United States
Environmental Protection
Agency

Research and Development

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

EPA-600/S7-82-065a Mar. 1983

Project Summary

The Adipic Acid Enhanced Flue Gas Desulfurization Process for Industrial Boilers: Volume 1. Field Test Results

P. A. Clarke, R. W. Gerstle, D. S. Henzel, K. W. Mason, and S. R. Sabatini

This study evaluated the effect of adding adipic acid on the SO_2 removal of a wet limestone flue gas desulfurization (FGD) system on a coal-fired industrial boiler at Rickenbacker Air National Guard Base near Columbus, OH. Emission data were collected in accordance with the regulations for SO_2 compliance data specified in the *Federal Register*. Test results show that adding adipic acid to the limestone slurry significantly improved the SO_2 removal efficiency of the FGD system. Limited baseline data on operations with limestone only indicated a performance level of 55 percent SO_2 removal. Adding about 2200 ppm of adipic acid to the limestone scrubbing systems, the unit's level of performance increased to an average of 94.3 percent SO_2 removal which was maintained within a standard deviation of 2.2 percent over a 30-day test period during which boiler load was 70 - 130 million Btu/hr and gas throughput varied 300 percent.

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

The report describes how the addition of adipic acid to a wet limestone scrubber system affects sulfur dioxide (SO_2) removal efficiency. The site selected for the test, Rickenbacker Air National Guard Base (RANGB) near Columbus, OH, has six spreader-stoker boilers with a total capacity of 222 GJ/h (210 x 10^6 Btu/h). The boilers produce hot water, primarily for space heating. SO_2 emissions are controlled by a scrubber system manufactured by Research-Cottrell under license from A. B. Bahco of Sweden. The FGD system, shown in Figure 1, consists of a mechanical collector, Swedish Bahco scrubber tower, limestone storage and handling system, clarifier (thickener), booster fan, sludge disposal pond, and associated ductwork, pumps, and controls. Table 1 gives key design parameters for the scrubbing system. During the test a mechanical dry feeder introduced the adipic acid into the scrubber system at the same location where fresh limestone is added.

Untreated flue gas from the individual boilers enters a common header equipped with a bypass stack and is fed through a mechanical collector for primary removal of particulates. The design removal efficiency of the mechanical collector is 70 percent. A fan then introduces the partially cleaned flue gas into the scrubbing tower for SO_2 removal.

The Bahco scrubber is a tower consisting of two inverted venturi scrubbing stages. Untreated gas entering the first stage is diverted down to impinge on the liquid slurry surface of the mill. The gas then rises through the first stage venturi, where it intimately mixes with the slurry droplets now entrained in it. The partially scrubbed gas is then diverted down onto the liquid slurry surface in the second-

Table 1. Design Process Information for Rickenbacker Air National Guard Base Scrubbing System

Total rating	*2600 Nm³/s (55,000 scfm)*
Number of boilers	*6*
Boiler capacity	*222 GJ/h (210 x 10^6 Btu/h)*
Number of separate FGD units	*1*
Control system vendor	*Research-Cottrell/Bahco*
Type of FGD system	*Retrofit*
Start-up date	*March 1976*
SO_2 removal efficiencies	*90%+ design with lime operation; lower with limestone operation*
Particulate removal efficiency	*98% design*
Water makeup	*Open loop*
Sludge or by-product disposal	*Unstabilized $CaSO_3/SO_4$ sludge to lined pond*

stage pan, and the process is repeated. The treated gas is then directed up into a cyclonic mist eliminator, where entrained slurry droplets are removed before the gas exits through a stub stack to the atmosphere.

A certified extractive continuous emission monitor (CEM) system and an onsite computer measured and recorded concentrations of SO_2 and O_2 in the flue gas stream. Equipment at RANGB includes a continuous SO_2 monitoring system on the scrubber, which was used during the test after some maintenance work and calibration. Research Triangle Institute, under contract to EPA, audited the monitoring system on March 5 and 6, 1981, and found it to be operating properly.

Both the certification (based on *Federal Register* procedures) and internal audits (based on certified SO_2 and O_2 gases) showed that the monitors were operating properly. Some problems entailing unscheduled maintenance were encountered during the initial 168-hour monitor conditioning period. Also, on March 20 a small leak was discovered in the SO_2 monitor internal valving system. Apparently, rich inlet gas had leaked through this valve into the outlet gas sample stream, causing a slightly higher outlet SO_2 concentration reading and correspondingly lower calculated SO_2 removal efficiency. The extent of the leak was determined by introducing audit gases and making manual SO_2 tests of the flue gases; a correction factor was applied to the outlet readings from March 18 until the leak was repaired on April 3.

