United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S7-83-038 Oct. 1983

Project Summary

Characterization of the NO_x and SO_2 Control Performances; Southern Indiana Gas and Electric Company, A. B. Brown Unit 1

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A continuous emissions monitoring program was conducted at Southern Indiana Gas and Electric Company's (SIGECO's) A.B. Brown Power Plant, to characterize the nitrogen oxide (NO_x) and sulfur dioxide (SO_2) control performances of Unit 1 in terms of process variables. NO_x results show that the unit operated at significantly below 70 percent of the existing NO_x standard (301 ng/J). Daily averages were 135-219 ng/J, with a mean of 163 ng/J. Thirty-day rolling averages were 160-167 ng/J. SO_2 results indicate a mean removal efficiency of 88.0 percent and emissions of 344 ng/J for the north tower, and 86.5 percent and 391 ng/J (respectively) for the south tower. Thirty-day rolling averages were 85.8-90.5 percent and 85.3-88.0 percent for the north and south towers, respectively. Thirty-day rolling average SO_2 outlet emission rates were 274-396 ng/J and 355-418 ng/J for the north and south towers, respectively.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

On June 11, 1979, the EPA promulgated the New Source Performance Standards (NSPS) for Utility Steam Generators, contained in Subpart Da of 40 CFR 60 and applying to generators on which construction started after September 18, 1978.

After promulgating a standard, the EPA is required to assemble data and to review the standard every 4 years. In preparing for this review, EPA's Office of Air Quality Planning and Standards (OAQPS) initiated an overall program pertaining to the SO_2 emission standard, aimed at documenting the performance of high efficiency SO_2 scrubber systems. This program subsequently involved the testing of two dual alkali and two lime wet scrubber systems. These system types were considered "state-of-the-art," demonstrating consistently high sulfur control performance.

GCA/Technology Division was contracted by EPA's Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP) to conduct the test program at the A. B. Brown Power Plant. Primary objectives of the program were to assess the SO_2 and NO_x control of the FMC dual alkali scrubber and the Babcock & Wilcox (B & W) wall-fired boiler, respectively. Of secondary importance was the evaluation of these performances in conjunction with various process data that were available. Sulfur emission control performance was of primary concern to OAQPS, while the correlation of process data to operational performance was of more interest to IERL-RTP.

The program lasted 10 months. Delays in the original proposed schedule resulted from a longer-than-anticipated monitor system setup time and various problems during data reduction.

The final report for this program is in five volumes, all of which are covered by this single project summary.

Facility Description

Southern Indiana Gas and Electric Company's (SIGECO's) A. B. Brown Unit 1 is a modern pulverized-coal-fired boiler with a generation capacity of 265 MWe and has been operating since early 1979. The unit is subject to the 1971 Federal NSPS which limit SO_2 emissions to 1.2 lb/10^6 Btu (516 ng/J), NO_x emissions to 0.7 lb/10^6 Btu (301 ng/J), and particulate emissions to 0.1 lb/10^6 Btu (43 ng/J).

Emissions of SO_2 are controlled by an FMC concentrated-mode dual alkali scrubber system. The three-stage two-module scrubber, shown schematically in Figure 1, was designed to meet the NSPS, when 4.5 percent sulfur coal is burned, by treating all the flue gases at an efficiency of about 85 percent. SIGECO normally burns 3.5 percent sulfur coal and, reportedly, has been able to meet the standard by treating 90 percent of the flue gas at 90 percent efficiency while by-passing the remaining 10 percent.

The boiler, designed and built by B&W, includes their dual register burners as shown in Figure 2. Emission tests have demonstrated that these burners limit NO_x emissions to less than 0.5 lb/10^6 Btu

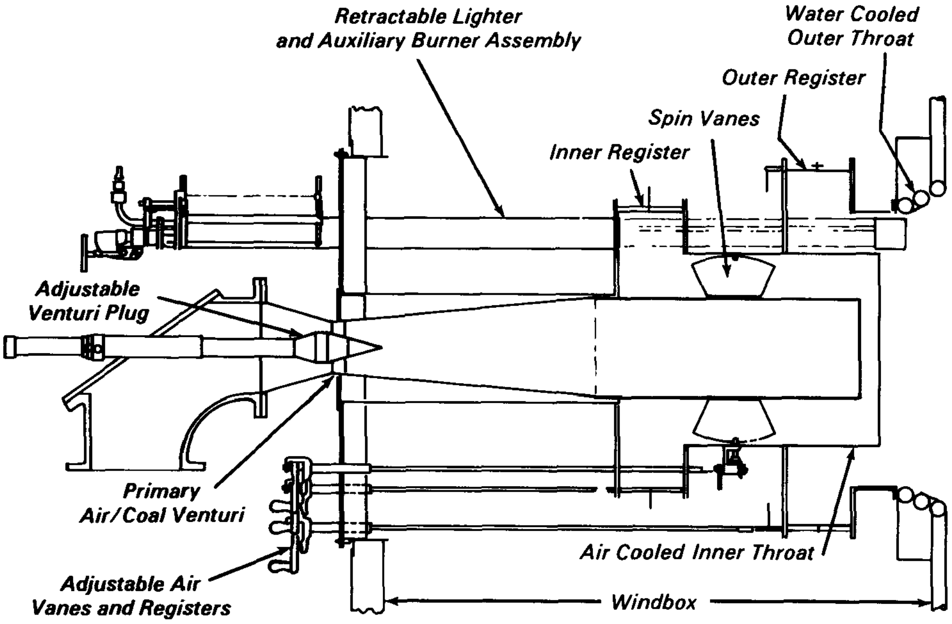

Figure 2. Dual register burner.

