Also, at the conclusion of testing it was found that a critical soot blower was not operational. In combination with items mentioned above, optimizing the sorbent particle mass mean diameter as well as in-furnace sorbent humidification may decrease slagging tendencies.

To determine the underlying nature of the slag material and its formation several lab analysis were performed. Several slag samples were taken directly from affect superheater tubes and sent for analysis. The lab information provides sufficient information to determine that limestone injection provided a base deposition on the pendent tubes. This base deposition over time allowed a slagging environment to cultivate. Tables 5 and 6 provide lab analysis showing a high percentage of calcium based products in the slag material. Typical coal burned at Cape Fear has on average .9% calcium oxide in an ash mineral analysis.

Table 5: Slag Layer Analysis - January 27, 2003 – Auburn Analytic Labs

Note: Method is x-ray diffraction. Light elements such as Na and K may be less than actual.

	Inside Layer	Mid Layer	Mid Layer	Outside Layer	Main Source
SiO2	30.8%	31.1%	32.4%	36.1%	Coal
Al2O3	18.1%	15.3%	17.0%	23.6%	Coal
FeO	12.2%	12.7%	20.0%	19.7%	Coal
CaSO4	12.0%	15.8%	11.0%	12.2%	Reacted Sorbent
CaO	7.0%	1.5%	1.3%	1.0%	Unreacted Sorbent
NaSO4	0.0%	0.0%	3.0%	0.0%	Reacted Sorbent
Na2O	0.0%	0.0%	1.0%	0.0%	Unreacted Sorbent
K2O	2.0%	2.9%	2.2%	3.0%	Coal
TiO2	3.0%	2.6%	2.7%	2.6%	Coal

Table 6: Total Slag Analysis - January 3, 2003 – Solvay Minerals

Note: Method is ICP atomic emission

	All Layers	Main Source
Si	15.7%	Coal
Na	11.3%	Sorbent
Al	10.0%	Coal
S	6.7%	Coal
Ca	5.6%	Sorbent
Fe	3.2%	Coal

A mixtures of coal and sorbent was sent for ash fusion and mineral analysis to determine the effect of sorbent on ash chemistry, Table 7 displays that limestone even at a moderate 2:1 calcium to sulfur ratio has a major impact on ash fusion temperature and slagging index. As reference, typical Cape Fear coal has an ash fusion temperature of 2700+ F and a low slagging index.

Table 7: Coal/Sorbent Analysis – February 4, 2003 – Commercial Testing & Engineering

Sorbent	Ratio	Fusion Temp	Slagging Index	Fouling Index
Limestone	2:1	2170 F	High	Low
Limestone	3:1	2180 F	High	Low
Trona	1:1	2322 F	Low	Low
Trona	2:1	2374 F	Med	Low
Trona	3:1	2397 F	Med	Low

Limestone lowered the ash fusion temperature to 2170F. Sorbents were mainly injected into ROFA levels 2 and 3 where furnace temperatures on average were 2200F and 1950F respectively. When the furnace temperature is above the ash fusion temperature, ash softening occurs changing the state of the ash particles. It is logical to conclude that particles did not have enough time to solidify before reaching the superheater pendent. Particles were still in a molten or in the plastic stage when reaching the pendent tubes allowing adherence.

Conclusions and Recommendations

Mobotec USA's multi pollutant reduction technology successfully reduced SO_2, mercury, HCl, NOx, and PM emissions at the Cape Fear Power Station. Stable SO_2 reductions of 69% were achieved with Trona and 64% with limestone. Mercury reductions of 89% were achieved with limestone and 67% with Trona. ROFA™ and ROTAMIX™ can be used efficiently for sorbent furnace injection creating an economical way to reduce SO_2, NOx, HCl, and mercury. In combination with the turbulent mixing inherent with the ROTAMIX and ROFA Mobotec Systems, furnace sorbent injection is superior to traditional scrubbers due to large SO_2 and mercury reductions at low capital and operating costs.

Mobotec USA seeks to enhance and commercialize the technology by performing another full scale evaluation using Trona as the sorbent.

Operational issues such as pendant section slagging may be overcome by controlling sorbent injection rate based on upper furnace temperature, a more aggressive and efficient soot blowing scheme, limestone humidification, and sorbent particle size optimization.

Appendix A: Sorbent test results obtained from URS.