Test Procedure

The adipic acid test period at RANGB was from February 9 to April 10, 1981, during which time the equipment was set up and calibrated and data were collected. The monitoring equipment began operating on February 13, but the first few weeks of the test were used for shakedown and calibration of the monitors. The data collected included measured SO_2 and O_2 concentrations in the gas stream at the scrubber inlet and outlet and chemical analyses of the scrubber slurry, limestone, and coal. Scrubber and boiler operating conditions were recorded several times daily.

The adipic acid feeder was set up for continuous addition of the adipic acid to the slaker--the same location at which fresh limestone is added. When large quantities were necessary to increase slurry concentrations, the adipic acid was manually introduced directly into the thickener tank because the sudden addition of adipic acid in large quantities to the slaker caused foaming in the slurry. This did not occur in the thickener.

Slurry was analyzed at the site, but periodic samples were also checked at the Base laboratory for quality control. The adipic acid analytical procedure utilized silicic acid and provided the concentration of all carboxylic acids, not just adipic. As indicated by the numbers in Figure 1, liquid samples were taken at (1) the limestone slurry feed into the scrubber, (2) the second-stage level tank, (3) the mill recycle loop (known as the mill pump sample), (4) the thickener inlet stream, (5) the thickener overflow, and (6) the thickener underflow stream. Because the limestone slurry feed sample was used as a control sample, it was taken twice a day. The mill pump sample was taken once a day, and samples were taken from all six locations once a week. Slurry solid samples, taken by filtering samples from the liquid sample streams, included the limestone slurry feed (once a week), the thickener inlet (three times a week), and the thickener underflow (once a week, usually while sludge was being pumped to the settling pond). Coal samples were taken once a day, and limestone samples were taken once a week. The coal samples were combined into weekly composites before being analyzed.

For highest SO_2 removal efficiency, best limestone utilization, and most efficient use of adipic acid, optimum scrubber operation was maintained by keeping the pH of the limestone dissolver tank slurry near 5.0. This was done by manually adjusting the limestone feed rate to correspond with changes in the boiler load. Except during occasional upsets in scrubber operations, the adipic acid feed rate remained constant at a concentration of 2000 - 2500 ppm throughout the test. On March 20 and 21 the limestone feed rate and adipic acid concentrations were increased in an effort to achieve still higher SO_2 removal efficiency.

From March 4 to April 10 the test was interrupted only twice because of scrubber operation. On March 23 the electrical power to the scrubber was interrupted, and on March 30 the scrubber was shut down because the thickener tank had plugged (apparently as the result of some plastic sheeting) and remained down until 8 a.m. on April 1. On April 10 the addition of adipic acid was stopped, and the continuous monitoring program was terminated. Sufficient data had been accumulated by that time, and warmer weather was resulting in increasingly reduced boiler loads.

Quality Assurance Plan for Continuous Monitoring

PEDCo performed a quality assurance check on the continuous emission monitoring system (CEMS) to ensure the reliability of the data collected. The check consisted of two distinct but equal functions: (1) assessment of the quality of the CEMS data by estimating precision and accuracy, and (2) the control and improvement of the quality of the CEMS data by implementng quality control policies and corrective actions. The second function was related to the first in that determination of data quality inadequacy resulted in an increase in the quality control effort until the data were considered acceptable.

The field operations included standard daily procedures for ensuring that the following activities were performed adequately.

Calibration of the CEMS

The CEMS was calibrated with gases of known SO_2 concentrations. Two gases and ambient air were run through the analyzer for each test mode (inlet and outlet). The results of each were re-

