TECHNICAL PUBLICATION

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ABSTRACT

For utilities presently burning bituminous coal and considering the burning of PRB (Powder River Basin) sub-bituminous coal in a boiler with pre-NSPS burners, this paper can serve as a guide in identifying potential areas of concern related to the change in fuel. If an improvement in emissions is the goal, the reduction in NO_x *may not be as dramatic as one might expect from other published accounts of switching to PRB coal.*

The Presque Isle Unit 6 boiler owned by WEPCo has a net capacity of 90 MWe. The boiler has eight highly turbulent Flare Type Burners. The Flare Type Burner is a pre-NSPS burner designed for maximum combustion efficiency. Its register is located near the furnace along with a high swirl impeller, at the furnace end of the burner nozzle. The burners in Unit 6 are arranged in two outside columns of three burners, and a center column of two.

The boiler normally burns a mixture of 9% petroleum coke and 91% bituminous coal. With this mixture and with the boiler at full load, the NO_x *averages 0.93 lb/MMBtu and the LOI is typically in the mid 20's.*

Recently, a series of tests were conducted on this unit with various combinations of PRB, petroleum coke, and bituminous coal to determine the impact of these fuel combinations on a number of items including:

- *Emissions, including* NO_x*, CO, and* SO_2
- *Boiler Load*
- *Main and Reheat Steam Temperatures*

- *Main and Reheat Steam Desuperheating Spray Flows*
- *Pulverizer Limitations including Power and Drying Capability*
- *FD and ID Fan Limitations*
- *Boiler Efficiency*
- *Fly Ash LOI*
- *Precipitator Performance*
- *Furnace Observations*

This paper discusses and compares the data collected and observations made during the test period.

INTRODUCTION

When firing PRB coal, the amount of ash was reduced; the amount of carbon in the ash also decreased significantly, which offset some of the effects of the low sulfur content PRB. In fact, the precipitator performance was better when firing 100% PRB, contrary to expectations.

PRB coals often leave a reflective, whitish deposit on the furnace walls from their high calcium content. Removal of the PRB deposit can be very difficult, often requiring special water-assisted soot blowers[1].

This deposit, although not usually very thick, can have a major impact on the furnace exit temperature. The increased furnace exit temperature can increase the main (and reheat, when applicable) steam temperatures, increasing desuperheating spray flows and tube metal temperatures.

Many PRB coals have ash with a high sodium content, greatly increasing the quantity of fouling deposits in the convective pass of the boiler and possibly requiring additional sootblowers in both the convection pass and in the regenerative air heater. In some cases the tube-to-tube side spacing may need to be increased in the convection pass to avoid uncontrollable plugging.

PRB coals have a high volatile content, making them subject to spontaneous combustion in the pulverizers and in the coal handling system. Some types of pulverizers, particularly those with a large coal inventory, may need an inerting system. The BBP ATRITA® Pulverizers at the PIPP have a very small inventory of coal, making them particularly suitable for this type of coal. They do not require an inerting system.[3,4,5] PRB coals may also have a significant quantity of coal fines that could lead to fires in the coal pile, coal-conveying system, and in the bunkers if the systems are not designed properly. In addition, the coal handling electrical equipment needs to be designed to meet NFPA and IEEE codes for handling this type of fuel.

UNIT DESCRIPTION

WEPCo Presque Isle Power Plant is located in Marquette, Michigan and has nine units in all, but the focus of this report is on Unit 6. Unit 6 is a front wall fired boiler, designed and manufactured by Babcock Borsig Power, Inc. (BBP, formerly Riley Stoker Corporation), and includes a Ljungstrom Model 23 ½-VI-55 air preheater, eight BBP Flare Type Burners (see Figure 1) and four 556S ATRITA® Pulverizers. Figure 2 is included to show the current BBP low NO_X Controlled Combustion Venturi (CCV®) Dual Air Zone Burner for comparison. The Unit 6 boiler is designed to operate at a maximum continuous capacity rating of 615,000 lb/hr of superheated steam at a pressure of 1,625 psig and a temperature of 1,005°F. The boiler's original capacity and performance were based on burning bituminous coal with a higher heating value (HHV) of 11,500 Btu/lb and a composition of 42.0% Fixed Carbon, 39.0% volatile, 8.0% moisture, and 11.0% ash. The design feedwater inlet temperature is 455°F. Unit 6 currently burns a blend of Sanborn Creek (bituminous coal) with 9% petroleum coke. The analysis of this blend can be found in Table 2 of this document.

The electrostatic precipitator, built by GE Buell, is a weighted wire unit, which originally consisted of three mechanical fields and nine electrical frames, segregated into four electrical fields, with a specific collecting area (SCA) of 222. The middle mechanical field has recently been replaced with a laminar flow fine particulate agglomerator designed by Environmental Elements Corporation. Precipitator performance is enhanced with a sulfur flue gas conditioning system designed by Wahlco.