Cape Fear Sorbent Injection Testing Program

Condition		Baseline			Limestone				Trona			
Run		1	2	Avg	1	2	Avg	% Red*	1	2	Avg	% Red*
Date		11/12/02	11/12/02		12/10/02	12/10/02			12/13/02	12/13/02		
Start Time		10:10	14:02		12:29	16:20			9:45	14:10		
End Time		12:19	16:10		14:43	18:32			12:01	16:22		
Flow (ESP Inlet)	dscfm	282,609	322,967	302,788	256,095	262,486	259,291		243,832	224,469	234,150	
	^oF	243	243	243	246	245	245		262	271	267	
O_2 (ESP Inlet)**	% dry	4.3	4.3	4.3	5.5	5.4	5.4		4.6	3.9	4.3	
H_2O (ESP Inlet)	% vol	8.0	7.5	7.8	5.3	6.3	5.8		6.6	7.4	7.0	
HCl (ESP Inlet)	ppmvd	64.8	67.5	66.2	53.3	62.8	58.1	12.3%	16.1	12.4	14.3	78.4%
	lb/MMBtu	0.13	0.14	0.14	0.12	0.14	0.13	5.8%	0.03	0.02	0.03	78.4%
	lb/hr	104.2	124.0	114.1	77.7	93.7	85.7	24.9%	22.3	15.9	19.1	83.3%
PM (ESP Inlet)	gr/dscf	5.01	4.84	4.92	3.95	4.12	4.03	18.0%	1.23	0.75	0.99	79.9%
	lb/MMBtu	8.8	8.5	8.7	7.5	7.8	7.6	11.9%	2.2	1.3	1.7	79.8%
	lb/hr	12,127	13,392	12,760	8,660	9,280	8,970	29.7%	2,577	1,441	2,009	84.3%
Flow (Stack)	dscfm	271,890	237,852	254,871	234,814	234,010	234,412		234,860	229,637	232,248	
	^oF	246	245	245	274	287	281		248	261	254	
O_2 (Stack)	% dry	7.5	6.5	7.0	9.3	10.5	9.9		8.0	6.3	7.1	
H_2O (Stack)	% vol	8.5	7.7	8.1	6.7	7.1	6.9		6.5	7.1	6.8	
SO_2 (Stack)	ppmvd	729.9	706.2	718.1	324.3	356.0	340.2	52.6%	296.1	291.0	293.5	59.1%
	lb/MMBtu	1.9	1.7	1.8	0.9	1.2	1.1	40.0%	0.8	0.7	0.7	58.6%
	lb/hr	2742	1675	2208	759	831	795.1	64.0%	694	666	679.9	69.2%
SO_3 (Stack)	ppmvd	0.47	0.54	0.51	0.06	0.06	0.06	87.5%	0.04	0.03	0.03	93.1%
	lb/MMBtu	0.0015	0.0016	0.0015	0.0002	0.0003	0.0002	84.2%	0.0001	0.0001	0.0001	93.0%
	lb/hr	0.0042	0.0047	0.0044	0.0006	0.0006	0.0006	86.9%	0.0003	0.0003	0.0003	93.0%
Hg^{PM} (Stack)	ug/Nm^3	0.10	0.01	0.05	0.18	0.01	0.09	-79.1%	0.04	0.11	0.08	-52.1%
	lb/MMBtu	8.6E-08	6.6E-09	4.6E-08	1.8E-07	8.2E-09	9.6E-08	-108.1%	4.1E-08	9.3E-08	6.7E-08	-45.2%
	lb/hr	9.2E-05	6.6E-06	4.9E-05	0.00015	5.8E-06	7.7E-05	-56.2%	3.7E-05	9.2E-05	6.4E-05	-30.5%
Hg^{+2} (Stack)	ug/Nm^3	7.95	8.16	8.06	0.90	1.04	0.97	87.9%	2.07	2.15	2.11	73.8%
	lb/MMBtu	7.1E-06	6.7E-06	6.9E-06	9.2E-07	1.2E-06	1.1E-06	84.7%	1.9E-06	1.7E-06	1.8E-06	73.5%
	lb/hr	0.0075	0.0068	0.0072	0.0007	0.0009	0.0008	88.9%	0.0017	0.0017	0.0017	76.1%
Hg^{O} (Stack)	ug/Nm^3	2.50	3.14	2.82	0.09	0.07	0.08	97.1%	1.54	1.28	1.41	50.1%
	lb/MMBtu	2.2E-06	2.6E-06	2.4E-06	9.2E-08	8.5E-08	8.9E-08	96.3%	1.4E-06	1.0E-06	1.2E-06	49.0%
	lb/hr	0.0024	0.0026	0.0025	0.0001	0.0001	0.0001	97.3%	0.0013	0.0010	0.0011	54.2%
Hg^{Total} (Stack)	ug/Nm^3	10.54	11.31	10.93	1.18	1.12	1.15	89.5%	3.65	3.54	3.60	67.1%
	lb/MMBtu	9.4E-06	9.3E-06	9.3E-06	1.2E-06	1.3E-06	1.2E-06	86.7%	3.4E-06	2.9E-06	3.1E-06	66.6%
	lb/hr	0.0100	0.0094	0.0097	0.0010	0.0009	0.0009	90.3%	0.0030	0.0028	0.0029	69.9%
PM (Stack)	gr/dscf			#DIV/0!			#DIV/0!	#DIV/0!			#DIV/0!	#DIV/0!
	lb/MMBtu			#DIV/0!			#DIV/0!	#DIV/0!			#DIV/0!	#DIV/0!
	lb/hr			#DIV/0!			#DIV/0!	#DIV/0!			#DIV/0!	#DIV/0!

* % reduction based on average values during sorbent injection tests compared to average values during baseline tests.

** ESP Inlet O_2 readings collected by URS appear to contain ambient air dilution. Values shown based on plant instrumentation at air heater (wet basis) for Limestone and Trona tests, Baseline value assumed equal to Trona value.

*** lb/MMBtu based on EPA Method 19 Fd factor of 9780 dscf/MMBtu