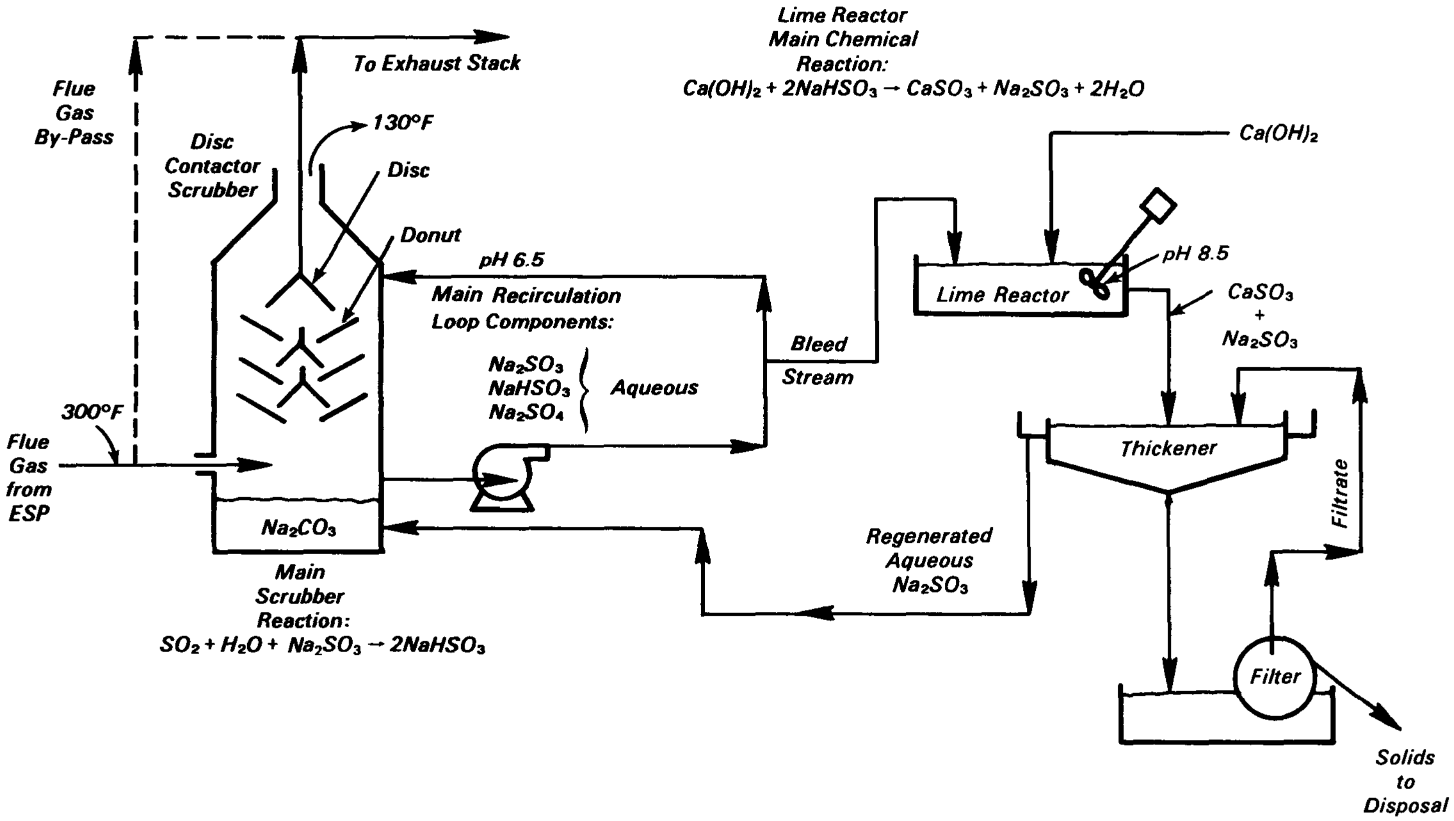

Figure 1. FMC Corporation's concentrated double alkali simplified process flow diagram.

(less than 70 percent of the NSPS emissions limitations). The burner limits NO_x formation to acceptable levels, by utilizing a relatively long, narrow flame. The initial burning in the center of the flame is in a fuel rich mixture. Turbulence is kept low to limit the degree of the fuel/air mixing to that which is required to sustain combustion and complete burning. The remaining air needed to complete combustion is admitted through a separate chamber to totally surround the inner combustion zone. The resulting slow but efficient combustion spreads heat evenly through the furnace, lowering flame temperature and reducing NO_x formation.

Particulates are removed from the flue gases by a Buell Envirotech coldside electrostatic precipitator (ESP) prior to SO_2 removal. Tests with the scrubber offline indicate that the ESP meets the standard of 0.1 lb/10^6 Btu (43 ng/J). Opacity monitors are at the ESP outlets, prior to the scrubbers, for compliance monitoring.

Program Approach

The technical program emphasized selected program objectives. The primary objective was to determine the SO_2 collection efficiency of each of the two scrubber modules and the NO_x emissions from the B&W boiler. A secondary, but also important, objective was to determine the influence of process parameters on SO_2 performance. Emissions of NO_x were also measured, and the effects of any variations in flue gas oxygen or CO content were evaluated. However, since NO_x emissions were approximately 0.5 lb/10^6 Btu, no variations in the operation of the dual register burners were suggested.

The primary program data were acquired using a mobile continuous emissions monitoring laboratory maintained by IERL-RTP. This system was used to acquire the appropriate emissions and diluent data at the inlets to and outlets from the parallel scrubber modules. Concurrent with the emissions data collection, applicable boiler and scrubber process data were continuously acquired. These data provided process documentation for the emissions data on a real time basis. The process and emissions data files were subsequently used to determine factors affecting the emission control performance of the unit.

Factors that may affect SO_2 collection efficiency were an important focus of the process evaluation. It was anticipated that, for example, gas flow to each module might vary efficiency by 85 - 92 percent. Absorber pH, sulfite ion concentration, and regenerator flow are other important factors affecting SO_2 efficiency which were considered in the initial tests.

Emissions parameters which applied to the SO_2 control device included inlet and outlet SO_2 and diluent levels. These measurements were conducted at the specified locations on both modules. In addition, the mobile laboratory could measure the gas flow rate through each module. Measurements related to NO_x included total NO_x prior to the scrubber, CO as a gauge for combustion upset conditions, excess air prior to the air preheater, and diluent at the monitoring points for NO_x.

In addition to the measurements/parameters mentioned above, other process signals logged from the plant control panel included various scrubber and boiler parameters and (initially) the plant's stack emissions measurements for SO_2/O_2. However, the stack emissions measurements were discarded due to the erratic behavior of this system. All data parameters were logged and processed by an onboard minicomputer.

Utilizing data obtained during the data acquisition phase of the program, GCA evaluated the performance of the NO_x and SO_2 control equipment. Throughout the data collection phase, a field engineer periodically observed and reviewed the data. At the end of the data collection phase, all data were evaluated to fulfill the program objectives.

Operational Profile

A. B. Brown Unit 1 is the most expensive plant to operate in the SIGECO system; therefore, it is the last unit to be dispatched and the first to reduce load. The actual load profile during the test program depended on the weather and the availability of other units. In addition A. B. Brown Unit 1 experienced pulverizer problems that forced load reductions. The average load during the test program was 50 percent of capacity, although both higher and lower loads were encountered. Figure 3 shows an hourly frequency distribution for boiler load. About 70 percent of the hourly average boiler loads were below 130 MWe; the average was 129 MWe.

Average excess air near the boiler (prior to the air preheater) was 36 percent. Oxygen concentrations at the same point averaged 5.45 percent. The range of observed oxygen concentrations is shown in the frequency distribution of Figure 4.