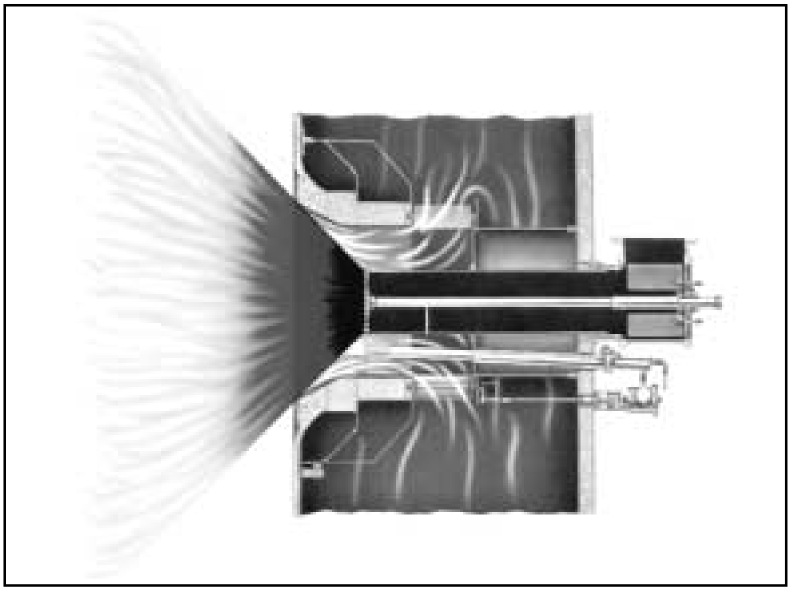

Figure 1 Flare Type Burner

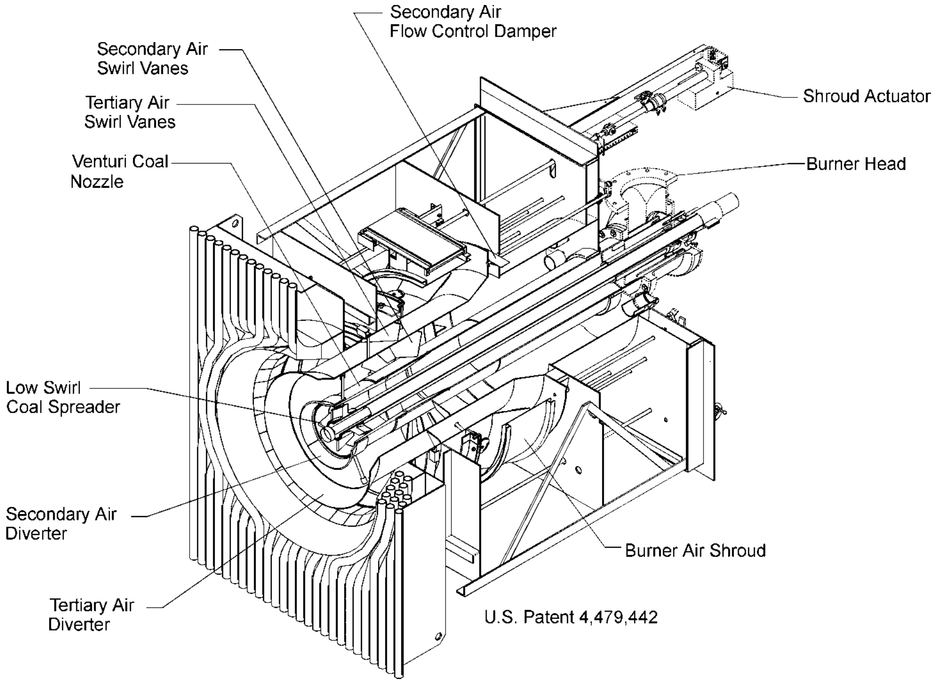

Figure 2 Controlled Combustion Venturi (CCV®) Dual Air Zone Burner

TEST MATRIX AND DESCRIPTION

The testing conducted on PIPP Unit 6 was done in two distinct phases. BBP conducted baseline testing of the unit while burning the current fuel blend of 91% Sanborn Creek and 9% petroleum coke. A total of seven tests were conducted to characterize the unit for future low NO_X burners similar to those depicted in Figure 2. This testing was Phase A of the unit testing. WEPCo subsequently conducted Phases B, C, and D to study three different burner/fuel arrangements and their impacts upon the unit. Table 1, shown below, details the tests presented in this paper including the test number, the phase during which the test was conducted, and a brief description of the tests and the coal being fired in each burner.

Figure 3 is a diagram showing the silo and burner arrangement. This figure is important for understanding the results of testing during phases B and C.

Table 1 Test Matrix

Phase of Testing	Description
A	Full load baseline test @ 85 MWg burning Sanborn Creek with 9% petroleum coke in all eight burners
A	Intermediate load testing @ 68 MWg burning Sanborn Creek with 9% petroleum coke in all eight burners
B	Maximum attainable load of 70 MWg burning PRB in burners B1, B2, B3 and C2 (Silo A) and Sanborn Creek with 9% petroleum coke in burners C1, C3, A1 and A2 (Silo B)
C	Maximum attainable load of 70 MWg burning Sanborn Creek with 9% petroleum coke in burners B1, B2, B3 and C2 (Silo A) and PRB in burners C1, C3, A1 and A2 (Silo B)
D	Maximum attainable load @ 66 MWg burning PRB in all eight burners

Table 2 Fuel Analyses

Test Phase		**A**	**A**	**B**	**C**	**D**
Boiler Load Gross MWg	**95**	**85**	**68**	**70**	**70**	**66**
Test Description	**Design**	**Baseline**	**Baseline**	**PRB in Silo A***	**PRB in Silo B***	**100% PRB**
Fuel fired	**100% Bituminous**	**91% Sanborn Creek 9% Petroleum coke**		**50% PRB 50% Baseline**		**100% PRB**
Moisture, % by weight	8.00	9.25	8.31	18.69	18.83	27.29
Carbon, % by weight	64.30	68.53	68.34	58.26	59.46	51.84
Hydrogen, % by weight	4.50	4.83	4.46	4.05	4.16	3.57
Nitrogen, % by weight	1.20	1.50	1.49	1.03	1.03	0.76
Oxygen, % by weight	7.50	8.23	8.65	10.14	10.63	11.34
Sulfur, % by weight	3.50	0.70	0.69	0.48	0.54	0.36
Ash, % by weight	11.00	6.96	8.06	7.35	5.35	4.84
HHV, Btu/lb	11,500	12,216	12,136	10,282	10,453	8,931
Volatiles, % by weight		34.57	35.10	32.58	33.07	30.56
Fixed Carbon, % by weight		49.22	48.53	41.38	42.75	37.31

*Mathematically blended analyses, even though the coals are separately fired in the furnace.

