Appendix 5.0-7

KODAK BOILER 15 ESP PERFORMANCE EVALUATION FOR MICRONIZED COAL REBURNING (MCR) AND BASELINE CONDITIONS

CLEAN COAL IV TECHNOLOGY DEMONSTRATION PROJECT

KODAK BOILER 15 ESP PERFORMANCE EVALUATION FOR MICRONIZED COAL REBURNING (MCR) AND BASELINE CONDITIONS

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LIST OF ABBREVIATIONS

AC	Alternating Current
acfm	Actual Cubic Feet Per Minute
am	Ante Meridium
ASTM	American Society for Testing and Materials
Avg	Average
BL	Baseline
Btu	British Thermal Unit
CCT-IV	Clean Coal Technologies IV
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CONSOL R&D	CONSOL Inc., Research & Development Department
dscf	Dry Standard Cubic Feet
EF	Degrees Fahrenheit
ft or ‘	Feet
DC	Direct Current
EPA	Environmental Protection Agency
ESP	Electrostatic Precipitator
fps	Feet per Second
ft	Feet
ft^2	Square Feet
ft^3	Cubic Feet
gm	Gram
gr	Grain
H_2O_2	Hydrogen Peroxide
hr	Hour
in. or “	Inches
in. H_2O	Inches Water Column
“ Hg	Inches Mercury
KV	Kilovolt
KW	Kilowatts
lb	Pound
MCR	Micronized Coal Reburning
MM	Million
N_2	Nitrogen
O_2	Oxygen
P	Pressure
PM	Particulate Matter
pm	Post Meridiem
ppmv	Parts per Million by Volume
QA/QC	Quality Assurance/Quality Control
rms	Root Mean Square
°R	Degrees Rankine
scfm	Standard Cubic Feet per Minute at 60°F and 1 Atm.

SoRI	Southern Research Institute
STD	Standard
SO_2	Sulfur Dioxide

LIST OF ABBREVIATIONS (Cont.)

V	Volt
Vel	Velocity
Vol	Volume
W	Watt
wt	Weight
Fm	Microns

ABSTRACT

This report presents the performance results for an electrostatic precipitator (ESP) operating on a 400,000 lb/hr steam, cyclone-fired boiler that was modified for micronized coal reburning (MCR) to control NO_x emissions. The ESP was tested under both normal baseline operating conditions with and without MCR. Under MCR operation, the particulate loadings to the ESP increased 2.8 times the baseline level and loading to the stack increased 1.8 times the baseline level. However, the average particulate removal efficiency for the MCR operations was greater than for the baseline operations and the ESP continued to meet the dust emission performance guarantee.

KODAK BOILER 15 ESP PERFORMANCE EVALUATION FOR MICRONIZED COAL REBURNING (MCR) AND BASELINE CONDITIONS

INTRODUCTION

Performance testing was completed on the Kodak Boiler 15 ESP to assess the impact of Micronized Coal Reburning (MCR) on ESP performance. This test program involved the simultaneous sampling of both the ESP inlet and ESP outlet for particulate mass loading. Four sets of paired inlet and outlet samples were collected for both the baseline and MCR test conditions. All sampling was completed during the week of June 2, 1998. As-fired coal samples were taken by plant operators during each test period to obtain daily composite samples. ESP electrical conditions were read manually from meters on the transformer-rectifier controller cabinets. All of the sampling and data collection was coordinated with the control room operators to assure that the testing was conducted during full load (nominally 400,000 lb/hr steam make) and normal operating conditions.

SUMMARY

The following main conclusions can be drawn from the MCR and baseline testing of the Kodak Boiler 15 ESP.

- The ESP removal efficiency did not decline for the reburn tests but actually increased slightly above the measured efficiency for the baseline tests. The average efficiency for the MCR tests was 97.1% compared to 95.5% for the baseline tests.

- The MCR operations increased particulate loading to the ESP by 2.8 times the baseline and the loading to the stack increased to 1.8 times the baseline.

- Measured ESP particulate removals exceeded the design removal of 94.4 wt % for all the MCR tests and for three of the four baseline tests. Therefore, the MCR operations do not appear to be detrimental to the ESP performance although mass emissions did increase.

- The MCR flue gas particulate was significantly coarser than the baseline particulate. Average particle diameters were: 23 to 25 μm for MCR and 5 to 8 μm for baseline.

- MCR operations increased the fly ash carbon content. For the MCR operations, the fly ash carbon LOI averaged 36.8 wt % versus 11.3 wt % for the baseline operations.

- There are significant differences between the ESP energization levels for MCR and baseline operations. Under MCR conditions, field energizations were significantly higher than under baseline conditions. This helps to explain why removal efficiencies remained high for MCR although particulate loadings were several times the baseline values.

SAMPLING LOCATIONS

ESP Inlet

The ESP inlet sampling location is shown in Figure 1. Sampling was conducted in the inlet duct located immediately upstream of the ESP. This duct is fitted with six, six-inch sampling ports. A sampling scheme using every sampling port was used for the particulate matter (PM) sampling. Three sample points were located for each port for a total of 18 sampling points for the duct. PM sampling was conducted for five minutes at each point which resulted in a total sampling time of 90 minutes.

ESP Outlet

The ESP outlet sampling location is also shown in Figure 1. Sampling was conducted in the location downstream of the ESP and the gas take-off duct that supplies the micronizing coal pulverizers with conveying gas. The duct is fitted with six, four-inch sampling ports. A sampling scheme using every sampling port was used for the PM sampling. Four sample points were located for each port. This plan resulted in 24 sampling points for the duct. PM sampling was conducted for four minutes at each point which resulted in a total sampling time of 96 minutes.

RESULTS

Particulate Loadings

The particulate loadings are summarized in Table 1. The results show that for MCR operations the ESP inlet loadings are about 2.8 times the baseline loadings and stack emission levels are about 1.8 times the baseline loadings. For the MCR operation, the ESP inlet loadings ranged from 1,361 to 1,757 lb/hr and averaged 1,503 lb/hr while baseline loadings ranged from 468 to 611 lb/hr and averaged 531 lb/hr. Stack loadings ranged from 23 to 53 lb/hr and averaged 41 lb/hr for the MCR operation and ranged from 16 to 33 lb/hr with an average of 22 lb/hr for the baseline tests. The average ESP particulate removal efficiencies were 97.1% and 95.5% for the MCR and baseline tests, respectively. Both values exceed the 94.4% design value indicating that the ESP is preforming well. However, because MCR significantly increases the inlet dust loading to the ESP, the average outlet loading is equal to the design guarantee value of 0.088 lb/10^6 Btu input and the average stack loadings are only slightly below at 0.081 lb/10^6 Btu input.

Because there is a recycle flue gas take off point between the ESP exit and the outlet duct sample ports, the ESP exit loadings were estimated from the ESP inlet particulate loading and the removal efficiency based on concentration (gr/dscf). Use of the efficiency based on particulate mass flows at the ESP inlet and the stack slightly overestimates the ESP efficiency. This is because some of the solids at the ESP exit are recycled back to the boiler with the slipstream flue gas to the micronizer mill. Calculating the removal efficiency using particulate concentrations avoids this problem. However, no corrections were made to the stack particulate concentrations for air leak or purge into the ESP. Accounting for the nominal 0.5% absolute rise in oxygen level across the ESP would have decreased the particulate removal efficiency based on concentration by about 0.1%.