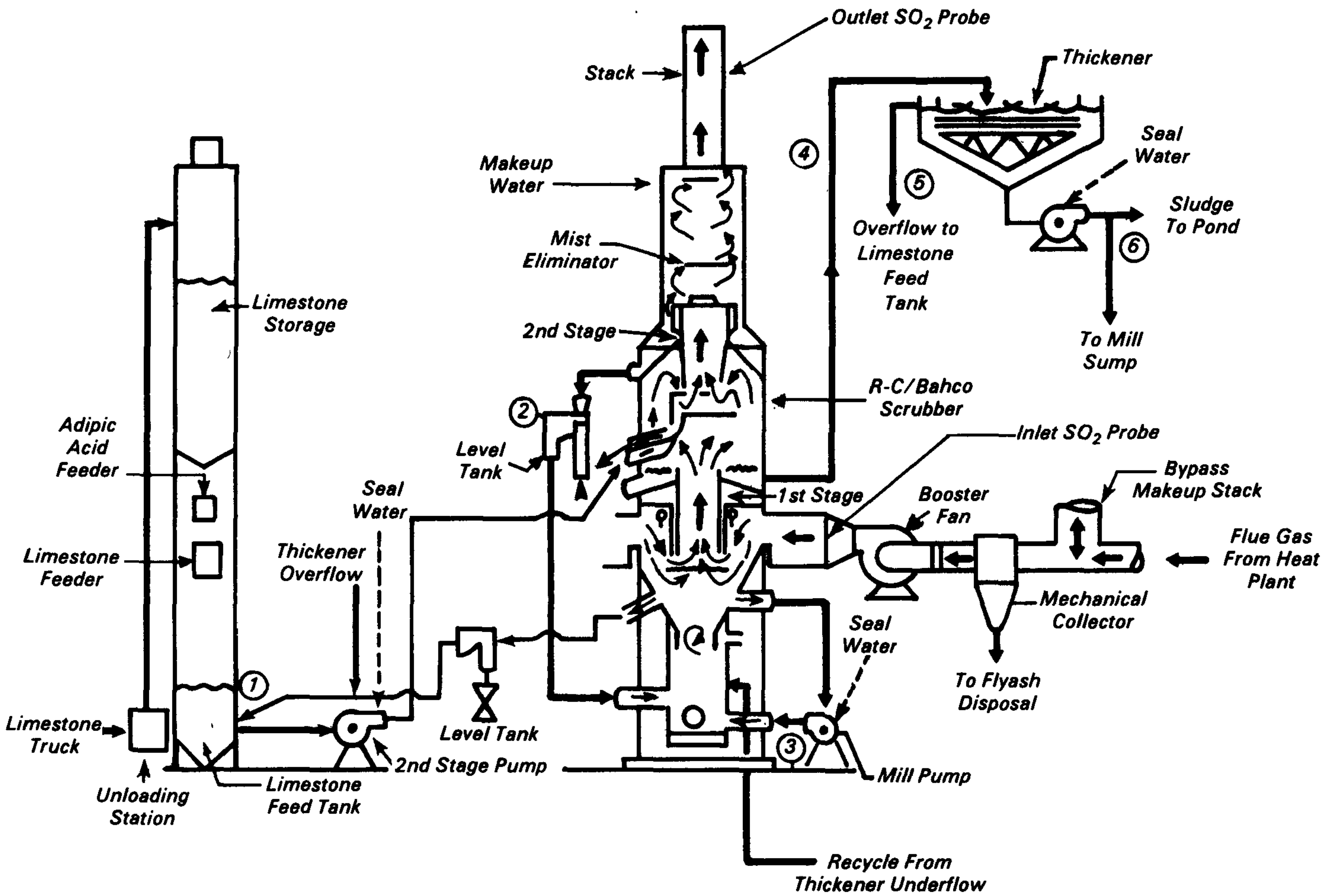

Figure 1. Flow diagram of the scrubber system at Rickenbacker.

corded, and any necessary adjustments were made.

All activities involved in routine calibration and adjustment of the CEMS were recorded daily in a standard calibration data log.

Calibration of Drift Determination

Daily initial calibration readings for all CEMS zero and span values were compared with the final calibration readings of the preceding day to determine if any change had occurred in 24 hours. Seven consecutive sets of these initial/final readings were recorded for each parameter to determine 24-hour drift.

Preventive Maintenance for CEMS

The CEMS was regularly inspected for problems that might lead to loss in operability or data quality. Each day the four separate systems of the CEMS were checked independently: the SO_2 analyzer, the O_2 analyzer, the instrument recorders, and the sampling interface.

Program of Corrective Action for Malfunctioning CEMS

Any CEMS malfunctions discovered during preventive maintenance checks prompted immediate corrective action. A complete log of all CEMS malfunctions and corrective actions was maintained.

Accuracy Assessment

PEDCo performed relative accuracy tests on the CEMS according to EPA reference methods and system audits with EPA-tested audit gases based on Standard Reference Materials (SRM).

Figures 2 and 3 show the locations of the CEM probes and reference method sampling ports for the inlet and outlet. Inlet and outlet sampling locations were selected to represent the streams tested and to achieve equivalence between manual and CEMS samples.

Performance Specification Test Regulations require that a minimum of 9 and a maximum of 12 sets of reference method data be taken at a rate of no more than one set per hour. Regulations also require that the analyzer monitor stack gas concentrations continuously during reference method testing.