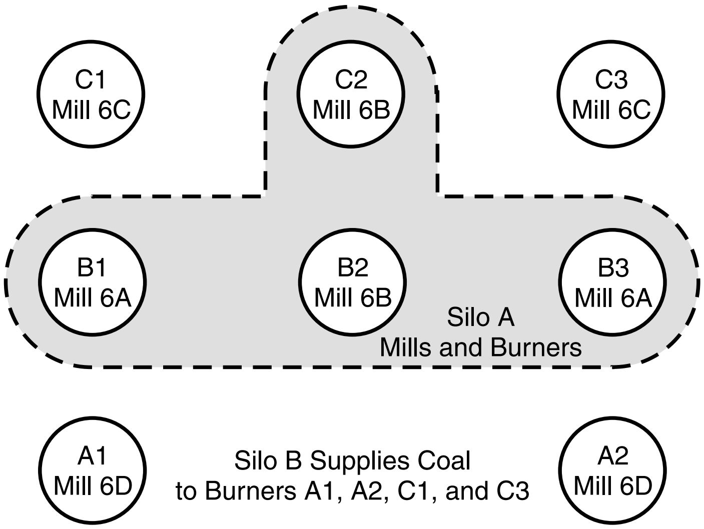

Figure 3 Burner Arrangement

FUELS

The fuels tested during this study included Sanborn Creek, a bituminous coal, pre-blended before delivery to the plant with petroleum coke, for phase A, and Powder River Basin (PRB) co-fired with the blend for phases B and C. The blend is the current fuel for this unit and PRB is a popular sub-bituminous fuel that is utilized at many utilities primarily because of its low sulfur content, low NO_X emissions, and favorable combustion characteristics. Table 2 lists the ultimate fuel analyses for all combinations of fuels. Notice there are two major differences between the Sanborn Creek with pet coke and the PRB, the moisture content and the higher heating value (HHV).

The pulverizer system is subjected to a two-fold increase in moisture, significantly impacting the drying capacity of the pulverizers. In addition, there is a 30 to 35% increase in coal flow for the same heat input because of the lower HHV of the PRB coal. Thus the pulverizer system often limits load when a plant switches from bituminous fuel to PRB and PIPP Unit 6 is no exception. Load was limited to 66 MWg from a design maximum of 95 MWg.

Another important parameter is the amount of nitrogen (on a fuel heat input basis) for each coal, because the nitrogen content of the fuel contributes to the NO_X emissions produced during combustion. Table 3 lists the nitrogen, sulfur, oxygen, and ash content of the fuels tested on a fuel heat input basis to accurately compare the fuels. With pre-NSPS burners this unit has a tendency to produce relatively high NO_X emissions even with PRB coal. Interestingly, the change in NO_X emissions is almost proportional to the nitrogen content of the coal blends on a lb/MMBtu basis. This is contrary to BBP experience with low NO_X burners[2].

Finally, the amount of ash, on a fuel heat input basis, is important to the combustible loss numbers. LOI does not consider the ash content of the coal but the combustibles loss does. The PRB coal burned during the testing had an ash content that was 20% less than the Sanborn Creek w/ 9% pet coke on a percent by weight basis. A direct comparison of the LOI is only important from an ash disposal point of view. Combustible losses must be calculated to determine the impact of various fuels on boiler efficiency.

Table 3 Normalized Fuel Constituents

Test Phase		A	A	B	C	D
Boiler Load Gross MWg	**95**	**85**	**68**	**70**	**70**	**66**
Test Description	**Design**	**Full Load Baseline**	**Baseline**	**PRB in Silo A**	**PRB in Silo B**	**100% PRB**
Nitrogen, lb/MMBtu	1.04	1.23	1.23	1.00	0.99	0.85
Oxygen, lb/MMBtu	6.50	6.74	7.13	9.86	10.17	12.70
Sulfur, lb/MMBtu	3.00	0.57	0.57	0.47	0.52	0.40
Ash, lb/MMBtu	9.60	5.70	6.64	7.15	5.12	5.42
Volatiles (dry ash free), % by weight	-	41.26	41.97	44.05	43.62	45.03

RESULTS

Testing phase A was conducted to determine the current performance of the system prior to the fuel changes that were tested in subsequent phases B, C and D. The testing in Phase A showed that the boiler burning Sanborn Creek with 9% petroleum coke was unable to obtain the original design maximum load. The boiler obtained 86% of the original design steam flow primarily because of an inability to maintain adequate mill discharge temperatures. Table 4 shows the main steam flow, spray flow, coal flow, steam temperature, the average mill data, and average emissions data for all the testing discussed in this paper.