Test Results

Data from the test program are summarized in three categories: emissions control performance, effects of process variables on emission control performance, and measurement system results.

Emissions Control Performance

NO_x Emissions

The mean NO_x emission rate for the full test program was 163 ng/J (0.38 lb/10^6 Btu). All the hourly readings were below 210 ng/J (0.49 lb/10^6 Btu) which is equivalent to 70 percent of the 1971 NSPS. Daily average emission rates were 135-219 ng/J (0.3-0.51 lb/10^6 Btu).

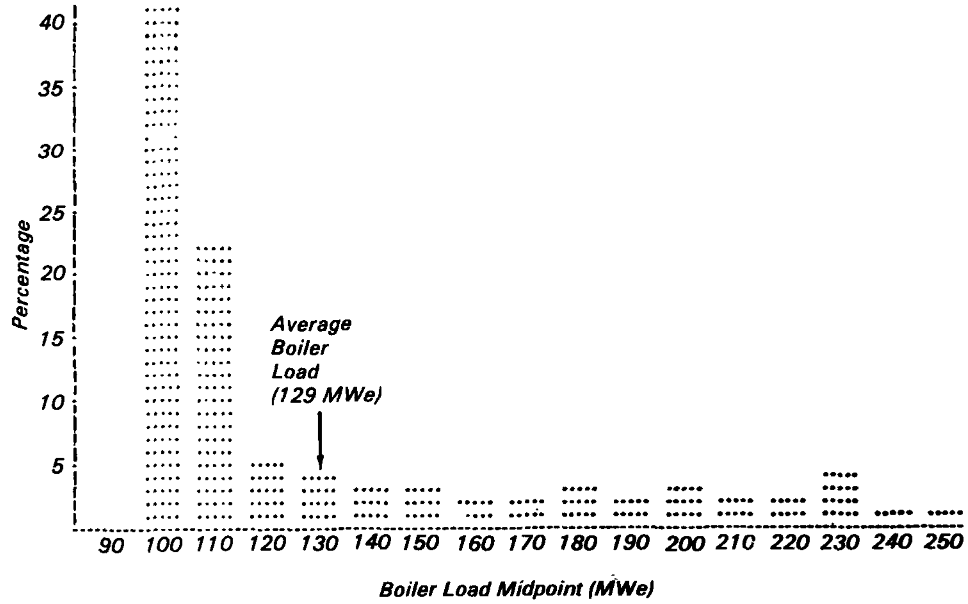

Figure 3. Hourly frequency distribution for boiler load.

The 30-day rolling averages for NO_x emissions were all below 168 ng/J (0.4 lb/10^6 Btu), ranging from 160 to 167 ng/J (0.370 to 0.388 lb/10^6 Btu) as shown in Table 1. Table 2 is a statistical summary of the NO_x data.

SO_2 Emissions

Emissions of SO_2 are controlled by two parallel FMC dual-alkali scrubbers. For these tests, SIGECO operated the FGD system in its customary manner to meet required regulations. The system was not operated to optimize SO_2 collection efficiency. Valid data were collected for the performance of the north module for 68 days and for the south module for 62 days. This data collection spanned a total time frame of 70 days. The boiler was shut down for 2 days late in the program due to pulverizer problems, and the south scrubber module model was offline during the first 5 days of the test program as a result of recirculation pump failure.

The mean SO_2 removal efficiency for the north module was 88.4 percent compared to 86.6 percent for the south module for the 30-day rolling average. The higher average efficiency for the north module was, in part, attributable to the first 6 days of data collection when the north module averaged 95.2 percent efficiency and the south module was not operating. Tables 2 and 3 and Figure 5 show the 30-day rolling averages beginning at the 30th day. The decline in the rolling average SO_2 collection efficiency coincides with the reduction in average boiler load which was lower during the end of the test program. As shown by the dotted line in Figure 5, the scrubber system consistently operated above the design guarantee.

Emissions of SO_2 for the north module averaged 344 ng/J (0.80 lb/10^6 Btu), while the south module averaged 391 ng/J (0.91 lb/10^6 Btu) on a daily average basis. Thirty-day rolling averages for the SO_2 emissions are shown in Table 3 and Figure 6. Thirty-day rolling averages for the south tower were 355-418 ng/J (0.81 - 0.98 lb/10^6 Btu).

Effects of Process Variables on Emission Control Performance

Various regression techniques were used to investigate possible effects of process variables on emission control performance. Hourly data consisting of up to 1400 hours were used to develop correlations between process variables and emission control performance as indicated by NO_x emission rates and SO_2 efficiencies from each module.

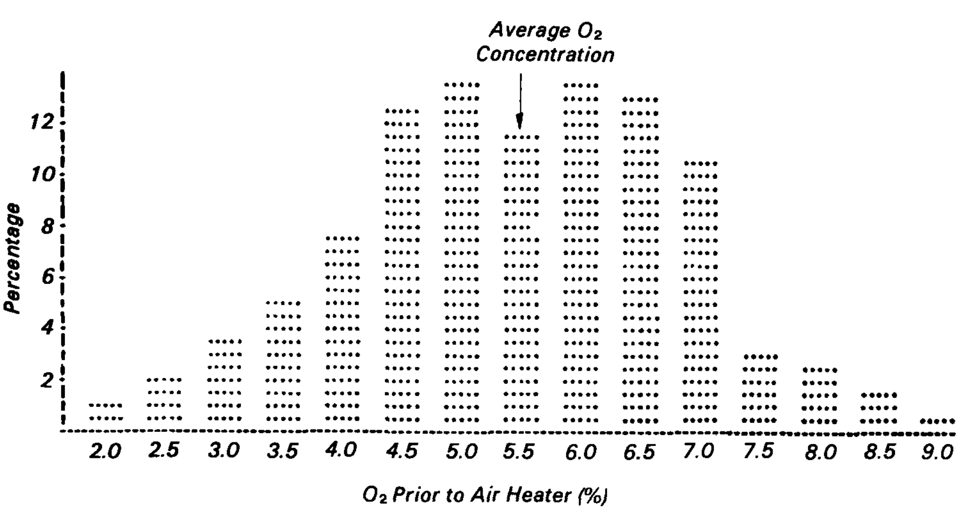

Figure 4. *Hourly frequency distribution for oxygen concentration prior to the air preheater.*