All data derived using the reference method and the continuous monitor are given on a dry basis; a moisture correction factor is used to give results on a consistent basis. SO_2 and oxygen tests were run simultaneously. The CEM analysis of moisture content was determined by measuring the temperature of a sample taken after the moisture trap in the samp-

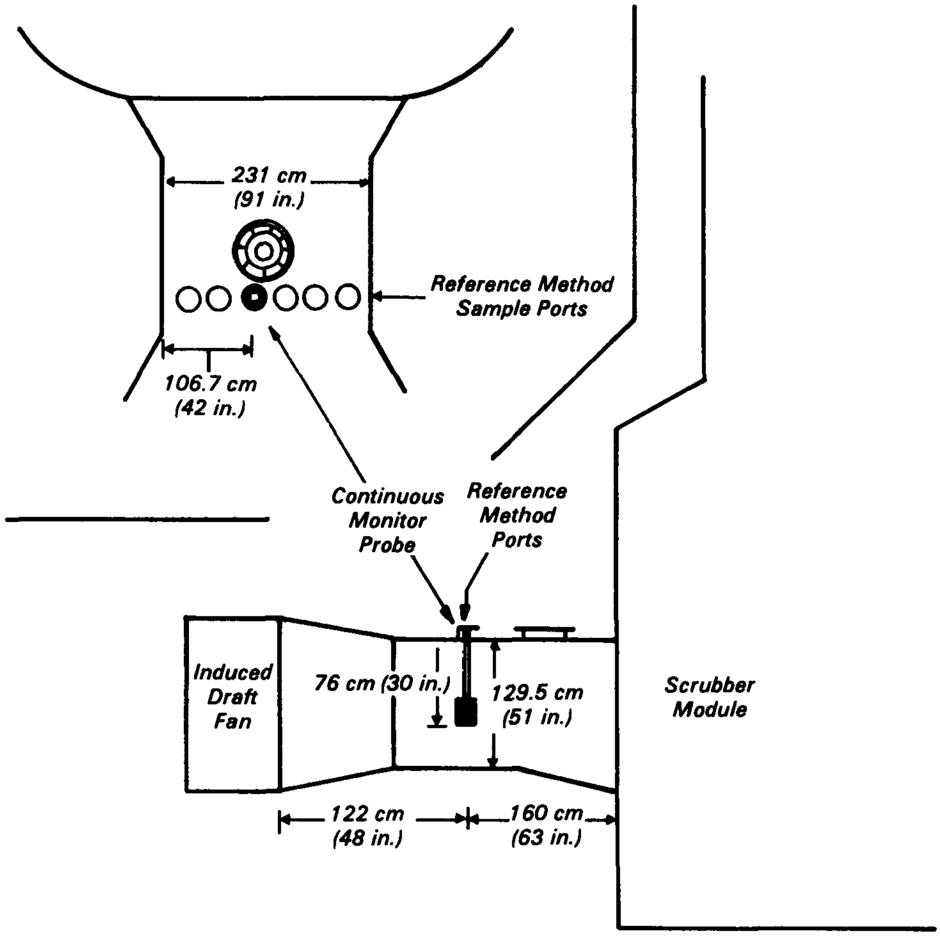

Figure 2. *Scrubber inlet sampling locations.*

ling system. Moisture content was then calculated because the gas stream being analyzed was saturated.

Tables 2 and 3 give the relative accuracy data for the initial certification period. Relative accuracy, based on nine sets of reference method data, was calculated according to equations in Section 7, Appendix B, *Federal Register,* Vol. 44, No. 197. These calculations showed that the relative accuracy at the inlet was 1.72 percent (based on SO_2 concentrations) and 7.30 percent (with SO_2 expressed on a weight per heat input basis). The corresponding values at the scrubber outlet were 18.67 and 16.43 percent, respectively.

Performance Audits

Performance audits were conducted to maintain quality control throughout the monitoring period. Audit gases certified by the EPA were introduced at the scrubber inlet through a manifold pressurized to 3.39 kPa (1 in. Hg) to duplicate sampling conditions. Audit gases were introduced at the scrubber outlet through an open-end manifold at ambient atmospheric pressure. No adjustments were made to the analyzer flow rates. Analyzer response to audit concentrations was determined by the computer used for storage and retrieval of the emission monitoring data. Results of these tests showed excellent agreement between the audit gas concentrations and analyzer readings for SO_2 and oxygen at both the inlet and outlet.

Results

Table 4 summarizes the daily average SO_2 monitoring data for those 30 days when 18 hours or more of acceptable readings were obtained and high efficiency was achieved. These data show that 94.3 percent was the mean SO_2 removal efficiency, with a corresponding standard deviation of 2.1. These data do not include days when the limestone feed rate was low or when other known operating problems occurred. The emission values are based on an F factor of 2.63 x 10^{-7} m^3/J (9780 dscf/10^6 Btu). The average inlet SO_2 loading for the test period was 2125 ng/J (4.94 lb/10^6 Btu) of heat input to the boiler; whereas, the average SO_2 outlet value measured was 122 ng/J (0.28 lb/10^6 Btu). Limited data obtained on February 12 - 16, before adding adipic acid, showed scrubber removal efficiency of 45 - 65 percent.