Table 4 System Data

Test Phase			A	A	B	C	D
Boiler Load Gross MWg		**95**	**85**	**68**	**70**	**70**	**66**
Test Description		**Design**	**Baseline**	**Baseline**	**PRB in Silo A**	**PRB in Silo B**	**100% PRB**
Main steam (FW flow and spray flows)	Klb/hr	615	525	398	433	425	376
Reheat spray	Klb/hr		0	0	0	0	8.57
Superheat spray	Klb/hr		0	0	0	0	5.28
Final superheater outlet	°F	1005	969	934	975	960	1000
Hot reheat outlet	°F	1005	1001	934	990	972	1000
Main steam at turbine	psig	1625	1471	1470	1470	1473	1450
Total Coal Flow	lb/hr	73,940	67,300	52,600	67,300	60,500	69,000
Avg. mill outlet temp.	°F	180	167	183	152	147	133
Avg. mill suction pressure	IWC		-0.8	-0.9	-0.5	-0.6	-0.6
Avg. mill draft	IWC		9.1	10.6	10.3	11.3	11.9
O_2 at economizer outlet	%		3.1	3.7	3.7	3.6	2.5
Excess air at econ. outlet	%	20	33.75	28.96	20.98	20.26	13.36
NO_x, CEMS	lb/MMBtu		0.930	0.813	0.749	0.837	0.650
CO, CEMS	PPM		11	7.8	16.1	7.5	6.0
SO_2, CEMS	lb/MMBtu		1.330	1.344	0.968	1.089	0.537
LOI	Wt%		24.85	18.35	12.90	15.00	1.03

These system numbers indicate that there were changes in the boiler during the fuel switch that were both positive and negative. The main steam temperatures for each test are plotted in Figure 4 and indicate that the introduction of PRB into the system actually increased the steam temperatures closer to the original design. One reason for this change is the ash generated from the combustion of PRB is highly reflective which decreases heat absorption into the furnace walls therefore the gas temperatures in the upper furnace are higher and more heat is transferred to the superheater and reheater.

Figure 5 illustrates the increase in furnace exit gas temperature and clearly shows that when PRB is fired the FEGT is higher by varying degrees due to the decreased heat transfer into the waterwalls. This change in performance is also illustrated by the need for spray water in both the superheater and reheater when firing 100% PRB. Normally, this unit does not require attemperator spray even at the current maximum full load of 85 MWg. Figure 6 shows the precipitator ash LOI values for each test. The change in LOI was the most significant finding during this series of tests. Notice that the LOI when burning Sanborn Creek

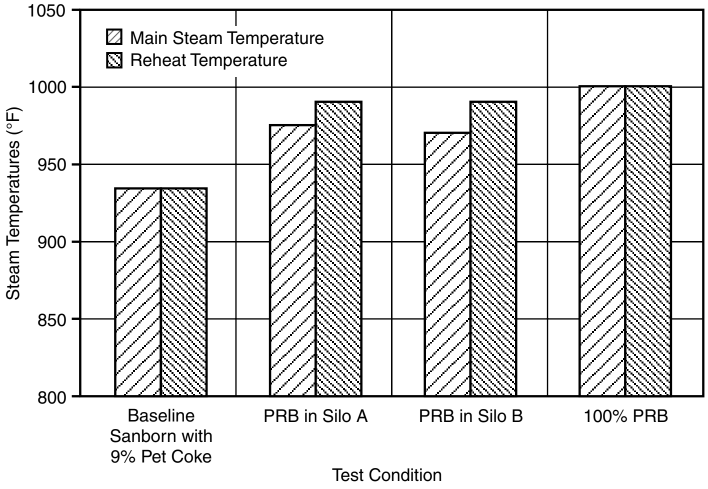

Figure 4 Main Steam and Reheat Temperature

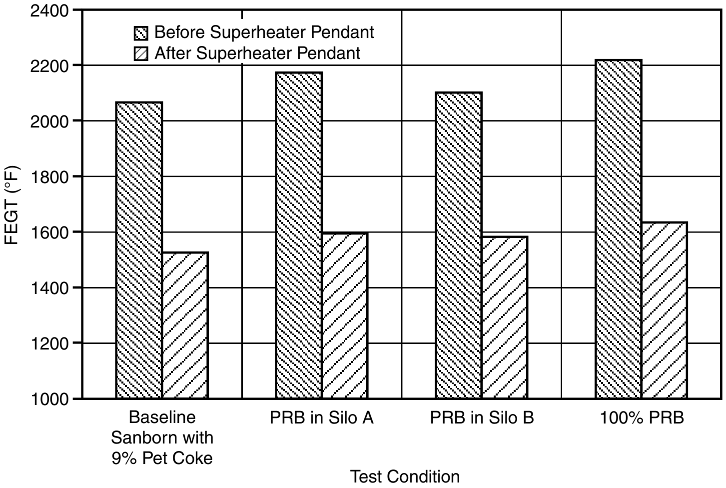

Figure 5 Locally Collected Furnace Exit Gas Temperature

w/ 9% pet coke is 18.35% but drops down to 1.03% for the 100% PRB tests. This change in LOI is due the increased combustion efficiency when burning PRB. The tests with the 50% PRB fuel did not show as dramatic a change in LOI but were also better than with the blend of Sanborn Creek w/ 9% pet coke alone.