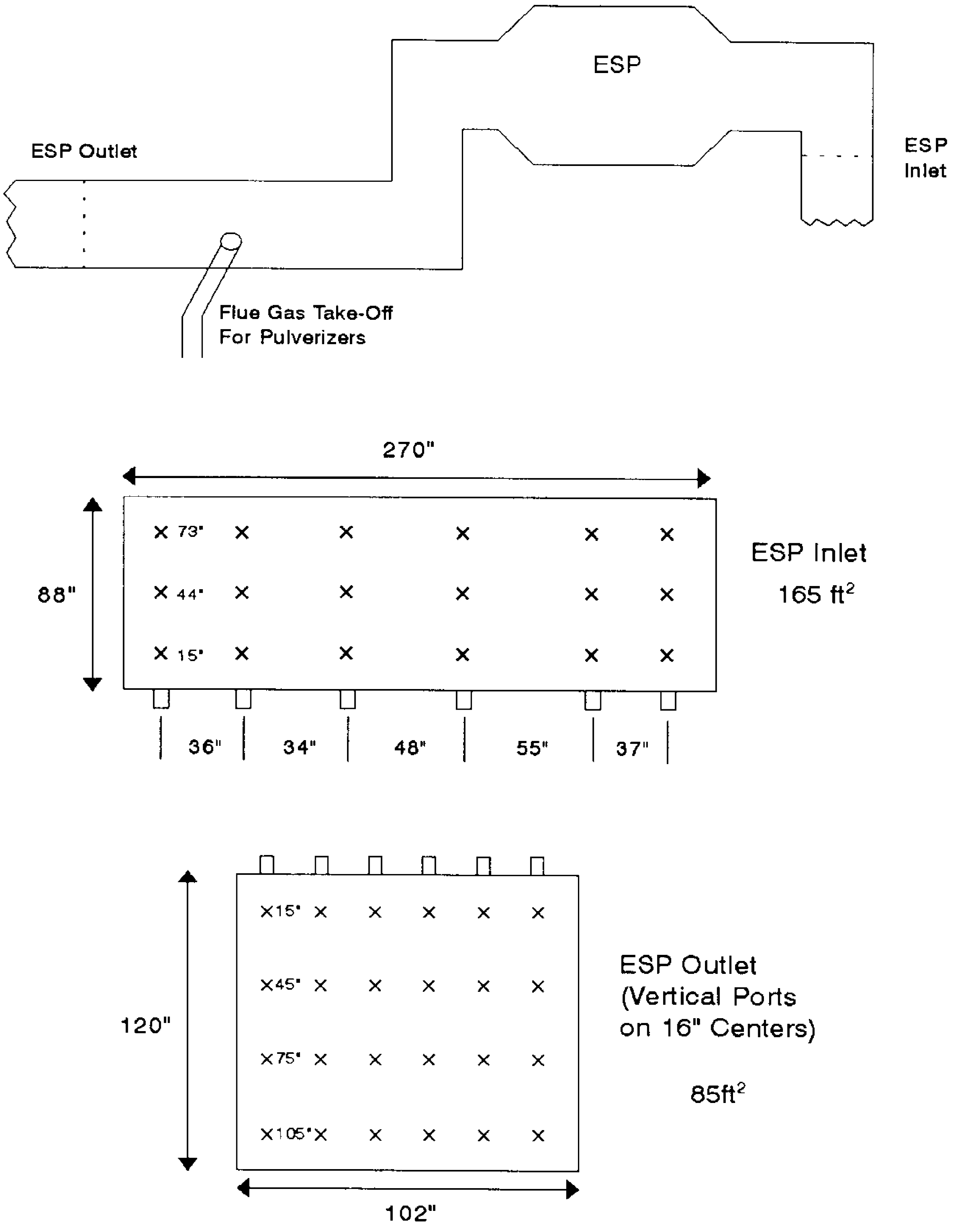


Figure 1.- Schematic of Sampling Duct and Sampling Port Location

Table 1
ESP Performance Summary

Test (Micronized Coal Reburn)	**MCR-1**	**MCR-2**	**MCR-3**	**MCR-4**	**Average**
Date	**06/02/98**	**06/02/98**	**06/03/98**	**06/03/98**	
ESP Inlet Loading, grains/dscf	1.602	1.942	1.534	1.582	1.665
Rate, lb/hr	1,493	1,757	1,361	1,401	1,503
lb/MM Btu (1)	2.931	3.527	2.759	2.788	3.001
ESP Exit Loading, grains/dscf	0.056	0.048	0.027	0.064	0.049
Rate, lb/hr (2)	52.2	43.3	24.1	56.5	44.0
lb/MM Btu (1)	0.102	0.087	0.049	0.112	0.088
Stack Loading, grains/dscf	0.056	0.048	0.027	0.064	0.049
Rate, lb/hr	46.9	39.1	22.6	53.3	40.5
lb/MM Btu (1)	0.092	0.079	0.046	0.106	0.081
Removal Efficiency Across ESP (3)	96.5%	97.5%	98.2%	96.0%	97.1%
Removal Efficiency ESP inlet to Stack (4)	96.9%	97.8%	98.3%	96.2%	97.3%

Test (Baseline)	**BL-1**	**BL-2**	**BL-3**	**BL-4**	**Average**
Date	**06/03/98**	**06/04/98**	**06/04/98**	**06/04/98**	
ESP Inlet Loading, grains/dscf	0.560	0.484	0.544	0.643	0.558
Rate, lb/hr	526	468	520	611	531
lb/MM Btu (1)	1.026	0.91	0.988	1.19	1.029
ESP Exit Loading, grains/dscf	0.018	0.024	0.036	0.022	0.025
Rate, lb/hr (2)	16.6	23.1	34.7	20.7	23.8
lb/MM Btu (1)	0.033	0.045	0.066	0.040	0.046
Stack Loading, grains/dscf	0.018	0.024	0.036	0.022	0.025
Rate, lb/hr	15.7	21.2	32.6	19.5	22.3
lb/MM Btu (1)	0.031	0.041	0.062	0.038	0.043
Removal Efficiency Across ESP (3)	96.8%	95.1%	93.3%	96.6%	95.5%
Removal Efficiency ESP inlet to Stack (4)	97.0%	95.5%	93.7%	96.8%	95.8%

(1) Based on F-Factor calculated coal feed rate for stack flue gas rate.
(2) Calculated from Inlet loading and removal efficiency.
(3) Based on concentration change.
(4) Based on mass flow change.

The individual run data are presented in appendix Tables A-1 and A-2. The data are shown chronologically with the micronized coal reburning tests first in Table A-1 and the baseline test data in Table A-2. The pertinent data and results shown include: duct operating conditions, gas analysis, flue gas flow rates, particulate loadings, particulate removal efficiency, coal analysis, fly ash analysis and estimated coal feed rates based on the measured stack flue gas rate and EPA F-factor calculations.

Ash Carbon Levels

The fly ash carbon levels are provided in Tables A-1 and A-2. For the MCR testing, the carbon levels ranged from 34.1 to 38.9 wt % and averaged 36.8 wt %. Baseline levels were much lower ranging from 7.1 to 14.7 wt % and averaging 11.3 wt %. Based on the coal feed rates and the ESP inlet fly ash loadings, the average carbon losses represent 0.17% of the fuel heating value for the baseline tests and 1.60% for the MCR Tests. The higher MCR carbon losses are not surprising given that the fuel is injected into the boiler in a less reactive environment than the cyclone fuel and the time for burnout is reduced.

Particulate Sizing

Size distributions were obtained by Malvern™ analysis for several samples of the ESP inlet particulate collected for the particulate loading measurements. The data are presented in Table 2. Size measurements were obtained for baseline tests 1 and 3 and for MCR tests 1 and 3. The distributions are plotted using log-normal probability scaling in Figure 2. The plot shows that the baseline test fly ash is very fine with average particle sizes of only 5 and 8 Fm for Tests 1 and 3, respectively. This is the size range expected for cyclone firing. The baseline particle size plots are generally linear, indicating that the particle sizes are indeed log-normally distributed.