Analyses of the coal burned during the initial monitor operating period and the test period are shown in Table 5. These data show that the coal sulfur content during the continuous monitoring period was 2.22 - 3.55 percent by weight on a dry basis. Based on these data, the calculated SO_2 emission rate (assuming that 95 percent of the sulfur is converted to SO_2) was 1299 - 2210 ng/J (3.02 - 5.14 lb/10^6 Btu).

The average daily feed rates for limestone and adipic acid for the entire test period are shown in Table 6. This table also gives the quantity of coal used per day, which indicates the variation in boiler load. From March 4 to April 10, 1981, coal usage varied from 60.8 to 138 Mg/day (55 to 125 tons/day), reflecting the effect of changes in daily temperature on the boiler heat output demand. Of particular interest is the ratio of adipic acid to limestone used to maintain the high SO_2 removal efficiencies during the test; the ratio varied from 6 to 30 g/kg (12 to 60 lb/ton) and averaged 12 g/kg (24 lb/ton). Uniform limestone and adipic acid addition was difficult to maintain because of the use of manual controls, the varying boiler load, and the intermittent discharge of sludge to the holding pond.

Conclusions

The project resulted in the successful completion of a certified continuous SO_2 monitoring performance test which verified that the addition of adipic acid did enhance the SO_2 removal capability of the Rickenbacker FGD limestone control unit without having any adverse effect on operating parameters. Before the test, this limestone scrubber was achieving about 55 percent SO_2 removal. The adipic acid additive increased the unit's SO_2 removal efficiency to 90 - 97.4 percent (averaging 94.3 percent) over a 30-day test period.