The most enlightening results from this testing involve the NO_X emissions recorded for each test condition listed in Table 1. The NOx emissions from the testing are plotted in Figure 7. The testing showed that when firing 100% PRB coal, NO_X experienced its greatest reduction from baseline at an operating load of 68-70MWg. However, the reduction was only 20% when comparing the baseline at 68 MWg to 100% PRB at 66MWg. This 20% reduction is significantly less than the 50% reduction experienced when burning 100% PRB in another BBP boiler which has low NO_X burners, rather than the pre-NSPS burners in this PIPP boiler[2]. The tests from Phase B and C indicate the burner arrangement for burning PRB is important in reducing NO_X if it were going to be done by filling one of the two silos with PRB instead of pre-blending. The results indicate that when PRB is burned in the center burners, the NO_X decreased more than when the PRB was in the outside corner burners (refer to Figures 3 and 7).

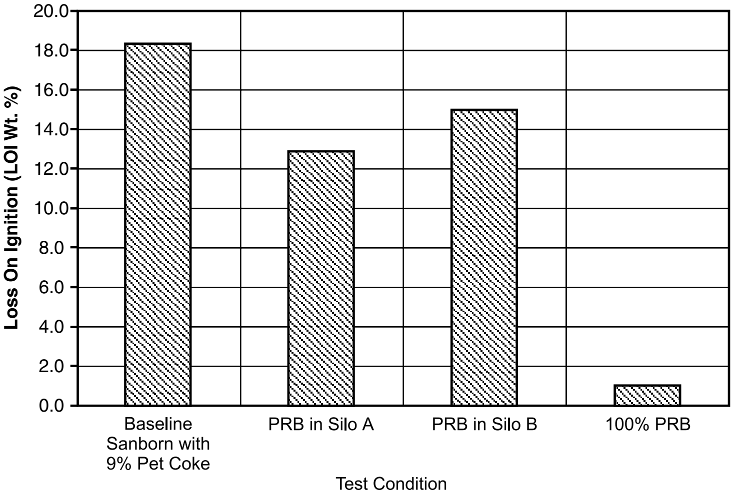

Figure 6 Precipitator LOI Collected During Testing

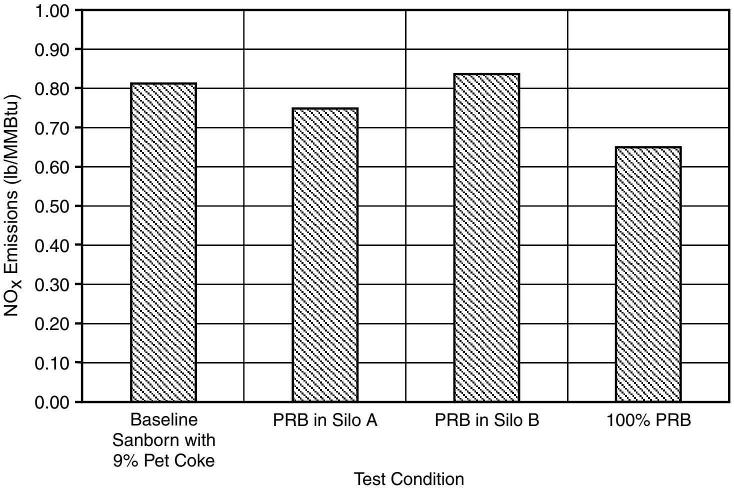

Figure 7 NO_X Emissions Recorded by the CEMS

Figure 8 shows that the CO levels from the test with PRB in Silo A were two times greater than the baseline but well within acceptable levels. Figure 9 shows the opacity for these tests and follows the higher CO levels recorded during Phase B test. The opacity recorded for Phase D testing was lower than the Phase B and C tests. Recall Figure 6 that shows the LOI for Phase D testing was much lower than for Phases B and C. This undoubtedly had a favorable impact on flyash resistivity and improved precipitator performance.

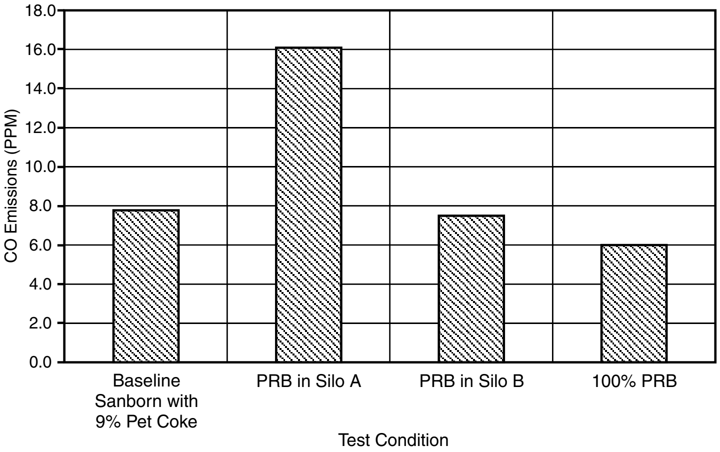

Figure 8 CO Emissions Recorded by the CEMS

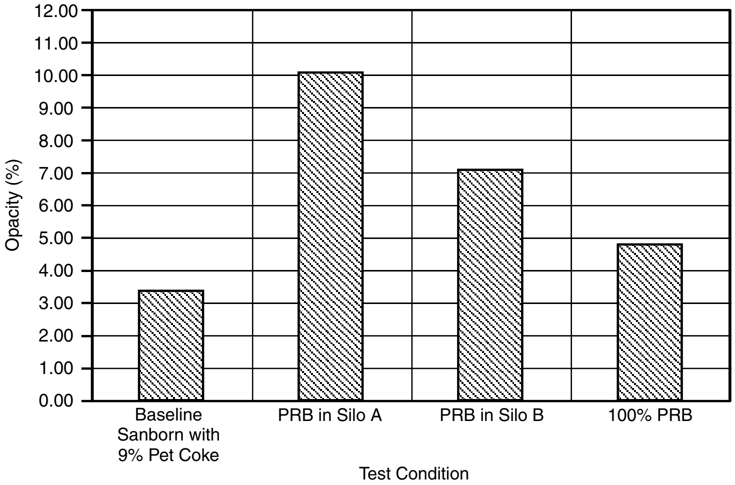

Figure 9 Opacity Recorded by the CEMS

The last emission that was monitored was the SO_2 levels recorded by the CEMS. The levels shown in Figure 10 are consistent with what is expected, based on the sulfur content of the fuels being burned during testing.