As shown in Figure 2, the MCR sizing data were consistent and nearly identical for the two tests. The distributions are bimodal since the curves can be represented by two straight lines which intersect at about the 23 Fm diameter. The plot clearly shows that coal reburning significantly increases the size of the particulate at the ESP inlet. The average particle diameter increases from the 5-8 Fm for baseline tests without coal reburning to 23-25 Fm when coal is reburned. The bimodal distribution of the MCR fly ash indicates that the ash is made up of two distinct components; the very fine material from the cyclone burners and coarser material left over from the combustion of the MCR fuel. Since most of the particulate from coal reburning is greater than 20 Fm in size, its removal would not be expected to pose a problem for the ESP operation. Fly ash of this size is removed with close to 100% efficiency in normally functioning precipitators. This appears to be true for the Kodak ESP since high removal efficiencies were obtained for the MCR tests which had much higher particulate loadings than the baseline tests.

ESP Electrical Performance and ESP Modeling

The electrical condition of the ESP was manually recorded during each test period. The was done as a historical record and to establish if the ESP preformed differently for operations with and without coal reburning. The data are presented in Appendix Table A-3. The data include the primary AC volts and amperages, the secondary DC kilovolts and milliamps, spark rate, and the calculated power determined from the secondary V-I data.

Table 2
KODAK Unit 15 ESP Inlet Particle Sizes*

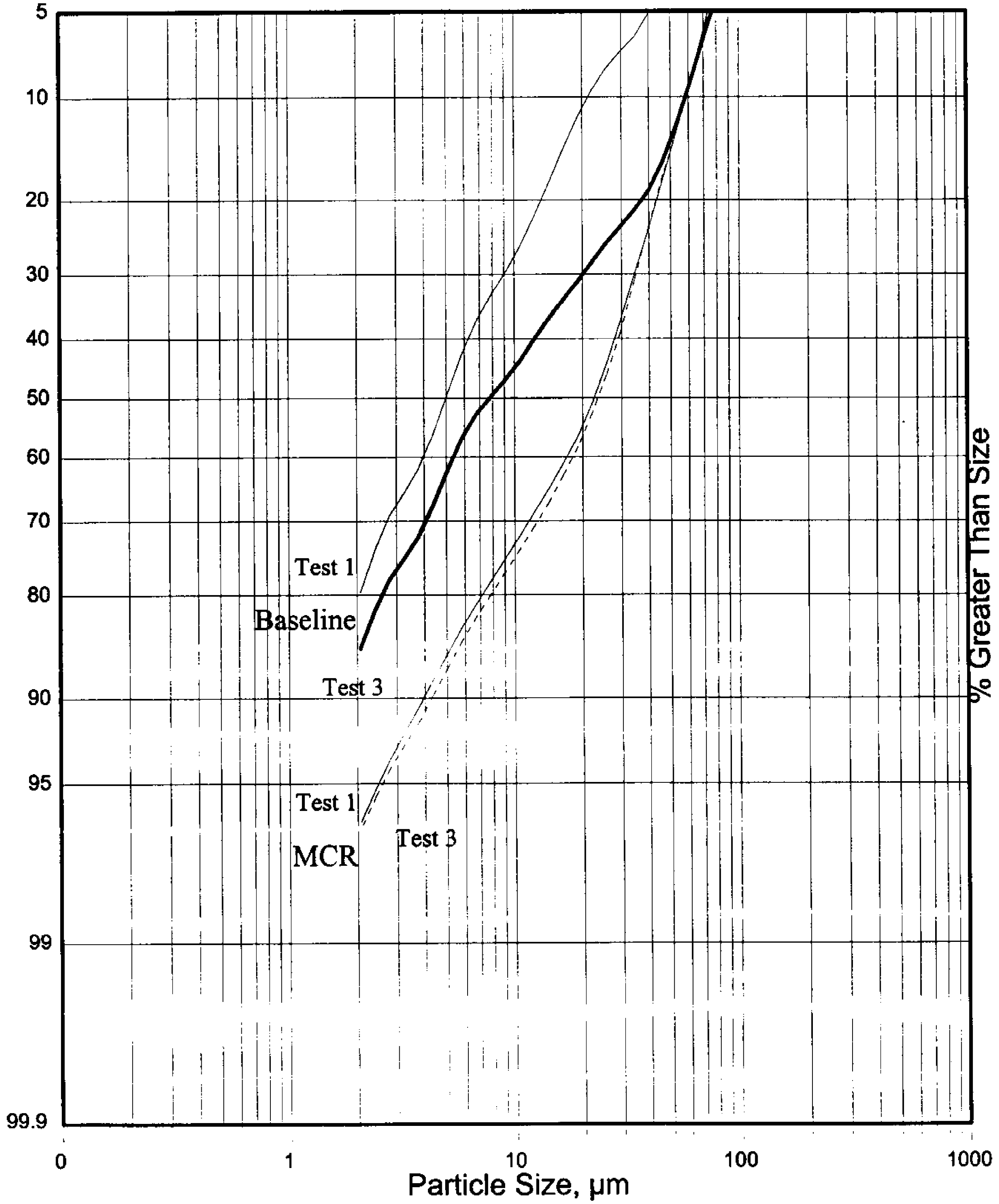
Avg. Diameter		Fraction Greater Than Size			
Fm	Test	MCR-1	MCR-3	Baseline-1	Baseline-3
175.0		0.0000	0.0040	0.0000	0.0065
151.0		0.0000	0.0075	0.0000	0.0130
130.5		0.0015	0.0125	0.0000	0.0195
112.5		0.0055	0.0180	0.0000	0.0250
96.9		0.0150	0.0250	0.0000	0.0305
83.7		0.0315	0.0370	0.0000	0.0400
72.2		0.0545	0.0590	0.0000	0.0595
62.3		0.0855	0.0895	0.0000	0.0870
53.8		0.1255	0.1260	0.0080	0.1210
46.4		0.1760	0.1715	0.0295	0.1570
40.0		0.2350	0.2325	0.0510	0.1890
34.5		0.2990	0.3075	0.0625	0.2130
29.8		0.3710	0.3895	0.0705	0.2340
25.7		0.4425	0.4610	0.0805	0.2565
22.2		0.5105	0.5270	0.0955	0.2830
19.1		0.5660	0.5835	0.1165	0.3115
16.5		0.6105	0.6300	0.1450	0.3390
14.3		0.6505	0.6715	0.1805	0.3685
12.3		0.6865	0.7080	0.2210	0.4020
10.6		0.7210	0.7410	0.2605	0.4365
9.1		0.7535	0.7715	0.2975	0.4695
7.9		0.7830	0.7990	0.3325	0.4985
6.8		0.8100	0.8250	0.3715	0.5290
5.9		0.8360	0.8500	0.4255	0.5695
5.1		0.8620	0.8750	0.4930	0.6220
4.4		0.8855	0.8975	0.5635	0.6785
3.8		0.9070	0.9170	0.6205	0.7250
3.3		0.9235	0.9305	0.6585	0.7550
2.8		0.9385	0.9430	0.6930	0.7820
2.4		0.9525	0.9555	0.7420	0.8180
2.1		0.9650	0.9670	0.7975	0.8585

* Malvern Analyses

Figure 2

KODAK Unit 15 ESP Inlet Particle Size

Log-Normal Probability Plot



To better assess operating differences, averaged data for each test are plotted in Figure 3. The plots clearly show a significant difference in the ESP response to coal reburning. Power levels to the first four fields are significantly higher for MCR operations than for the baseline operations without coal reburning. However, the power levels to the 5th field are only slightly higher for the MCR operations. The data can be interpreted in the following fashion. In a normally operating ESP most of the power is consumed in the last fields where there is the least amount of particulate. This appears to hold true for the Kodak ESP. As shown in the previous section, the baseline particulate is much finer than the MCR particulate. In general, the efficiency of an ESP to remove fly ash particulate decreases with decreasing size down to about 0.5 to 1 Fm and then begins to increase with decreasing size. The low level of energization indicated for the first four fields under baseline conditions may indicate small incremental removals in the front fields which keeps dust loadings relatively high. When the flue gas reaches the 5th field loadings are low enough that high energization is achieved. The relatively high energizations for MCR indicates that most of the material is being collected in the first field. The coarse, high-carbon particulate may be helping to "screen out" the finer materials as the dust travels to the collecting plates. Dust loadings would then be relatively low in the downstream fields. Alternately, there may be significant differences in the resistivities of the fly ashes. A high resistivity for the baseline particulate would limit power levels. This can not be confirmed now since resistivity measurements were not part of the test program.