Table 1. *NO_x Emissions, 30-Day Rolling Averages*

Day	Blr load (MWe)	Daily average NO_x (ng/J)	30-day rolling average (ng/J)	Day	Blr load (MWe)	Daily average NO_x (ng/J)	30-day rolling average (ng/J)
212	99	149	[a]	247	102	b	162
213	141	155	[a]	248	112	168	162
214	137	170	[a]	249	99	163	163
215	118	159	[a]	250	123	164	162
216	132	173	[a]	251	158	143	162
217	113	166	[a]	252	153	135	162
218	142	170	[a]	253	167	146	162
219	115	162	[a]	254	191	151	161
220	105	166	[a]	255	117	154	161
221	104	168	[a]	256	109	153	161
222	160	167	[a]	257	157	144	160
223	121	179	[a]	258	114	166	161
224	134	166	[a]	259	122	173	160
225	161	166	[a]	260	100	172	161
226	178	161	[a]	261	97	175	160
227	101	161	[a]	262[c]	-	-	-
228	102	169	[a]	263[c]	-	-	-
229	112	171	[a]	264	98	219	160
230	173	174	[a]	265	106	209	161
231	173	174	[a]	266	106	198	162
232	178	167	[a]	267	119	191	163
233	166	170	[a]	268	109	190	164
234	131	180	[a]	269	107	189	164
235	143	170	[a]	270	106	196	164
236	209	158	[a]	271	108	200	164
237	177	155	[a]	272	120	204	165
238	129	162	[a]	273	143	189	166
239	106	168	[a]	274	126	139	167
240	109	164	[a]	275	105	184	167
241	141	163	160	276	105	187	167
242	142	154	160	277	101	175	167
243	139	152	160	278	156	172	166
244	111	161	161	279	134	190	166
245	104	159	161	280	151	182	166
246	102	[b]	161	281	191	166	167

[a] *Not applicable.*
[b] *Insufficient data (<18 hrs).*
[c] *Boiler down.*

Table 2. *Unit 1 - Performance Summary Statistics*

Averaging period	*Statistical parameter*	*Sulfur emissions (ng/J)*		*Tower efficiency (%)*		*NO_x Emissions*
		North	*South*	*North*	*South*	
Hourly	*Mean*	*341*	*391*	*88.0*	*86.5*	*163*
	Std Dev	*115*	*101*	*4.1*	*3.4*	*15.8*
	Min	*29*	*102*	*75.9*	*71.2*	*76*
	Max	*662*	*887*	*99.0*	*96.7*	*209*
Daily	*Mean*	*344*	*391*	*88.0*	*86.5*	*163*
	Std Dev	*92*	*62*	*3.3*	*2.2*	*10.9*
	Min	*67*	*216*	*81.1*	*82.5*	*135*
	Max	*544*	*600*	*97.7*	*92.2*	*219*
30-day Rolling	*Mean*	*341*	*394*	*88.4*	*86.6*	*163*
	Std Dev	*35*	*19*	*1.6*	*1.0*	*2.5*
	Min	*274*	*355*	*85.8*	*85.3*	*160*
	Max	*396*	*418*	*90.5*	*88.0*	*167*

Table 3. *SO_2 Performance: Daily and 30-Day Rolling Average*

		North tower				*South tower*			
		Outlet emissions (ng/J)		*Efficiencies(%)*		*Outlet emissions (ng/J)*		*Efficiencies(%)*	
Day	*Blr load (MWe)*	*Daily*	*30-day Rolling*	*Daily*	*30-day Rolling*	*Daily*	*30-day Rolling*	*Daily*	*30-day Rolling*
212	*99*	*148*	*a*	*94.5*	*a*	*b*	*a*	*b*	*a*
213	*141*	*129*	*a*	*95.6*	*a*	*b*	*a*	*b*	*a*
214	*137*	*67*	*a*	*97.7*	*a*	*b*	*a*	*b*	*a*
215	*118*	*134*	*a*	*95.2*	*a*	*b*	*a*	*b*	*a*
216	*132*	*158*	*a*	*94.4*	*a*	*b*	*a*	*b*	*a*
217	*113*	*170*	*a*	*93.5*	*a*	*b*	*a*	*b*	*a*
218	*142*	*235*	*a*	*91.0*	*a*	*362*	*a*	*86.3*	*a*
219	*115*	*396*	*a*	*85.3*	*a*	*413*	*a*	*84.8*	*a*
220	*105*	*503*	*a*	*81.1*	*a*	*433*	*a*	*83.8*	*a*
221	*104*	*357*	*a*	*86.6*	*a*	*293*	*a*	*88.9*	*a*
222	*160*	*237*	*a*	*91.3*	*a*	*218*	*a*	*92.0*	*a*
223	*121*	*288*	*a*	*89.4*	*a*	*216*	*a*	*92.2*	*a*
224	*134*	*241*	*a*	*91.6*	*a*	*330*	*a*	*88.6*	*a*
225	*181*	*315*	*a*	*89.6*	*a*	*382*	*a*	*87.6*	*a*
226	*178*	*273*	*a*	*91.0*	*a*	*365*	*a*	*88.1*	*a*
227	*101*	*258*	*a*	*93.0*	*a*	*392*	*a*	*88.8*	*a*
228	*102*	*247*	*a*	*91.3*	*a*	*343*	*a*	*88.1*	*a*
229	*112*	*239*	*a*	*91.7*	*a*	*328*	*a*	*88.7*	*a*
230	*173*	*182*	*a*	*93.8*	*a*	*299*	*a*	*90.1*	*a*
231	*173*	*293*	*a*	*90.6*	*a*	*423*	*a*	*86.3*	*a*
232	*178*	*252*	*a*	*91.4*	*a*	*274*	*a*	*90.6*	*a*
233	*166*	*211*	*a*	*93.2*	*a*	*245*	*a*	*92.0*	*a*
234	*131*	*242*	*a*	*92.2*	*a*	*325*	*a*	*89.5*	*a*
235	*143*	*323*	*a*	*89.5*	*a*	*404*	*a*	*86.8*	*a*
236	*209*	*314*	*a*	*90.0*	*a*	*358*	*a*	*88.4*	*a*
237	*177*	*242*	*a*	*92.1*	*a*	*331*	*a*	*89.2*	*a*
238	*129*	*398*	*a*	*86.9*	*a*	*379*	*a*	*87.6*	*a*
239	*106*	*372*	*a*	*87.5*	*a*	*461*	*a*	*84.6*	*a*
240	*109*	*322*	*a*	*89.0*	*a*	*364*	*a*	*87.6*	*a*
241	*141*	*306*	*274*	*89.7*	*90.5*	*440*	*355*	*85.1*	*88.0*
242	*142*	*373*	*278*	*87.3*	*90.4*	*397*	*357*	*86.3*	*87.9*
243	*139*	*464*	*283*	*83.9*	*90.2*	*484*	*359*	*83.2*	*87.8*
244	*111*	*465*	*286*	*83.8*	*90.1*	*477*	*360*	*83.3*	*87.7*
245	*104*	*434*	*297*	*83.9*	*89.9*	*496*	*366*	*82.5*	*87.7*
246	*102*	*445*	*304*	*c*	*89.8*	*523*	*370*	*c*	*87.7*
247	*102*	*506*	*313*	*c*	*89.6*	*600*	*375*	*c*	*87.7*
248	*112*	*524*	*320*	*84.5*	*89.5*	*493*	*377*	*84.2*	*87.8*
249	*99*	*410*	*319*	*86.7*	*89.7*	*478*	*378*	*84.6*	*87.9*
250	*123*	*383*	*321*	*87.4*	*89.5*	*438*	*380*	*85.6*	*87.8*
251	*158*	*332*	*319*	*87.9*	*89.7*	*441*	*383*	*83.7*	*87.7*
252	*153*	*274*	*320*	*89.3*	*89.6*	*353*	*386*	*86.2*	*87.5*
253	*167*	*244*	*318*	*91.7*	*89.7*	*328*	*384*	*88.9*	*87.6*
254	*191*	*277*	*319*	*89.7*	*89.6*	*365*	*386*	*86.3*	*87.5*
255	*117*	*283*	*318*	*89.1*	*89.6*	*359*	*385*	*86.2*	*87.4*
256	*109*	*345*	*320*	*87.7*	*89.5*	*451*	*388*	*83.8*	*87.3*