Finally, attention needs to be given to the auxiliary equipment that is affected by changing to PRB coal. The FD Fan is not normally affected since the combustion airflow for PRB is within 3% of the flow needed for the bituminous coal blend. Figure 11 shows that for the testing conducted the FD Fan amps did not change significantly over the range of testing.

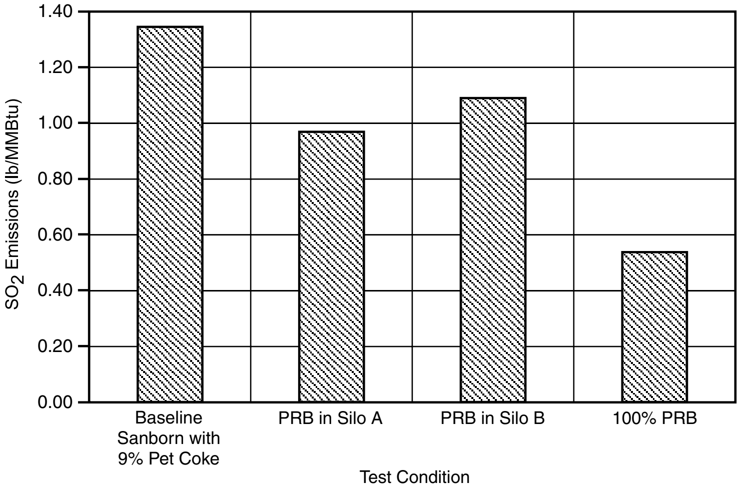

Figure 10 SO_2 Emissions Recorded by the CEMS

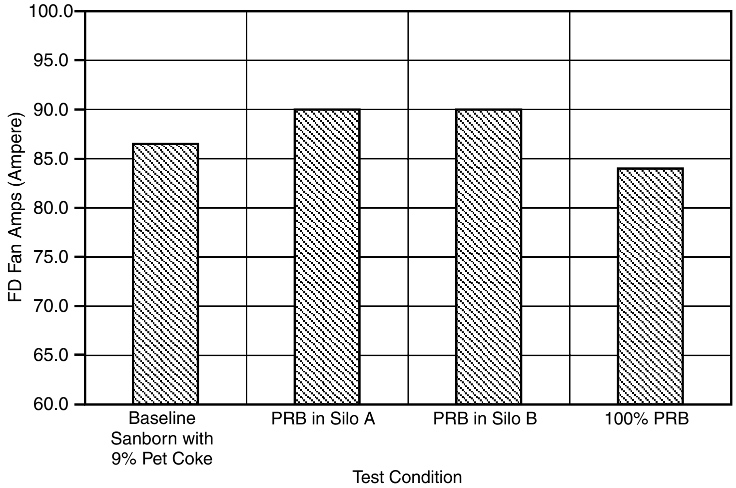

Figure 11 Forced Draft Fan Amps

Figures 12, 13, and 14 illustrate the changes in the milling system amps, discharge and suction pressures. All of these changes can indicate potential problems with the mill obtaining full load while burning PRB. The mill amps shown in Figure 12 increased by 11% on average when milling PRB. Mill discharge pressures varied over the whole testing program but seem to be 1 to 4 IWC higher when burning PRB.

The mill discharge temperature was recorded to show the capacity of the mills for drying the coal. Figure 15 shows the discharge temperatures, which decreased as expected. The mill discharge temperatures decreased an average of 49°F. It is typical to have lower discharge temperatures when milling PRB for several reasons. First, PRB contains about three times as much surface moisture as the base fuel and therefore the mills are required to evaporate more water in order to produce enough pulverized fuel for the load demand. Second, the mills had to process 69,000 lb/hr of PRB compared to 52,600 lb/hr of the blend to achieve the same load because of the decrease in HHV from 12,135 BTU/lb to 8,931 BTU/lb. The temperatures on these mills fell below practical operating levels, limiting load.