As a final check of the ESP performance, the measured performance was compared to predicted performance using the CONSOL R&D ESP model. This model is based on the SoRI mathematical model developed by Southern Research Institute for the EPA. The results of the modeling effort are shown in Figure 4. The Kodak ESP was originally designed for a low removal efficiency of 94.4%; presumably because the dust loadings from cyclone burners are relatively low (most of the coal ash reports to the bottom slag) and extreme removal efficiency is not required to achieve required emission limits. As shown in the figure, the measured MCR and baseline removal efficiencies overlap and for all but test BL-3, are greater than the design efficiency. The model results agree reasonably well the actual removal efficiencies for the MCR cases. Using a standard 10% sneakage assumption, the model on average over predicts the actual removal by about 1.2% for MCR. Similarly for the baseline tests, the model under predicts the measured removal by about 2.9%. This relatively large under prediction can not be readily explained at this time. The very fine nature of the baseline particulate coupled with the measured low energization levels would be expected to result in low removal efficiencies. However, the measured efficiency remained high.

Figure 3

Field Energizations - Secondary Power

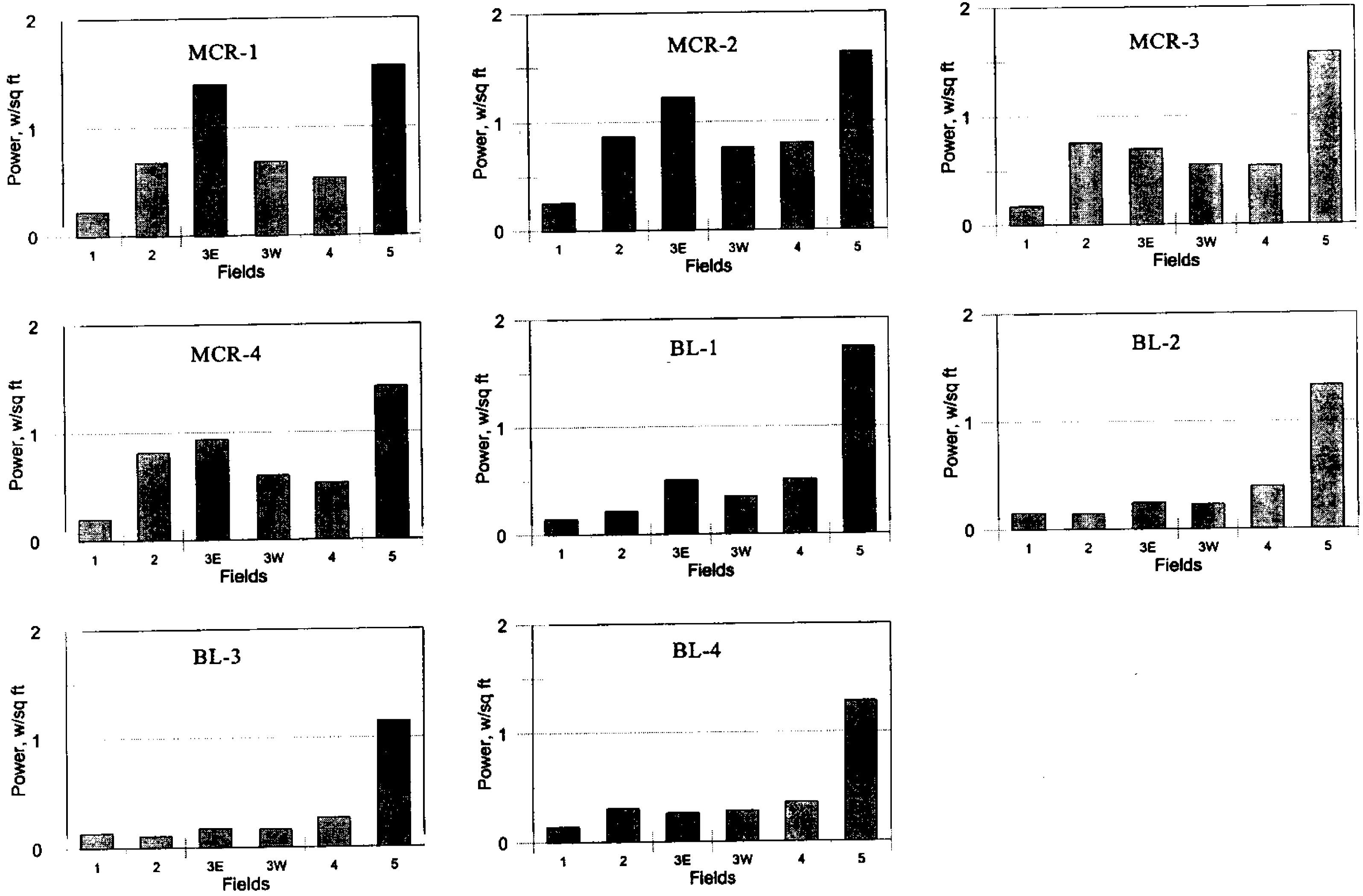
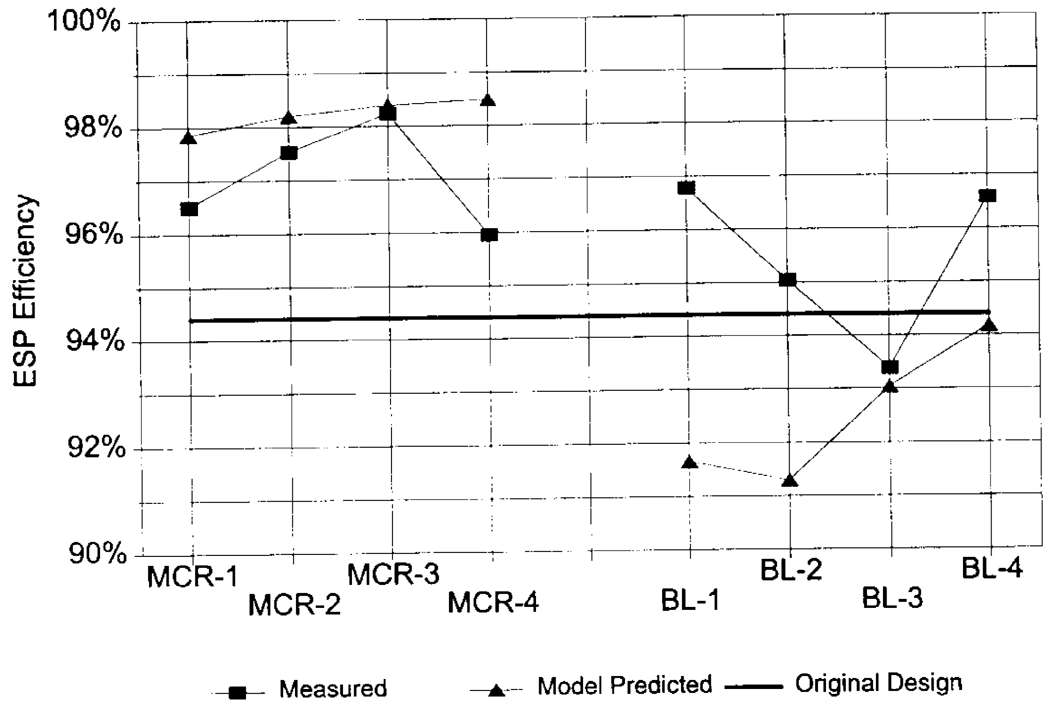


Figure 4

Kodak Unit 15 ESP Performance



EXPERIMENTAL

The emission sampling was conducted using EPA reference techniques, where applicable. In cases where no suitable reference method applied, sampling was conducted using EPA endorsed methodologies or other published, well-documented procedures. A summary of the sampling procedures used in this test program is provided below.