Oxides of Nitrogen

Emissions of NO_x appeared to be related to the flue gas oxygen concentration as measured at the inlet locations (the north tower inlet value was used), boiler load, and CO concentration. It was expected that the oxygen concentration in the boiler, as indicated by the concentration prior to the air preheater, might affect NO_x emissions, but this proved to be a very weak correlation.

The equation selected to predict NO_x emissions is:

$$NO_x\ (ng/J) = 27.8 + 12.9\ (O_2,\ \%) + 0.216\ (\text{load, MWe}) - 0.0495\ (\text{CO, ppm}) \qquad (1)$$

This equation explained 52 percent of the variation in NO_x emissions and was highly significant as indicated by the F value of 491. The predicted and measured NO_x emissions are compared in Figure 7. If the linear regression explained all the variation in NO_x emission rates, all the points would fall on the indicated 45 degree line. Because the selected equation explains 52 percent of the variation in emissions, the data points are scattered around its 45 degree line.

The linear regression equation developed for the NO_x data collected at A. B. Brown defines a real and statistically significant relationship that was observed in the data base. It does not prove a physical or chemical cause and effect relationship nor should it be applied to data from other sites. Further investigation of the observed relationship between process variables and emissions may be appropriate.

Sulfur Dioxide

The development of correlations between SO_2 control (efficiency) and process parameters was approached using venturi scrubber models as background information. According to these models, the main variable which affects collection efficiency is liquid drop surface area. The surface area is directly proportional to the flue gas velocity. The higher the gas velocity, the smaller the drop size and, consequently, the larger the surface area an atomized liquid will exhibit.

Similarly, FMC's tower design depends on gas velocity for atomization. Consequently, these towers are expected to exhibit higher collection efficiencies at full loads.

Collection efficiencies for both towers were affected by gas flow only as shown by the equations below:

North Module:

$$\text{eff} = 6.4\text{x}10^{-7}\ (\text{flow})^{2.5} - 3.4\text{x}10^{-6}\ (\text{flow})^{3.5} + 4.7\text{x}10^{-9}\ (\text{flow})^{4.5} \qquad (2)$$

$$R^2 = 0.9814 \text{ for } N = 530$$

Table 3. *(Continued)*

Day	Blr load (MWe)	North tower				South tower			
		Outlet emissions (ng/J)		Efficiencies (%)		Outlet emissions (ng/J)		Efficiencies (%)	
		Daily	30-day Rolling	Daily	30-day Rolling	Daily	30-day Rolling	Daily	30-day Rolling
257	157	325	322	88.3	89.5	373	387	86.5	87.2
258	114	298	324	89.1	89.4	355	387	87.1	87.2
259	122	360	326	86.6	89.4	429	389	84.0	87.2
260	100	386	333	85.5	89.0	446	394	83.3	86.9
261	97	402	336	85.2	88.8	461	395	83.0	86.8
262	d	d	d	d	d	d	d	d	d
263	d	d	d	d	d	d	d	d	d
264	98	418	347	84.7	88.4	c	407	c	86.3
265	106	443	352	83.3	88.1	454	409	83.1	86.1
266	106	438	357	84.2	87.8	462	413	83.3	85.8
267	119	409	363	85.1	87.4	424	417	84.5	85.6
268	109	407	364	85.4	87.4	408	418	85.4	85.5
269	107	376	364	86.3	87.3	362	414	86.9	85.6
270	106	399	367	85.6	87.1	382	415	86.3	85.6
271	108	436	372	84.3	86.9	424	414	84.8	85.5
272	120	394	373	85.7	86.8	388	414	86.0	85.5
273	143	441	375	84.2	86.7	368	412	86.7	85.6
274	126	474	378	83.6	86.6	385	412	86.8	85.6
275	105	544	382	81.6	86.3	510	413	83.1	85.4
276	105	524	389	82.2	86.1	490	414	83.5	85.4
277	101	517	393	82.1	85.9	489	413	83.2	85.3
278	156	442	392	85.2	85.9	388	412	86.8	85.3
279	134	422	395	86.3	85.8	380	410	87.1	85.4
280	151	373	395	87.1	85.8	358	407	87.8	85.4
281	191	365	396	87.4	85.8	318	405	89.1	85.4

[a] *Not applicable.*
[b] *Scrubber module offline.*
[c] *Insufficient data (<18 hrs).*
[d] *Boiler offline.*