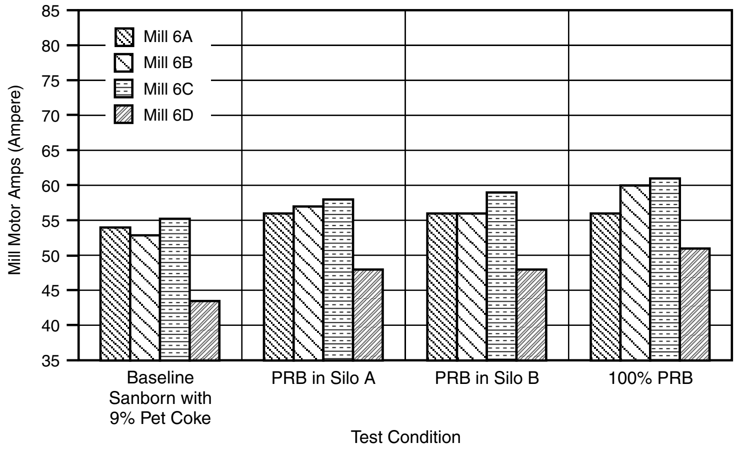

Figure 12 Mill Motor Amps

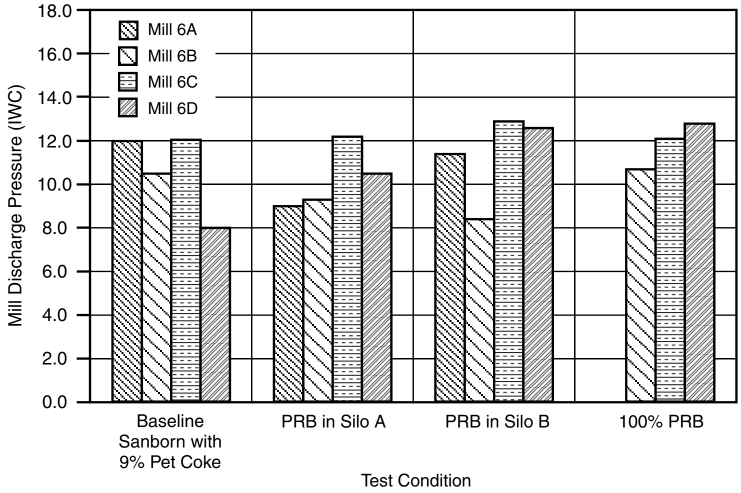

Figure 13 Mill Discharge Pressures

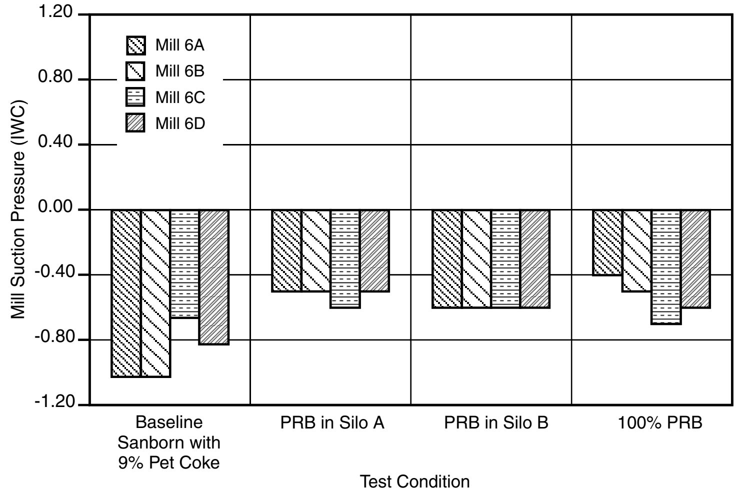

Figure 14 Mill Suction Pressures

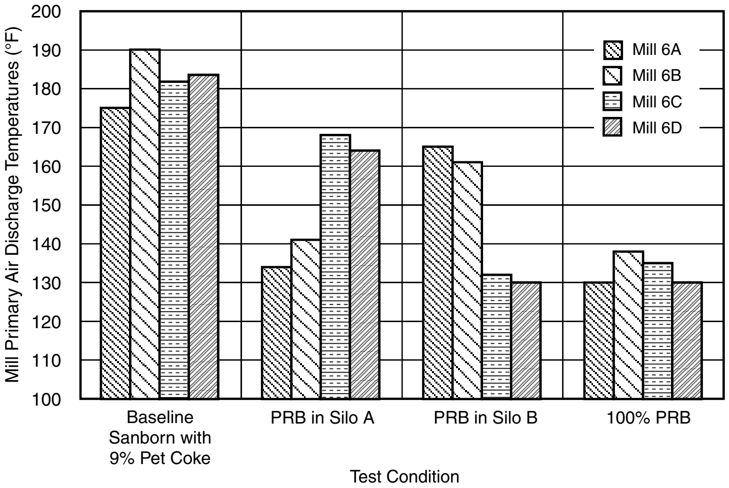

Figure 15 Mill Discharge Temperatures

Precipitator performance generally degraded during test phases B and C, when burning 50% PRB and 50% of the combinations. Performance improved significantly after switching to 100 % PRB. Opacity readings trended upward to a value greater than 10% with the initial co-firing of PRB in the A Silo burners, and plant personnel added additional SO3 after seven days of operation in this mode. The average value for opacity with PRB in the A Silo was 9.2 %. This average value dropped to 7.2% with the changeover of PRB from the A Silo to the B Silo. The most dramatic change occurred with the switch to 100% PRB, when the average opacity for the eight-day period of 100% PRB dropped to 4.1%. Additionally, the spark rate dropped about 35% and the current and voltage readings were noticeably higher while burning 100% PRB than they were when burning bituminous coal or the PRB blend. The improved performance with 100% PRB is partly a result of lower ash content of the PRB, as well as the lower excess air used to burn it. The resistivity of the low LOI flyash when firing 100% PRB was very likely better for precipitator performance, as well. Additionally, there is speculation that the SO3 was less effective when attempting to condition two different types of flyash at the same time.