Selection of Sampling Points

The sampling points at both locations were selected as described in EPA Method 1. Both the ESP inlet and outlet locations failed to meet the optimum location criteria but these were the only locations possible.

Volumetric Flow Rate

Individual point velocities and duct volumetric flow rates were determined in conjunction with the PM sampling using the procedure outlined in EPA Method 2. The particulate sampling probes were equipped with calibrated type "S" pitot assemblies complete with thermocouples.

Gas Composition (O_2, CO_2, and N_2)

Flue gas compositions at both locations were determined using a Teledyne Model Max 5 combustion gas analyzer. This instrument uses an electrochemical sensor to determine oxygen and calculates the CO_2 concentration based on fuel chemistry. Nitrogen is determined by difference. The O_2 and CO_2 concentration determined by this instrument were previously confirmed by ORSAT analysis conducted on gas bag samples. The dry molecular weight of the flue gas samples were calculated from these data using the calculations outlined in EPA Method 3.

Flue Gas Moisture Content

Flue gas moisture was determined by measuring the condensate collected in the impinger assemblies for each of the PM samples. This procedure is outlined in both EPA Method 4 and Method 5.

Particulate Matter Concentrations

PM sampling was conducted at both the ESP inlet and outlet as outlined in EPA Method 17. This method specifies the use of an in-stack filter which is located at the front end of the sampling probe. Particulate matter is defined as any material that is collected on the filter at the duct temperature and pressure. Both the ESP inlet and outlet locations had a nominal average temperature of ~360°F and an absolute pressure of ~29"Hg.

A stainless steel filter canister fitted with a high efficiency ceramic filter was used for the inlet locations. This assembly can hold up to 50 grams of particulate and is particularly well suited for high particulate loading applications.

EPA Method 5 uses an out-of-stack, heated filter and sampling train which are close coupled to the sampling probe. The equipment setup is best suited for use with horizontally located sampling ports which allow the probe and sampling train to be easily supported and moved. The ESP outlet sampling ports are located on top of the ductwork requiring vertical traversing. This makes it almost impractical to use the standard Method 5 equipment setup. Because of this, an in-stack filter system was also used at the ESP outlet.

The high particulate removal efficiency of the ESP results in very little particulate penetration. To enhance the accuracy of the weight measurement of the collected sample, an in-stack 2.5 inch stainless steel filter holder fitted with a 2.5 inch quartz filter was used. These filters have greater weight stability than the conventional Method 17 thimble filter and also are more easily recovered from the filter holder after sampling. Both of these attributes result in more accurate mass measurements. As with the inlet sampling, the filter temperature is maintained at the flue gas temperature. Particulate matter is defined as any material that is collected on the sampling media at duct conditions of ~360EF and an absolute pressure of ~29" Hg. . A schematic contrasting the two particulate trains is shown in Figure 5.

SO_2 Emissions

SO_2 emissions were measured by replacing the water solution in the PM sampling impingers with a 3% hydrogen peroxide solution. After sampling, the impinger contents were analyzed for SO_2 as described in EPA Method 6. This technique is a $BaCl_2$ titration to a thorin end point.

QA/QC PROCEDURES

All of the testing and analysis was completed by trained individuals with experience specific to emission measurements and analysis. The sampling and associated QA/QC procedures were followed as prescribed in the sampling methods. All sampling was conducted under normal, base-load conditions.
Pretest calibrations were performed on the major sampling equipment, and included the pitot tubes, sampling nozzles, dry test meters, meter orifices, barometer, and temperature readouts. The analytical balance used for the gravimetric filter analyses is checked out twice a year. The accuracy of this balance was checked daily with class "S" standard weights. The calibration data are on file at CONSOL R&D, Pittsburgh, PA.

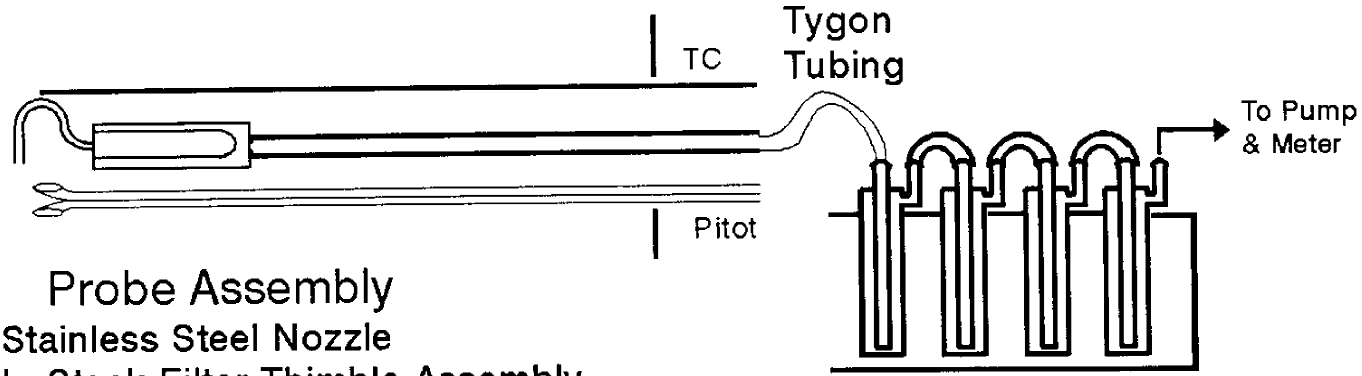
All field data were recorded on standard forms and are contained in a file binder at the CONSOL R&D office complex. All of the field data sheets and calculations were checked by two senior test professionals.

The coal samples were analyzed in duplicate following standard ASTM methodology. All of the coal analyses fell well within the ASTM criteria for data quality. The analysis of standard reference material used as QC checks is available upon request.

The sampling team was in daily communication with the unit operators to assure that the unit was operating at the required test conditions.

EPA Method 17 Particulate Sampling Trains

(ESP Inlet Sampling with Ceramic Thimble)



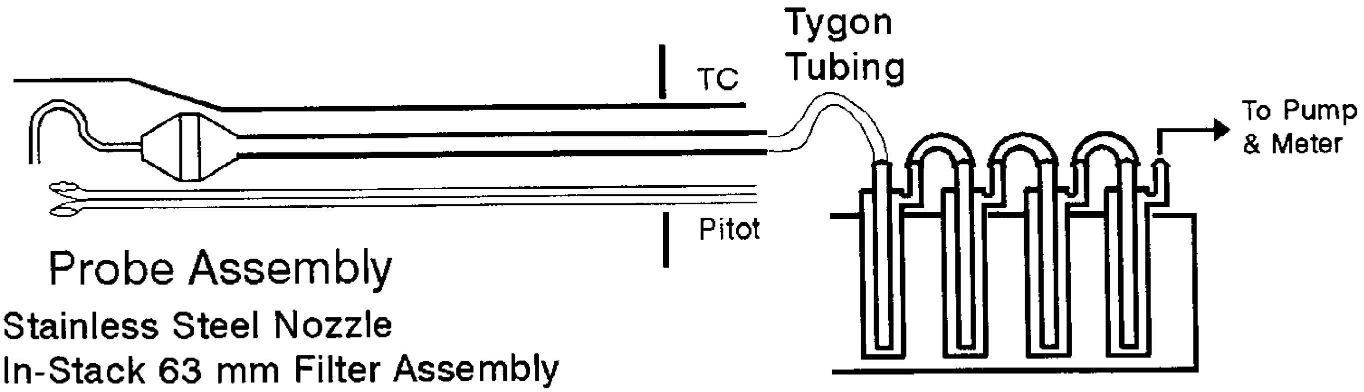
Probe Assembly

Stainless Steel Nozzle
In-Stack Filter Thimble Assembly
Ceramic Filter Thimble
Pitot Tube
Stack Thermocouple