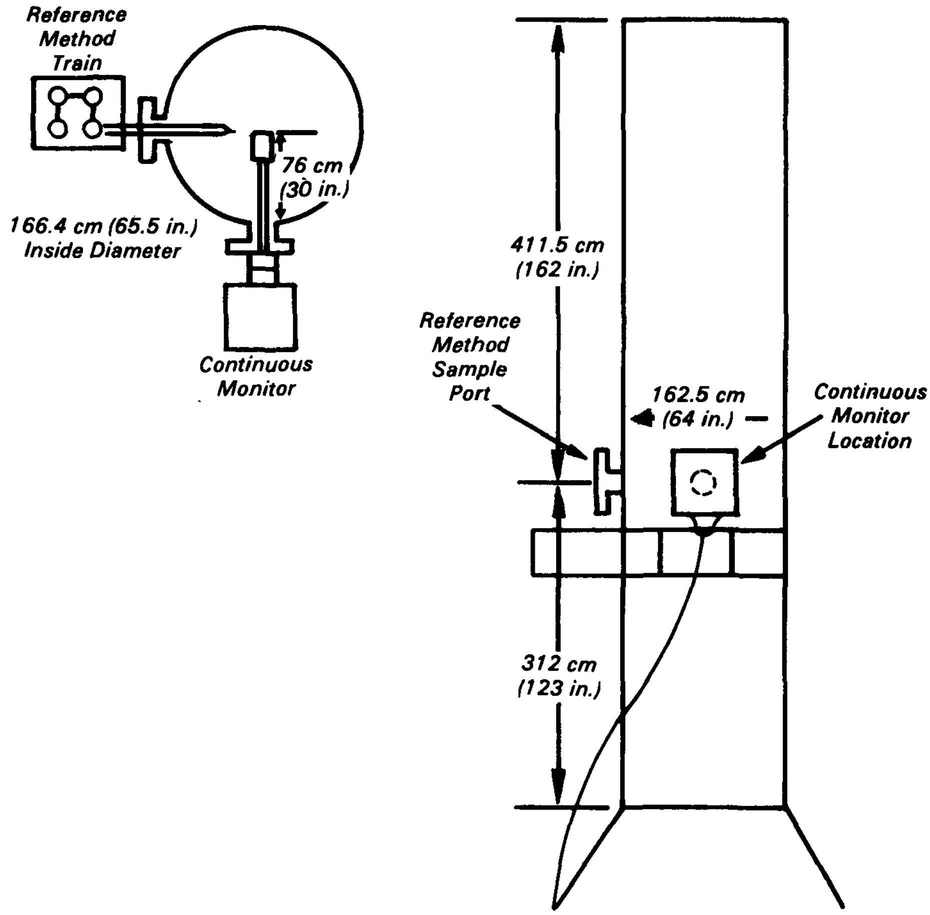

Figure 3. *Scrubber outlet sampling locations.*

Table 2. *Inlet Reference Method and CEM Results*

		Reference method								Monitor[a]			
Test No.	Time	Vm[b] (std) Nm³	(dscf)	g/Nm³	(10⁻⁴ lb/dscf)	SO₂, ppm	ng/J	(lb SO₂/ 10⁶ Btu)	%O₂	SO₂, ppm	ng/J	(lb SO₂/ 10⁶ Btu)	%O₂
RIC-1	0749-0819	0.0251	(0.888)	2.03	(1.27)	775	1965.1	(4.57)	15.2	753	1930.7	(4.49)	14.9
RIC-2	0926-0951	0.0257	(0.908)	2.15	(1.34)	816	1849.0	(4.30)	14.5	803	2132.8	(4.96)	15.1
RIC-3	1010-1035	0.0254	(0.897)	2.11	(1.32)	802	1849.0	(4.28)	14.6	805	2029.6	(4.72)	14.8
RIC-4	1110-1135	0.0257	(0.908)	1.94	(1.21)	734	1840.4	(4.28)	15.1	736	1887.7	(4.39)	14.9
RIC-5	1210-1235	0.0254	(0.896)	1.76	(1.10)	671	1831.8	(4.26)	15.6	668	1711.4	(3.98)	14.9
RIC-6	1310-1335	0.0274	(0.967)	2.02	(1.26)	766	1763.0	(4.10)	14.6	793	1874.8	(4.36)	14.4
RIC-7	1410-1435	0.0277	(0.979)	1.92	(1.20)	753	1737.2	(4.04)	14.6	768	1874.8	(4.36)	14.6
RIC-8	1510-1535	0.0265	(0.937)	1.83	(1.14)	693	1732.9	(4.03)	15.1	694	1874.8	(4.36)	15.2
RIC-9	1610-1635	0.0278	(0.982)	1.83	(1.14)	697	1732.9	(4.03)	15.1	689	1797.4	(4.18)	15.0
RIC-10	1710-1735	0.0286	(1.01)	1.86	(1.16)	703	1775.9	(4.13)	15.1	707	1724.3	(4.01)	14.6

[a] Three monitor readings taken during reference method run. Monitor readings were then averaged for final emission results.
[b] Vm = metered volume (dry basis).

Table 3. Outlet Reference Method and CEM Results

Test No.	Time	Reference method[a]: Vm[b] (std) Nm³	(dscf)	g/Nm³	(10^{-4} lb/dscf)	SO_2, ppm	ng/J	(lb SO_2/ 10^6 Btu)	%O_2	Monitor: SO_2, ppm	ng/J	(lb SO_2/ 10^6 Btu)	%O_2
ROC-1	0832-0857	0.0270	(0.952)	0.072	(0.045)	27.4	63.2	(0.147)	14.6	26.6	56.7	(0.132)	13.7
ROC-2	0952-1017	0.0266	(0.941)	0.051	(0.032)	19.2	43.4	(0.101)	14.4	39.2	72.6	(0.169)	12.6
ROC-3	1052-1117	0.0263	(0.930)	0.091	(0.057)	34.5	78.6	(0.183)	14.5	40.2	103.6	(0.241)	12.8
ROC-4	1202-1227	0.0286	(1.01)	0.062	(0.039)	23.7	54.6	(0.127)	14.5	29.0	78.2	(0.182)	15.2
ROC-5	1302-1327	0.0284	(1.002)	0.061	(0.038)	23.2	52.4	(0.122)	14.5	29.2	61.5	(0.143)	13.6
ROC-6	1412-1437	0.0275	(0.972)	0.087	(0.054)	32.8	67.9	(0.158)	13.9	33.1	67.0	(0.156)	13.3
ROC-7	1512-1537	0.0278	(0.982)	0.075	(0.047)	29.2	64.5	(0.150)	14.2	35.3	83.8	(0.195)	12.7
ROC-8	1612-1637	0.0323	(1.14)	0.067	(0.042)	25.6	55.4	(0.129)	14.2	34.1	64.5	(0.150)	12.8
ROC-9	1717-1742	0.0289	(1.022)	0.062	(0.039)	24.0	57.2	(0.133)	14.9	20.1	44.3	(0.103)	13.9
ROC-10	1807-1832	0.0296	(1.046)	0.088	(0.055)	33.6	80.8	(0.188)	14.9	36.3	71.3	(0.166)	13.1
ROC-11	1907-1932	0.0298	(1.053)	0.095	(0.059)	36.2	82.5	(0.192)	14.6	34.6	81.7	(0.190)	14.4
ROC-12	2007-2032	0.0276	(0.973)	0.088	(0.055)	33.7	68.8	(0.160)	13.9	37.4	83.4	(0.194)	14.0

[a] Emission results based on use of 0.001 N barium perchlorate.
[b] Vm = metered volume (dry basis).