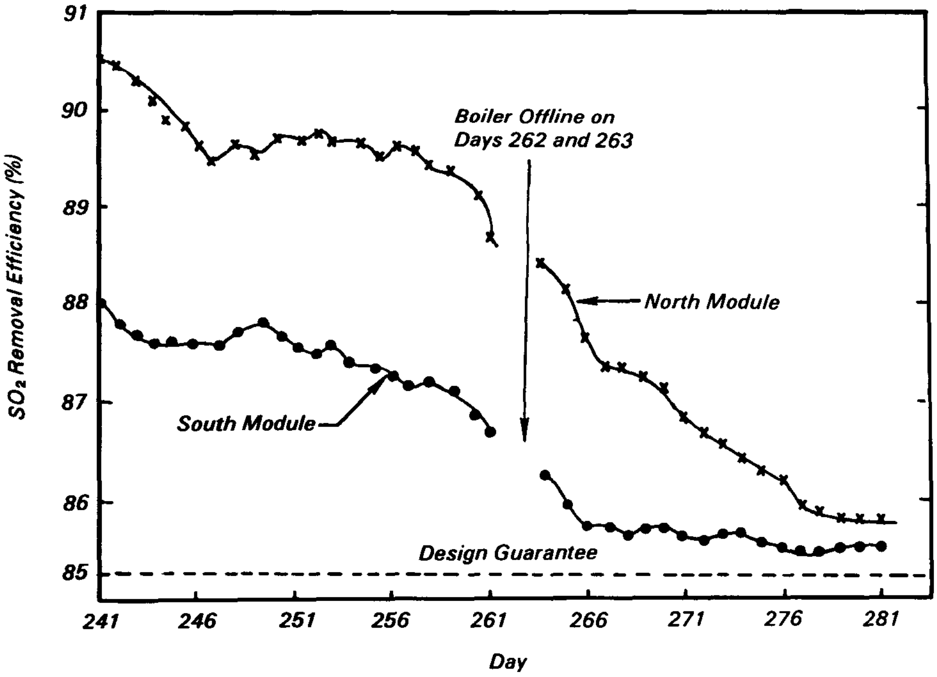

Figure 5. *SO_2 efficiency, 30 day rolling average.*

South Module:

$$eff = 1\text{x}10^{-3}\,(flow)^{2.5} - 6.3\text{x}10^{-6}\,(flow)^{3.5} + 1.0\text{x}10^{-8}\,(flow)^{4.5} \qquad (3)$$

$$R^2 = 0.9280 \text{ for } N = 506$$

where eff is the SO_2 removal efficiency (%),
flow is the gas flow rate (10^3 acfm),
R^2 = goodness of fit constant, and
N = number of data points analyzed.

These equations describe greater than 92 percent of the process variation for the data segment analyzed. Note, however, that these correlations may indicate only the data set obtained from this test site; they may not represent performances which may be exhibited by other dual alkali systems.

As long as the pH of the system is in tolerance, the variation of control performance is only a function of gas flow rate. In the FMC system, the scrubbants are highly buffered and automatically regenerated. In addition, the liquid circulation rate is held constant through the tower and regenerated automatically as required.

Figure 8 is a plot of SO_2 removal efficiency as a function of gas flow rate. As shown, the removal efficiency is only affected by the gas flow rate through the tower as long as the pH of the system is within design tolerances. According to the data set and the extrapolation of the curve, one can expect a removal efficiency approaching 90 percent at a gas flow rate of 400,000 acfm. As stated above, this plot depicts a trend in the data and should not be applied to other dual alkali scrubber systems.

No equations were generated to describe outlet emission performance, since the equations describing efficiency can also be rearranged to describe outlet emission rates.

Measurement System Results

Operational Experience

The mobile emissions laboratory, used to collect the primary emissions data, initially was anticipated to require a setup and checkout period of about 1 month. Subsequently, 1 week was scheduled for the performance specifications tests designed to assess the precision and relative accuracy of the measurement system. Actual setup and commencement of monitoring required an additional 6 weeks for equipment troubleshooting, remedial modifications and subsequent checkout.

Problems most commonly encountered throughout this program involved leakage within the extraction system and a spurious voltage induction problem which caused the baseline of the analytical instrumentation to shift. The latter problem was reme-

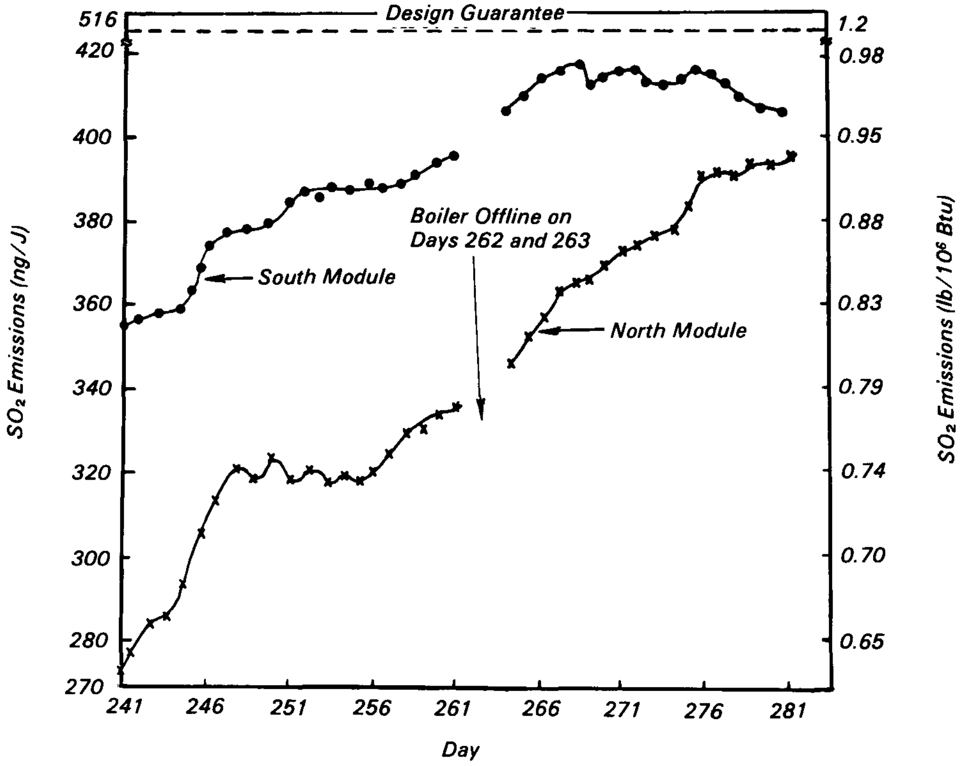

Figure 6. *SO_2 emissions, 30 day rolling average.*

died prior to monitoring. Leakage throughout the system was due to valve diaphragm ruptures and the flowing of Teflon sample lines at connection points throughout the system. These problems were remedied by system modifications.

After correcting the system problems, approximately 68 days of data were collected from July 31 through October 8, 1981. During this time, the plant was offline 2 days.

After system start-up, very little data loss resulted from hardware failure. Hardware availability during the program approached 98 percent, while the data availability rate (including primary and backup data systems) approached 95 percent. Valid data capture was approximately 93 percent for the primary emission parameters, and 70 percent for associated process measurements. The process data capture rate was significantly lower than the emissions capture rate because these signals were not connected to a backup logger and most were often not available from control room log sheets.