Boiler observations on the slag deposits were taken during all phases of testing. During baseline testing the boiler had little slagging on the superheater tubes and furnace walls but did experience “eyebrows” on the burner throats. Maintenance personnel must remove these deposits periodically in order to prevent them from falling and damaging the lower furnace. During Phases B and C it was observed that the burners with the Sanborn Creek blend were still experiencing “eyebrows.” The burner zone was somewhat cleaner when burning the 50% PRB as compared to the baseline. However, with 50% PRB the slag increased noticeably at the bottom of the superheater platens and furnace walls. To combat the increased rate of deposition, soot blowing frequency was increased from two times per day to six times per day. Phase D with 100% PRB had an even more dramatic change in the fouling characteristics of the unit. The burner throats were free of “eyebrows” and the flame was clearer than during the baseline as shown in Figure 16.

The soot blowing cycle was increased to remove the molten slag from the superheater platens but the cleaning was less effective than the Phase B and C tests. Also, the slag was thicker on the walls and superheater and the build up occurred quicker than during the other tests, see Figure 17.

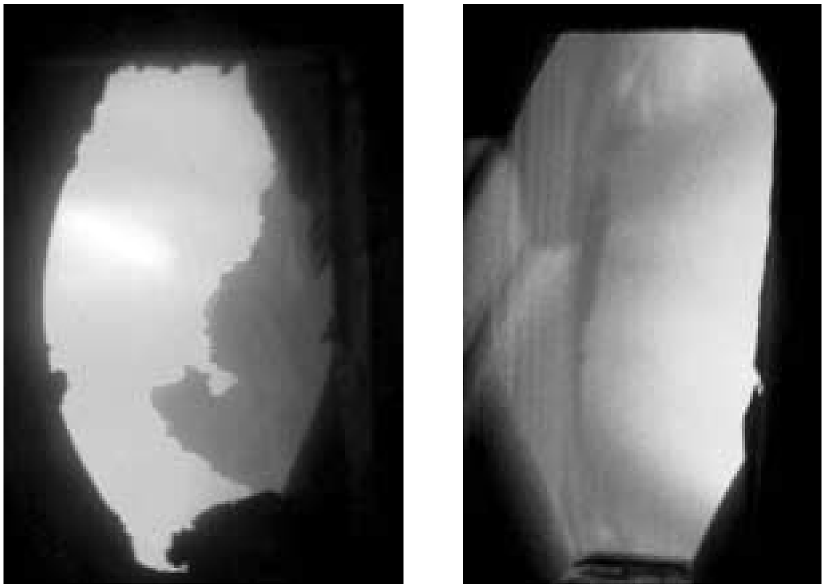

Figure 16 (left) Eyebrow on Burner with Sanborn Creek and Pet Coke Blend (right) Clear Burner Throat with 100% PRB Coal

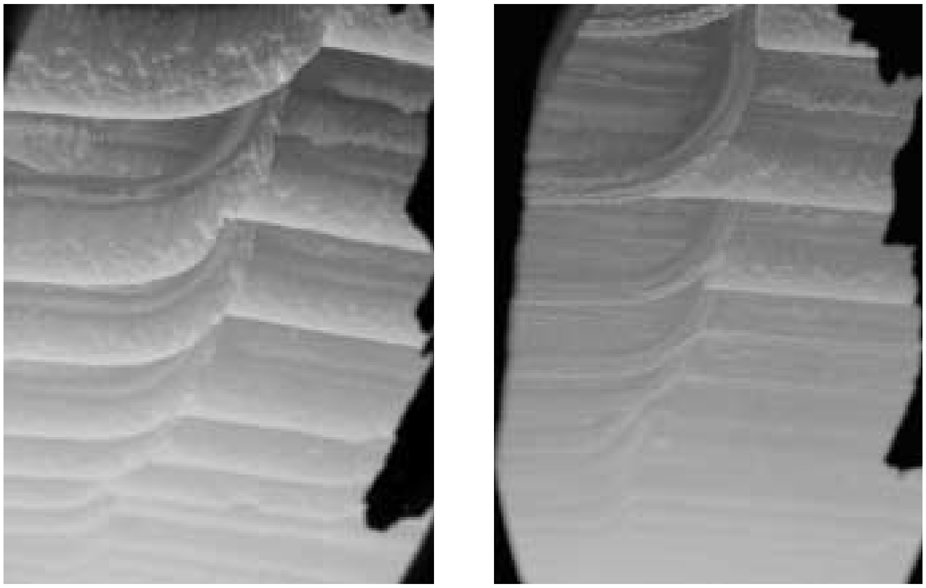

Figure 17 (left) Slag Before 2L Sootblower Use (right) Slag After 2L - Sootblower

CONCLUSIONS

The burning of PRB with pre-NSPS burners did decrease the NO_X emissions marginally and LOI very dramatically while increasing the boiler main steam temperature. The increased moisture and lower HHV of the PRB coal decreased the boiler efficiency, decreased the milling system load carrying capability, decreased the mill outlet temperatures, and increased the ID Fan power requirements. Furthermore, increased slagging of the furnace walls increased the FEGT, which adversely affected deposition on the superheater platens in the upper furnace. Also note that the soot blowing cycle had to be increased by three times the normal cycle just to maintain tolerable boiler conditions.

It is also very interesting to note that when PRB is burned in pre-NSPS burners the NO_X emissions are only reduced by about 20% compared to the NO_X emissions associated with burning bituminous coal. When the fuel is switched from bituminous coal to PRB coal in a unit with low NO_X burners, such as the BBP CCV® Dual Air Zone Burner (Figure 2), the reduction in NO_X is usually in the range of 45 to 50%. As a matter of fact, in many units it is possible to achieve NO_X levels of 0.15 lb/MMBTU when burning PRB coals with CCV® Dual Air Zone Burners[2].

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