Table 4. 30-Day Summary of SO_2 Concentrations and Scrubber Efficiency March-April 1981

Date		Hours CEM Data	SO_2 Inlet lb/10^6 Btu	ng/J	SO_2 Outlet lb/10^6 Btu	ng/J	Eff %
March	4	24	4.00	1719.8	0.30	129.0	92.5
March	5	18	3.10	1332.9	0.14	60.2	95.5
March	6	21	4.11	1767.1	0.24	103.2	94.2
March	7	23	3.82	1642.4	0.30	129.0	92.1
March	8	19	4.16	1788.6	0.37	159.1	91.1
March	9	20	4.17	1792.9	0.27	116.1	93.5
March	10	20	4.88	2098.2	0.27	116.1	94.5
March	11	19	4.37	1878.9	0.21	90.3	95.2
March	12	18	4.45	1913.3	0.22	94.6	95.1
March	14	18	6.19	2661.4	0.45	193.5	92.7
March	15	22	5.21	2240.1	0.30	129.0	94.2
March	20	21	4.95	2128.3	0.32	137.6	93.5
March	21	19	5.22	2244.4	0.15	64.5	97.1
March	22	23	4.64	1995.0	0.25	107.5	94.6
March	24	22	5.48	2356.1	0.55	236.5	90.0
March	25	18	4.97	2136.9	0.32	137.6	93.6
March	26	21	6.15	2644.2	0.32	137.6	94.8
March	27	21	4.85	2085.3	0.29	124.7	94.0
March	28	23	4.52	1943.4	0.43	184.9	90.5
March	29	19	6.43	2764.6	0.61	262.3	90.5
March	30	18	5.38	2313.1	0.36	154.8	93.3
April	2	24	4.83	2076.7	0.14	60.2	97.1
April	3	21	5.07	2179.9	0.13	55.9	97.4
April	4	22	4.79	2059.5	0.18	77.4	96.2
April	5	22	5.27	2265.9	0.33	141.9	93.7
April	6	22	5.15	2214.3	0.19	81.7	96.3
April	7	22	5.40	2321.7	0.17	73.1	96.9
April	8	23	5.50	2364.7	0.21	90.3	96.2
April	9	22	6.16	2648.5	0.34	146.2	94.5
April	10	23	5.06	2175.6	0.16	68.8	96.8
Mean			4.94	2125.1	0.28	122.1	94.3
Maximum			6.43	2764.6	0.61	262.3	97.4
Minimum			3.10	1332.9	0.13	55.9	90.0
STD DEV			0.75	323.1	0.12	50.4	2.1
% STD DEV			15.2	15.2	41.3	41.3	2.2

Table 5. *Coal Composition[a] (%, except as noted)*

	Date 1981											
	2/12	2/13	2/14	2/16	2/17	2/24	3/2-6[b]	3/9-13[b]	3/16-20[b]	3/23-27[b]	3/30-4/3[b]	4/6-10[b]
Sulfur	2.62	2.80	3.00	1.62	2.51	1.64	2.86	3.55	2.85	2.70	2.73	2.22
Carbon	73.06	73.67	69.37	76.23	74.71	74.29	71.48	72.19	74.98	72.61	74.13	75.50
Hydrogen	5.24	5.22	4.72	5.11	5.26	5.30	5.37	5.19	5.37	3.64	5.33	5.61
Oxygen	9.24	8.38	13.84	7.19	7.59	9.06	7.76	7.72	7.83	11.77	9.78	8.99
Nitrogen	1.58	1.56	1.51	1.81	1.64	1.74	1.54	1.56	1.65	1.54	1.49	1.67
Chlorine	0.19	0.21	0.20	0.20	0.18	0.14	0.18	0.12	0.16	0.09	0.09	0.12
Volatile matter	41.65	41.54	41.71	37.47	38.61	37.18	38.99	39.08	40.82	40.01	40.58	40.93
Fixed carbon	50.09	50.09	50.73	54.49	53.10	54.85	50.20	51.25	52.02	52.34	52.97	53.18
Ash	8.26	8.37	7.56	8.04	8.29	7.97	10.81	9.67	7.16	7.65	6.45	5.89
Heat value, kJ/kg	31,410	31,040	31,225	31,550	31,410	31,690	30,250	30,510	31,620	31,010	31,240	32,470
(Btu/lb)	(13,500)	(13,340)	(13,420)	(13,560)	(13,500)	(13,620)	(13,000)	(13,114)	(13,590)	(13,328)	(13,427)	(13,955)
Moisture	3.66	3.57	3.81	3.70	2.34	2.02	8.62	7.92	9.35	6.99	6.35	4.26

[a]Dry basis except for moisture.
[b]Composite.