During the tests, the mobile laboratory was attended by a full-time operator. Daily, the operator conducted calibration checks, performed routine maintenance, accessed the previous day of data (printouts), and filled out daily maintenance check lists and site logs. Most of the day was spent reducing data and performing program related paperwork. All data were processed into report format by the onsite computer.

Stratification Results

Before initiating the routine monitoring phase, stratification tests were conducted at each monitoring location. This test sequence ensured that the probe locations would provide representative flue gas samples. The procedure involves traversing the cross-sectional area of the flue gas stream to define the spatial variability of the analyte of interest. This procedure is normally conducted where the probability of stratification is high (e.g., after wet scrubbers). Periodically, the tests were repeated to verify that the representativeness of the flue gas samples remained unchanged.

Table 4 summarizes the stratification results. Data in the first two columns were obtained during the initial stratification tests. Based on these initial tests the probes were placed in the geometric center of each monitoring location. Subsequent tests at the outlet locations indicated that the average points of concentration at the outlet locations were unchanged. Further testing was not conducted at the inlets due to the low probability of variable stratification.

Performance Specifications Tests

Results of the performance specifications tests are summarized in Tables 5 and 6. Due to a shortage in span gases, the optional 2 hour drift test was not conducted. All analyzers conformed to the 24 hour drift and calibration error criteria, except the outlet SO_2 analyzer (which exceeded the midscale calibration error criterion) and the NO_x analyzer (which exceeded the calibration drift and the high scale calibration error criteria). Due to these results, the NO_x span gases were analyzed to reverify the "true" concentration; however, results of the analyses did not alter the performance results.

Results of the relative accuracy testing are shown in Table 6. Generally speaking, the results were favorable and, except for the NO_x results, were less than the stated compliance limit of 20.0 percent relative accuracy in terms of emission rate. The results for the NO_x analyzer were 30 percent in terms of emission rate. This high value for relative accuracy is the result of a large confidence interval and not an absolute bias. This denotes random scatter when comparing the differences between the reference method and the analyzer.

Emission rates for SO_2 were calculated using both the O_2- and CO_2-based "F" factors. As shown by the results, the different methods for calculating the emission rate in some cases did not yield comparable relative accuracy results. This discrepancy may be a result of the high CO_2 relative accuracy (e.g., 0.8 percent CO_2) and the opposite relative bias for the O_2 and CO_2 analyzers.

Monitoring System Precision and Accuracy

Individual instrument precision and accuracy estimates were determined according to the proposed Quality Assurance Regulations, scheduled to be promulgated as 40 CFR 60, Appendix F. These precision estimates were determined by GCA, utilizing the daily zero and span data; the accuracy of each instrument was assessed by an independent auditor.

Results of instrument precision and accuracy are listed in Table 7. Precision estimates for the total data collection period appear satisfactory: results of the performance audit were "*acceptable*" as defined by the auditors.

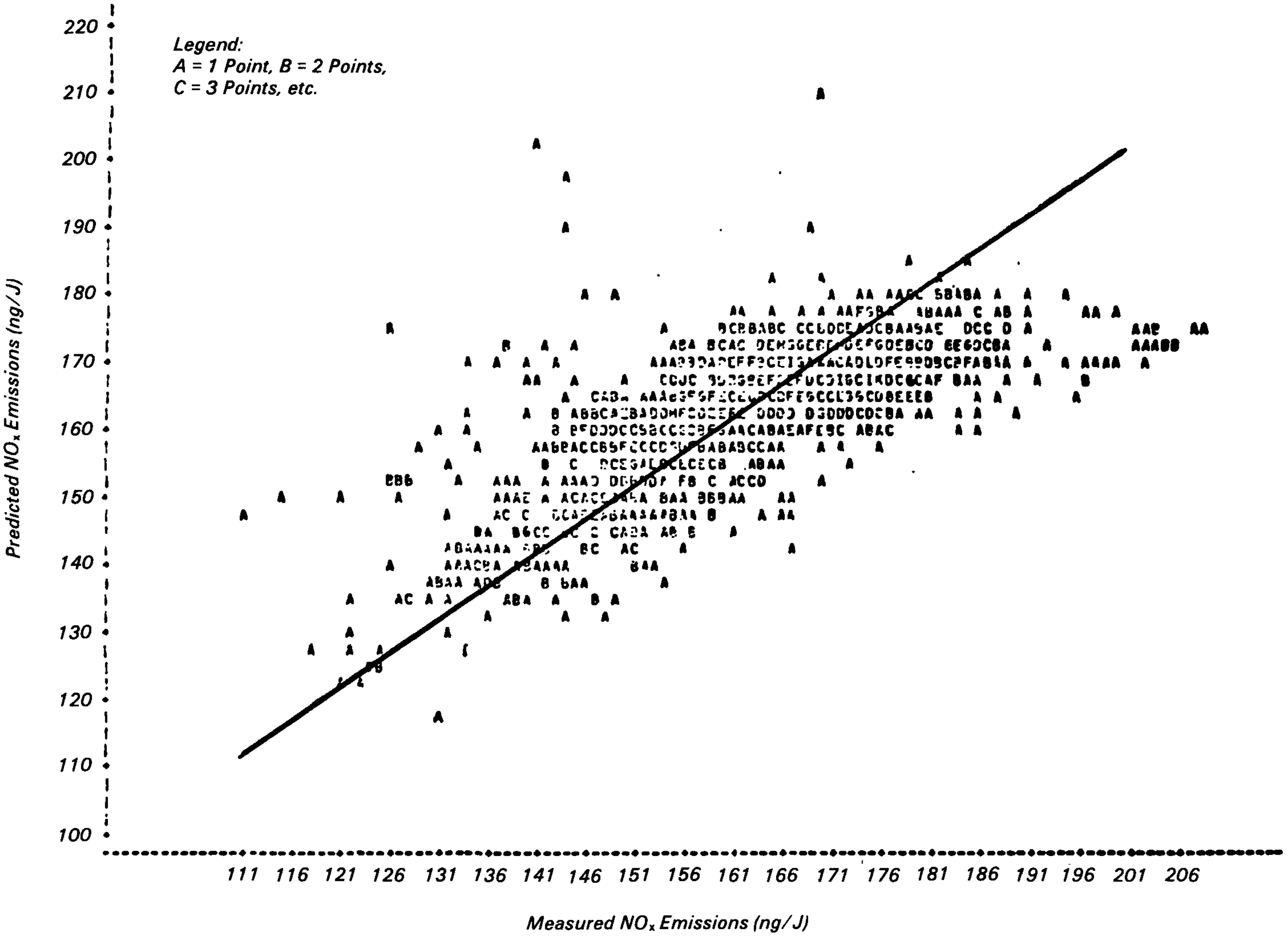

Figure 7. Comparison of hourly predicted NO_x and measured NO_x emissions.