Impinger Assembly

#1 & 2 - 3% H_2O_2
#3 - Blank
#4 - Silica Gel

(ESP Outlet Sampling with Quartz-Fiber Filter Disk)



Probe Assembly

Stainless Steel Nozzle
In-Stack 63 mm Filter Assembly
63 mm Quartz-Fiber Filter
Pitot Tube
Stack Thermocouple

Impinger Assembly

#1 & 2 - 3% H_2O_2
#3 - Blank
#4 - Silica Gel

Figure 5 - Schematics of Particulate Sampling Trains

APPENDIX

Table A-1

KODAK BOILER 15 DATA ESP PERFORMACE TEST DATA

MICRONIZED COAL REBURN TESTING

June 2-3, 1998

Location		INLET	OUTLET	INLET	OUTLET	INLET	OUTLET	INLET	OUTLET	INLET AVG	OUTLET AVG
Date		June 2	June 2	June 2	June 2	June 3	June 3	June 3	June 3		
Start Time		1020	1025	1340	1340	0830	0835	1150	1150		
Stop Time		1215	1230	1530	1535	1012	1035	1330	1335		
Test Number		MCR-1	MCR-1	MCR-2	MCR-2	MCR-3	MCR-3	MCR-4	MCR-4		
SAMPLING DATA:											
Y factor of dry gas meter	-	1.015	1.000	1.015	1.000	1.015	1.000	1.015	1.000		
Gas Volume	- ft^3	38.79	45.51	38.04	45.63	36.35	43.55	36.73	44.47		
Delta H of dry gas meter	- " H_2O	0.65	0.75	0.63	0.75	0.57	0.72	0.57	0.72		
Meter Temperature	- °F	81.9	69.7	88.4	78.3	83.6	60.8	84.5	67.8		
C Factor of pitot tube	-	0.817	0.729	0.817	0.729	0.817	0.729	0.817	0.729		
Nozzle Diameter	- inches	0.336	0.268	0.336	0.268	0.336	0.268	0.336	0.268		
Area of Nozzle	- ft^2	0.00062	0.00039	0.00062	0.00039	0.00062	0.00039	0.00062	0.00039		
Area of Stack	- ft^2	165	85	165	85	165	85	165	85		
H_2O Weight	- gm	64.5	83.4	74.1	81.4	65.4	65.8	65.4	73.0		
Sample Time	- minutes	90	96	90	96	90	96	90	96		
Barometric Pressure	- " Hg	29.04	29.04	28.98	28.98	29.18	29.18	29.18	29.18		
Static Pressure	- " H_2O	1.20	-0.61	1.20	0.54	1.00	-0.84	1.10	-0.69		
% Oxygen	-	3.7	3.4	3.0	3.4	3.0	3.6	2.8	3.4	3.1	3.5
% Carbon Dioxide	-	16.3	16.6	17.0	16.6	17.1	16.4	17.1	16.6	16.9	16.6
ppmv CO	-	30	11	42	21	39	15	41	15		
% N_2 + CO	-	80.0	80.0	80.0	80.0	79.9	80.0	80.1	80.0		
Stack Temp	- °F	351	352	345	348	346	345	340	342	346	347
"S" sample (rms vel head)	- " H_2O	0.077	0.299	0.074	0.284	0.070	0.283	0.069	0.289		
Dust Weight	- gm	3.8695	0.1600	4.5366	0.1346	3.4782	0.0760	3.6177	0.1796		
CALCULATED DATA:											
Sample Volume	- dscf	37.28	44.10	36.05	43.42	34.99	43.12	35.29	43.45	35.90	43.52
Absolute Stack Pressure	- " Hg	29.13	29.00	29.07	29.02	29.25	29.12	29.26	29.13	29.18	29.07
Absolute Stack Temp	- °R	811	812	805	808	806	805	800	802	806	807
H_2O	- % by Vol	7.5	8.2	8.8	8.1	8.1	6.7	8.0	7.3	8.1	7.6
Water Volume	- std ft^3	3.04	3.93	3.49	3.83	3.08	3.10	3.08	3.44		
Dry Molecular Weight	- lb/lb-mole	30.76	30.79	30.84	30.79	30.86	30.77	30.85	30.79	30.83	30.79
Wet Molecular Weight	- lb/lb-mole	29.79	29.75	29.71	29.75	29.82	29.91	29.82	29.85	29.78	29.82
% Excess Air	-	21.2	19.2	16.6	19.2	16.6	20.5	15.3	19.2	17.4	19.5
GAS FLOW DATA:											
Gas Velocity, Direct	- fps	18.74	33.07	18.34	32.13	17.76	31.87	17.57	32.17	18.10	32.31
acfm	-	185,500	168,600	181,600	163,900	175,900	162,600	173,900	164,100	179,200	164,800
dscfm	-	108,700	97,600	105,500	95,500	103,500	96,800	103,200	97,500	105,200	96,900
Excess Air Free dscfm	-	89,500	81,700	90,400	80,000	88,600	80,100	89,400	81,600	89,500	80,900
PARTICULATE LOADING:											
Grains/dscf	-	1.602	0.056	1.942	0.048	1.534	0.027	1.582	0.064	1.665	0.049
lb/hr	-	1,492.7	46.9	1,756.5	39.2	1,361.4	22.6	1,399.6	53.3	1,502.5	40
lb/MM Btu	-	2.931	0.092	3.523	0.079	2.760	0.046	2.785	0.106	3.00	0.08
ESP Collection Efficiency by Concentration			96.5%		97.5%		98.2%		96.0%		97.1%
ESP Collection Efficiency by Mass Loading			96.9%		97.8%		98.3%		96.2%		97.3%
% ISOKINETIC	-	102.2	102.3	101.8	102.9	100.7	100.8	101.9	100.9	101.67	101.72
SO_2 CALCULATIONS:											
lb/dscf	-	2.33E-04	2.45E-04	2.56E-04	2.34E-04	2.61E-04	2.30E-04	2.64E-04	2.51E-04	2.54E-04	2.40E-04
lb/hr	-	1,517	1,437	1,623	1,343	1,622	1,338	1,634	1,466	1,599	1,396
ppmv @ DUCT CONDITIONS	-	1,491	1,574	1,647	1,504	1,679	1,477	1,696	1,608	1,628	1,541
ppmv @ 0% OXYGEN	-	1,811	1,880	1,924	1,796	1,961	1,784	1,958	1,920	1,913	1,845
lb/MM,Btu (O_2 Based)	-	2.72	2.82	2.88	2.69	2.97	2.71	2.97	2.92	2.89	2.79
COAL ANALYSIS:											
% Carbon (dry)		77.96	77.96	77.96	77.96	78.71	78.71	78.71	78.71	78.34	78.34
% Hydrogen (dry)		5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25
% Nitrogen (dry)		1.59	1.59	1.59	1.59	1.58	1.58	1.58	1.58	1.59	1.59
% Sulfur (dry)		2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
% Oxygen (dry)		6.34	6.34	6.34	6.34	5.61	5.61	5.61	5.61	5.98	5.98
% Ash (dry)		6.67	6.67	6.67	6.67	6.66	6.66	6.66	6.66	6.67	6.67
% Volatile Matter (dry)		39.87	39.87	39.87	39.87	39.65	39.65	39.65	39.65	39.76	39.76
Btu/lb (dry)		14,227	14,227	14,227	14,227	14,206	14,206	14,206	14,206	14,217	14,217
F-Factor		9,626	9,626	9,626	9,626	9,744	9,744	9,744	9,744	9,685	9,685
%Total Moisture		5.89	5.89	5.89	5.89	5.67	5.67	5.67	5.67	5.78	5.78
Calculated F-Factor Firing Rate, lb/hr-dry			35,800		35,050		34,720		35,370		35,240
Calculated F-Factor Firing Rate, lb/hr-wet			38,040		37,240		36,810		37,500		37,400
FLY ASH ANALYSIS:											
% Ash (dry)		59.68		59.58		63.91		62.07		61.31	
% Carbon (dry)		38.95		37.49		34.12		36.51		36.77	
% Sulfur (dry)		0.91		1.17		0.96		0.95		1.00	