Table 6. *Adipic Acid, Limestone, and Coal Usage*

Date (1981)		Average adipic acid feed, kg/h (lb/h)[a]	Average limestone feed, kg/h (lb/h)[b]	Mg (tons) of coal used/day
February	20			85.0 (77.1)
	21			90.3 (81.9)
	22			92.7 (84.0)
	23		261 (575)	112.1 (101.6)
	24		281 (619)	126.6 (114.8)
	25		331 (729)	127.8 (115.9)
	26	3.63 (8)	319 (702)	113.4 (102.8)
	27	3.63 (8)	325 (716)	130.4 (118.2)
	28	1.81 (4)	311 (686)	113.5 (102.9)
March	1	1.81 (4)	321 (707)	124.6 (113.0)
	2	3.63 (8)	327 (720)	108.6 (98.5)
	3	2.72 (6)	341 (752)	106.1 (96.2)
	4	6.35 (14)	362 (798)	100.8 (91.4)
	5	2.72 (6)	372 (820)	112.6 (102.1)
	6	4.54 (10)[c]	360 (793)	132.0 (119.7)
	7	5.44 (12)[c]	388 (854)	131.4 (119.1)
	8	3.63 (8)[c]	387 (853)	138.1 (125.2)
	9	4.54 (10)[c]	370 (814)	123.1 (111.6)
	10	3.63 (8)	347 (765)	121.1 (109.8)
	11	3.63 (8)	350 (771)	99.9 (90.6)
	12	3.63 (8)	353 (778)	94.6 (85.8)
	13	2.62 (6)	337 (742)	97.5 (88.4)
	14	4.08 (9)	331 (728)	102.1 (92.6)
	15	4.08 (9)	332 (731)	101.1 (91.7)
	16	4.54 (10)	311 (686)	112.3 (101.8)
	17	3.63 (8)	220 (489)	133.2 (120.8)
	18	7.26 (16)[c]	246 (542)	118.5 (107.4)
	19	4.54 (10)	320 (704)	136.4 (123.7)
	20	7.26 (16)[c]	404 (890)	127.1 (115.2)
	21	6.35 (14)[c]	391 (861)	113.2 (102.6)
	22	1.81 (4)[d]	318 (700)	99.2 (89.9)
	23	2.72 (6)	218 (479)	103.2 (93.6)
	24	3.63 (8)	236 (520)	98.8 (89.6)
	25	4.54 (10)	298 (656)	98.5 (89.3)
	26	3.63 (8)	285 (627)	94.2 (85.4)
	27	4.54 (10)	270 (595)	97.9 (88.8)
	28	4.54 (10)	262 (576)	95.1 (86.2)
	29	3.63 (8)	213 (468)	78.4 (71.1)
	30	2.27 (5)[b,e]	184 (405)[e]	69.4 (62.9)
	31	0 (0)[f]	0 (0)[f]	79.9 (72.4)
pril	1	6.35 (14)[c]	292 (644)	71.1 (64.5)
	2	5.44 (12)	212 (467)	76.1 (69.0)
	3	3.63 (8)	198 (435)	60.8 (55.1)

Table 6. *(continued)*

Date (1981)	Average adipic acid feed, kg/h (lb/h)[a]	Average limestone feed, kg/h (lb/h)[b]	Mg (tons) of coal used/day
4	3.63 (8)	218 (480)	60.9 (55.2)
5	1.81 (4)[d]	239 (526)	74.2 (67.3)
6	4.54 (10)	276 (608)	68.1 (61.7)
7	4.54 (10)	225 (496)	68.4 (62.0)
8	2.72 (6)	207 (455)	66.2 (60.0)
9	2.72 (6)	203 (447)	63.4 (57.5)
10	2.27 (5)	212 (467)	74.2 (67.3)

[a]24-hour basis.
[b]Based on hours of feed.
[c]Adipic acid was dumped in the thickener.
[d]Vibrator was turned off. Adipic acid feeder plugged.
[e]Scrubber was bypassed at 1940 because the thickener was plugged. Limestone and adipic acid feeds were turned off at that time.
[f]The scrubber was still off-line. It was restarted before 8 a.m. on April 1.

P. A. Clarke, R. W. Gerstle, D. S. Henzel, K. W. Mason, and S. R. Sabatini are with PEDCo Environmental, Inc., Cincinnati, OH 45246.
***J. David Mobley** is the EPA Project Officer (see below).*
The complete report, entitled "The Adipic Acid Enhanced Flue Gas Desulfurization Process for Industrial Boilers: Volume 1. Field Test Results," (Order No. PB 83-144 774; Cost: $32.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300