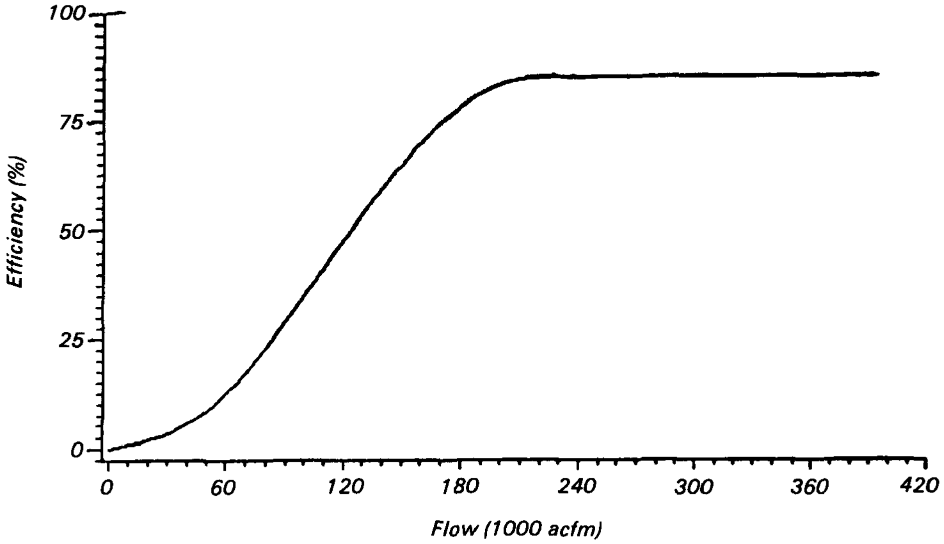

Figure 8. Plot of gas flow rate as a function of SO_2 removal efficiency.

Table 4. A.B. Brown Stratification Test Summary

	Outlets (6/30)		Inlets (7/8)		Outlets (9/17)		Outlets (10/8)	
	Full load		Full load		Low load		Low load	
Port	North (ng/J)	South (ng/J)	North (ng/J)	South (ng/J)	North (ng/J)	South (ng/J)	North (ng/J)	South (ng/J)
Mean[a]	512	169	2999	3031	312	381	294	251
S[b]	32	48	103	31	36	31	26	26
Ref/mean[c]	1.00	1.08	1.05	1.0	1.02	1.01	0.89	0.96

[a] Average of all traverse measurements (ng/J).
[b] Standard deviation of all traverse measurements (ng/J).
[c] Ratio of measurement at probe placement point to mean concentration.

Table 5. 24-Hour Zero and Calibration Drift Summary (A. B. Brown)

	24-hour drift		Calibration error	
Parameter	Zero[a] (%)	Calibration[a] (%)	Mid (%)	High (%)
Inlet SO_2	0.5	1.1	4.1	0.3
Outlet SO_2	1.6	4.9[b]	9.4[b]	3.6
Inlet O_2	0.1 (O_2)	0.1 (O_2)	1.5	1.5
Outlet O_2	0.1 (O_2)	0.2 (O_2)	1.3	3.4
Inlet NO_x	0.1	3.3[b]	1.6	5.6[b]
Inlet CO	0.9	1.3	3.2	2.5
Outlet CO_2	0.2 (CO_2)	0.3 (CO_2)	1.7	3.8

[a] O_2 and CO_2 results are presented in terms of O_2 and CO_2 concentrations, not percent of full scale.
[b] Exceeded performance specifications test criteria.

Table 6. *Summary of Relative Accuracy Test Results for A. B. Brown Unit 1*

	North Tower (% RA or % CO_2/O_2)						South Tower (% RA or % CO_2/O_2)					
	Inlet			Outlet			Inlet			Outlet		
Parameter	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
SO_2	16.9	5.5	21.4	16.4	14.6	13.5	28.7	12.5	14.7	14.8	14.7	18.4
O_2	0.46	0.30	1.10	0.13	1.14	0.55	0.53	0.14	1.09	0.40	0.62	1.33
CO_2	---	---	---	0.81	2.29	1.17	---	---	---	1.98	0.97	1.14
NO_x	23.9	29.0	26.5	---	---	---	[a]	[a]	[a]	---	---	---
$E_{SO_2(O_2F)}$[b]	17.3	6.1	13.6	17.0	12.9	14.1	28.6[d]	12.5	12.8	11.8	14.2	14.4
$E_{SO_2(CO_2F)}$[c]	---	---	---	21.0[d]	27.9[d]	8.7	---	---	---	16.1	12.8	19.2
$E_{NO\,(O_2F)}$	36.6[d]	31.0[d]	23.9[d]	---	---	---	[a]	[a]	[a]	---	---	---

[a] Test runs invalidated.

[b] Relative accuracy based on O_2 "F" factor emission rate.

[c] Relative accuracy based on CO_2 "F" factor emission rate.

[d] Exceeds 20 percent relative accuracy based on emission rate.

---Not applicable.

Table 7. *A.B. Brown Precision Estimate Results*

			Zero precision estimate (%)		Span precision estimate (%)	
Location	Parameter	Month	Lower	Upper	Lower	Upper
Inlet	SO_2 (Horiba)	August	-0.9	0.5	-1.6	2.3
		September	-0.3	0.8	-1.5	1.5
		October[a]	-0.2	0.8	-0.4	-3.9
	O_2 (MSA)	August	-1.0	0.7	-4.0	1.8
		September	-0.3	0.0	-1.8	1.4
		October[a]	-0.3	0.0	-2.7	1.3
Outlet	SO_2 (DuPont)	August	-7.2	6.1	-16.2	9.1
		September	-8.2	12.5	-8.3	4.4
		October[a]	-2.3	2.9	-6.6	5.0
	O_2 (MSA)	August	0.0	0.5	-2.5	1.7
		September	0.0	0.6	3.7	4.6
		October[a]	-0.1	0.3	0.6	0.8
	CO_2 (Horiba)	August	-0.5	1.2	-4.0	0.8
		September	-0.5	1.3	-2.7	2.5
		October[a]	0.5	0.6	1.8	4.0

[a] Less than 10 entries used for calculating these estimates.

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J. David Mobley is the EPA Project Officer (see below).

The complete report consists of five volumes, entitled "Characterization of the NO_x and SO_2 Control Performances; Southern Indiana Gas & Electric Company, A. B. Brown Unit 1:" all five volumes are available as a set: Order No. PB 83-240 663; Cost: $91.00 or individually as—

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