Table A-2

KODAK BOILER 15 DATA ESP PERFORMACE TEST DATA

BASELINE TESTING

June 3-4, 1998

Location		ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet	ESP Inlet	ESP Outlet	INLET AVG	OUTLET AVG
Date		June 3	June 3	June 4	June 4	June 4	June 4	June 4	June 4		
Start Time		1700	1700	0820	0820	1040	1040	1500	1500		
Stop Time		1840	1850	1000	1010	1220	1228	1640	1650		
Test Number		BL-1	BL-1	BL-2	BL-2	BL-3	BL-3	BL-4	BL-4		
SAMPLING DATA:											
Y factor of dry gas meter	-	1.015	1.000	1.015	1.000	1.015	1.000	1.015	1.000		
Gas Volume	- ft^3	39.02	47.37	38.34	46.59	39.50	47.55	39.26	46.98		
Delta H of dry gas meter	- " H_2O	0.65	0.86	0.66	0.83	0.66	0.86	0.65	0.82		
Meter Temperature	- °F	87.9	65.8	84.2	64.6	89.5	70.3	91.0	71.2		
C Factor of pitot tube	-	0.817	0.729	0.817	0.729	0.817	0.729	0.817	0.729		
Nozzle Diameter	- inches	0.336	0.268	0.336	0.268	0.336	0.268	0.336	0.268		
Area of Nozzle	- ft^2	0.00062	0.00039	0.00062	0.00039	0.00062	0.00039	0.00062	0.00039		
Area of Stack	- ft^2	165	85	165	85	165	85	165	85		
H_2O Weight	- gm	69.3	79.9	60.6	80.3	66.7	76.7	66.3	74.2		
Sample Time	- minutes	90	96	90	96	90	96	90	96		
Barometric Pressure	- " Hg	29.18	29.18	29.25	29.25	29.24	29.24	29.19	29.19		
Static Pressure	- " H_2O	1.59	-0.73	1.50	-0.73	1.34	-0.76	1.47	-0.55		
% Oxygen	-	3.6	4.1	3.6	4.1	3.4	3.9	3.7	4.3	3.6	4.1
% Carbon Dioxide	-	16.5	15.9	16.4	15.9	16.6	16.1	16.2	15.8	16.4	15.9
ppmv CO	-	<2	30	<4	NA	~5	NA	<1	NA		
% N_2 + CO	-	79.9	80.0	80.0	80.0	80.0	80.0	80.1	79.9		
Stack Temp	- °F	366	363	365	369	376	377	364	361	368	368
"S" sample (rms vel head)	- " H_2O	0.080	0.335	0.083	0.336	0.083	0.345	0.081	0.338		
Dust Weight	- gm	1.3522	0.0533	1.1593	0.0711	1.3301	0.1093	1.5553	0.0643		
CALCULATED DATA:											
Sample Volume	- dscf	37.27	46.47	36.96	45.92	37.70	46.35	37.30	45.63	37.31	46.09
Absolute Stack Pressure	- " Hg	29.30	29.13	29.36	29.20	29.34	29.18	29.30	29.15	29.32	29.16
Absolute Stack Temp	- °R	826	823	825	829	836	837	824	821	828	828
H_2O	- % by Vol	8.1	7.5	7.2	7.6	7.7	7.2	7.7	7.1	7.7	7.4
Water Volume	- std ft^3	3.26	3.76	2.85	3.78	3.14	3.61	3.12	3.49		
Dry Molecular Weight	- lb/lb-mole	30.78	30.71	30.77	30.71	30.79	30.73	30.74	30.70	30.77	30.71
Wet Molecular Weight	- lb/lb-mole	29.75	29.76	29.85	29.74	29.81	29.81	29.76	29.80	29.79	29.78
% Excess Air	-	20.6	24.1	20.5	24.1	19.2	22.6	21.2	25.6	20.4	24.1
GAS FLOW DATA:											
Gas Velocity, Direct	- fps	19.23	35.15	19.52	35.30	19.67	35.90	19.33	35.23	19.44	35.40
acfm	-	190,380	179,300	193,300	180,000	194,800	183,100	191,300	179,700	192,400	180,500
dscfm	-	109,600	103,600	112,700	103,400	111,400	104,500	110,800	104,600	111,100	104,000
Excess Air Free dscfm	-	90,700	83,300	93,300	83,100	93,300	85,000	91,200	83,100	92,100	83,600
PARTICULATE LOADING:											
Grains/dscf	-	0.560	0.018	0.484	0.024	0.544	0.036	0.643	0.022	0.558	0.025
lb/hr	-	526.1	15.7	467.7	21.2	520.1	32.6	611.3	19.5	531	22
lb/MM Btu	-	1.026	0.031	0.910	0.041	0.989	0.062	1.189	0.038	1.03	0.04
ESP Collection Efficiency by Concentration			96.8%		95.1%		93.3%		96.6%		95.5%
ESP Collection Efficiency by Mass Loading			97.0%		95.5%		93.7%		96.8%		95.8%
% ISOKINETIC	-	101.4	101.5	97.8	100.5	100.9	100.3	100.4	98.8	100.11	100.28
SO_2 CALCULATIONS:											
lb/dscf	-	2.51E-04	2.38E-04	2.48E-04	2.39E-04	2.52E-04	2.41E-04	2.48E-04	2.37E-04	2.50E-04	2.39E-04
lb/hr	-	1,649	1,482	1,679	1,485	1,682	1,508	1,647	1,488	1,664	1,491
ppmv @ DUCT CONDITIONS	-	1,608	1,525	1,591	1,531	1,614	1,540	1,587	1,516	1,600	1,528
ppmv @ 0% OXYGEN	-	1,943	1,897	1,922	1,905	1,928	1,893	1,926	1,909	1,930	1,901
lb/MM,Btu (O_2 Based)	-	2.95	2.89	2.91	2.89	2.92	2.87	2.92	2.90	2.92	2.89
COAL ANALYSIS:											
% Carbon (dry)		78.71	78.71	78.63	78.63	78.63	78.63	78.63	78.63	78.65	78.65
% Hydrogen (dry)		5.25	5.25	5.12	5.12	5.12	5.12	5.12	5.12	5.15	5.15
% Nitrogen (dry)		1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
% Sulfur (dry)		2.19	2.19	2.22	2.22	2.22	2.22	2.22	2.22	2.21	2.21
% Oxygen (dry)		5.61	5.61	5.77	5.77	5.77	5.77	5.77	5.77	5.73	5.73
% Ash (dry)		6.66	6.66	6.68	6.68	6.68	6.68	6.68	6.68	6.68	6.68
% Volatile Matter (dry)		39.65	39.65	39.96	39.96	39.96	39.96	39.96	39.96	39.88	39.88
Btu/lb (dry)		14,206	14,206	14,202	14,202	14,202	14,202	14,202	14,202	14,203	14,203
F-Factor		9,744	9,744	9,701	9,701	9,701	9,701	9,701	9,701	9,712	9,712
% Total Mositure		5.67	5.67	7.62	7.62	7.62	7.62	7.62	7.62	7.13	7.13
Calculated F-Factor Firing Rate, lb/hr-dry			36,110		36,190		37,020		36,190		36,380
Calculated F-Factor Firing Rate, lb/hr-wet			38,280		39,180		40,070		39,180		39,180
FLY ASH ANALYSIS:											
% Ash (dry)		82.65		87.51		86.13		82.95		84.81	
% Carbon (dry)		14.68		7.08		9.11		14.36		11.31	
% Sulfur (dry)		1.18		1.25		1.31		1.23		1.24	

Table A-3

Unit 15 ESP Test Electrical Data
Kodak Unit 15 Boiler

				Primary		Secondary		Sec. Power		Spark Rate
Date	Time	Test	Field 5	V	Amps	KV	ma	KW	W/sq ft	Sparks/min
06/02/98	11:55 AM	MCR-1	1	200.0	9.8	35.5	35.0	1.24	0.203	36
			2	260.0	18.5	39.5	100.0	3.95	0.645	28
			3East	277.5	29.5	37.5	150.0	5.63	1.379	40
			3West	240.0	20.0	34.0	83.0	2.82	0.692	28
			4	210.0	21.0	34.0	90.0	3.06	0.500	30
			5	235.0	32.5	40.5	215.0	8.71	1.423	30
06/02/98	12:20 PM	MCR-1	1	175.0	8.7	33.0	45.0	1.49	0.243	38
			2	280.0	19.0	39.5	110.0	4.35	0.710	30
			3East	283.0	25.0	38.5	149.5	5.76	1.411	24
			3West	242.5	22.0	34.0	81.0	2.75	0.675	28
			4	205.0	22.0	34.5	100.0	3.45	0.564	34
			5	245.0	34.5	41.5	250.0	10.38	1.695	26
06/02/98	02:20 PM	MCR-2	1	200.0	12.0	36.0	45.0	1.62	0.265	36
			2	260.0	24.5	40.0	130.0	5.20	0.850	30
			3East	271.0	25.0	38.0	146.0	5.55	1.360	32
			3West	242.0	19.0	34.5	94.0	3.24	0.795	28
			4	210.0	27.0	34.5	125.0	4.31	0.705	32
			5	245.0	37.0	41.5	220.0	9.13	1.492	26
06/02/98	03:25 PM	MCR-2	1	200.0	10.4	34.0	45.0	1.53	0.250	32
			2	240.0	25.0	39.0	140.0	5.46	0.892	30
			3East	264.5	24.0	37.0	120.0	4.44	1.088	26
			3West	244.5	19.5	34.0	87.0	2.96	0.725	28
			4	220.0	29.0	36.5	150.0	5.48	0.895	29
			5	250.0	39.0	42.5	255.0	10.84	1.771	28
06/03/98	08:45 AM	MCR-3	1	180.0	8.9	35.0	35.0	1.23	0.200	29
			2	265.0	21.5	42.0	110.0	4.62	0.755	30
			3East	285.0	27.5	34.0	70.0	2.38	0.583	24
			3West	223.0	16.5	33.0	68.0	2.24	0.550	36
			4	195.0	22.0	34.5	100.0	3.45	0.564	30
			5	245.0	35.0	41.5	235.0	9.75	1.594	30
06/03/98	09:55 AM	MCR-3	1	190.0	8.1	36.0	25.0	0.90	0.147	22
			2	245.0	17.5	40.5	115.0	4.66	0.761	24
			3East	235.0	21.5	36.5	91.5	3.34	0.819	32
			3West	224.0	16.0	34.0	66.5	2.26	0.554	28
			4	190.0	19.5	34.0	95.0	3.23	0.528	32
			5	245.0	37.5	41.5	230.0	9.55	1.560	26
06/03/98	12:20 PM	MCR-4	1	190.0	8.2	34.5	35.0	1.21	0.197	32
			2	235.0	18.0	40.0	125.0	5.00	0.817	26
			3East	235.0	18.5	35.0	109.0	3.82	0.935	28
			3West	221.5	16.0	33.0	74.5	2.46	0.603	28
			4	195.0	21.0	34.0	95.0	3.23	0.528	34
			5	235.0	30.5	41.5	210.0	8.72	1.424	28

Table A-3 (Continued)

Unit 15 ESP Test Electrical Data

Kodak Unit 15 Boiler

				Primary		Secondary		Sec. Power		Spark Rate
Date	Time	Test	Field 5	V	Amps	KV	ma	KW	W/sq ft	Sparks/min
06/03/98	05:20 PM	Baseline-1	1	175.0	6.1	35.5	25.0	0.89	0.145	24
			2	185.0	7.2	39.0	40.0	1.56	0.255	26
			3East	244.5	12.0	39.5	67.5	2.67	0.653	24
			3West	222.5	11.0	36.5	46.5	1.70	0.416	30
			4	220.0	18.0	39.0	70.0	2.73	0.446	32
			5	260.0	38.5	42.5	260.0	11.05	1.806	24
06/03/98	06:20 PM	Baseline-1	1	175.0	5.9	36.5	25.0	0.91	0.149	24
			2	175.0	6.4	37.5	30.0	1.13	0.184	24
			3East	207.0	8.5	37.5	38.5	1.44	0.354	24
			3West	202.5	8.0	35.5	32.5	1.15	0.283	24
			4	210.0	18.5	39.0	90.0	3.51	0.574	32
			5	255.0	36.5	42.5	240.0	10.20	1.667	30
06/04/98	08:20 AM	Baseline-2	1	190.0	6.1	37.5	25.0	0.94	0.153	22
			2	170.0	5.5	39.5	25.0	0.99	0.161	24
			3East	216.5	8.0	39.0	34.0	1.33	0.325	28
			3West	204.5	8.0	35.5	31.5	1.12	0.274	28
			4	205.0	16.0	39.0	70.0	2.73	0.446	32
			5	250.0	32.0	43.5	215.0	9.35	1.528	26
06/04/98	10:00 AM	Baseline-2	1	175.0	5.5	38.0	25.0	0.95	0.155	24
			2	160.0	4.4	38.5	20.0	0.77	0.126	26
			3East	177.5	4.5	36.0	19.5	0.70	0.172	32
			3West	186.0	5.0	34.5	23.0	0.79	0.194	32
			4	195.0	13.0	39.0	55.0	2.15	0.350	32
			5	225.0	23.5	42.0	165.0	6.93	1.132	28
06/04/98	11:30 AM	Baseline-3	1	170.0	5.4	37.0	20.0	0.74	0.121	22
			2	155.0	4.2	38.0	15.0	0.57	0.093	26
			3East	175.0	4.5	35.0	20.5	0.72	0.176	28
			3West	172.5	5.0	34.0	18.5	0.63	0.154	32
			4	170.0	10.7	36.5	45.0	1.64	0.268	28
			5	215.0	21.5	41.5	165.0	6.85	1.119	24
06/04/98	12:45 PM	Baseline-3	1	175.0	5.5	36.5	25.0	0.91	0.149	24
			2	160.0	4.7	38.0	20.0	0.76	0.124	26
			3East	181.0	5.0	35.0	20.5	0.72	0.176	28
			3West	183.0	5.5	33.5	22.0	0.74	0.181	24
			4	170.0	11.5	36.5	45.0	1.64	0.268	28
			5	225.0	23.0	41.5	175.0	7.26	1.187	30
06/04/98	02:35 PM	Baseline-4	1	175.0	6.1	34.5	25.0	0.86	0.141	24
			2	185.0	7.2	38.0	30.0	1.14	0.186	20
			3East	177.5	6.0	33.5	26.0	0.87	0.213	32
			3West	186.5	7.0	33.0	30.5	1.01	0.247	28
			4	180.0	11.0	36.5	55.0	2.01	0.328	24
			5	215.0	23.0	41.5	170.0	7.06	1.153	26
06/04/98	04:20 PM	Baseline-4	1	175.0	6.0	35.5	25.0	0.89	0.145	22
			2	225.0	10.4	40.5	65.0	2.63	0.430	34
			3East	207.5	8.5	35.5	36.0	1.28	0.313	24
			3West	213.5	10.5	34.5	37.0	1.28	0.313	28
			4	195.0	15.0	37.0	65.0	2.41	0.393	30
			5	250.0	34.0	42.5	205.0	8.71	1.424	30