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APPENDIX B

Developing a Coal Quality Expert: The Prediction of Ash Deposit Effects on Boiler Performance

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ABSTRACT

The overall objective of the Coal Quality Expert (CQE) Clean Coal I Program is the development of a Coal Quality Expert -- a comprehensive PC based expert system for evaluating the potential for coal cleaning, blending and switching options to reduce emissions while producing the lowest cost electricity. A key part of the CQE model will be the development of a sub-model to predict the effects of ash deposition on boiler performance under various operating conditions. To facilitate sub-model development, a combination of full, pilot, and bench scale testing has been carried out on a series of coals and coal blends which were of interest to the Public Service of Oklahoma (PSO) at their Northeastern Station. A series of full-scale tests were also performed on PSO's Northeastern Unit #4 to characterize boiler performance when firing a "baseline coal" (their normal or desired fuel feed stock) and two blends comprised of the baseline coal blended with various amounts of an alternate coal. Actual furnace conditions were then closely matched during a series of tests performed in Combustion Engineering's pilot scale combustor, the Fireside Performance Test Facility (FPTF). Pilot scale testing allowed in-depth analysis of furnace deposits during and after formation under well-controlled conditions. Ash deposit properties were characterized during pilot scale furnace operation and in subsequent bench scale analyses. Determination of deposit behavior as a function of important operating parameters during the FPTF testing has permitted the prediction of expected performance for various coal/coal blends in PSO's Northeastern Units and allows a prediction of boiler performance for other units firing these fuels.

INTRODUCTION

As part of the CQE Clean Coal Program, Combustion Engineering Inc. (CE) has been contracted to evaluate, in their pilot scale facility, the fireside performance characteristics of a number of individual coals and coal blends representing fuels selected for a total of five (5) field units. Coals and coal blends to be tested by CE are obtained either during full scale testing at utility units or are cleaned versions of the coals tested at utility units and are produced at CQ Inc.'s coal cleaning facility. One of the central focuses of this portion of CQE development is to predict ash deposition characteristics as a function of coal type and boiler operating conditions. Currently used ash behavior prediction indices generally employ ASTM data which do not always show the high level of reliability needed by industry and in the CQE. The goal of the subject program is to produce algorithms for slagging and fouling which will be quantitative in nature. Among the quantitative effects to be predicted are deposit thermal properties, limiting conditions above which deposit removal is inadequate with convential soot blowers, and the frequency of soot blowing required to maintain acceptable boiler thermal performance.

This paper summarizes the fireside characteristics found during pilot-scale testing of the first series of coals chosen in conjunction with PSO's baseline and baseline/alternate coal blends. Full-scale testing was performed at PSO's Northeastern Unit #4 during the summer and fall of 1990. Coal samples were obtained from the belt system feeding the individual crushed coal hoppers for each pulverizer on Unit #4 during the full-scale testing to insure procurement of samples which were representative of the coals burned in the field. The pilot scale testing was carried out in the winter of 1990 and the early spring of 1991.

TEST FUELS

Under the CQE project, the four coal/coal blends from PSO's Northeastern Unit #4 tested in the FPTF for this project were: 100% Baseline, 90% Baseline/10% Alternate, 70% Baseline/30% Alternate and 70% Baseline/30% Alternate Cleaned. For purposes of this paper Baseline coal refers to the Wyodak Seam in Wyoming while the Alternate coal refers to the Croweburg seam in Oklahoma. ASTM and other specialized analyses were performed on four coal/coal blends and are reported in Table 1. Due to the similarities in ash chemistry of the baseline and alternate coals, blending had little effect on ash fusibility temperatures and forms of sulfur. Relatively small differences are noticed in the ratios generally used as indicators for fouling and slagging potentials.

COMBUSTION PERFORMANCE EVALUATIONS

The combustion and fireside performance of the test fuels were evaluated in CE's Fireside Performance Test Facility (FPTF). A brief schematic of the FPTF is given in Figure 1; a full description of the FPTF is given elsewhere (1). Testing was conducted at firing rates ranging from 3.2 MBtu/hr to 4.0 MBtu/hr under conditions similar to those found in the field. Each coal was tested at various firing rates (heat inputs) to identify furnace operating conditions where deposit removability became limited, i.e., where conventional soot blowers could no longer adequately remove deposits to the extent required for continuous, successful boiler operation. Ash deposits generally become more difficult to remove as a function of increasing gas temperature and corresponding higher furnace thermal loadings. A major objective in setting up test conditions was to match localized total heat fluxes between the FPTF and those measured in the Northeastern Unit #4. As can be seen in Figure 1, heat fluxes measured in Northeastern's Unit #4 and those measured in the FPTF show that the total heat flux seen by the FPTF ash deposition panels match full-scale boiler local water wall heat flux conditions rather closely. The total heat fluxes, for both the field and the FPTF, were measured with a water-cooled total heat flux meter.

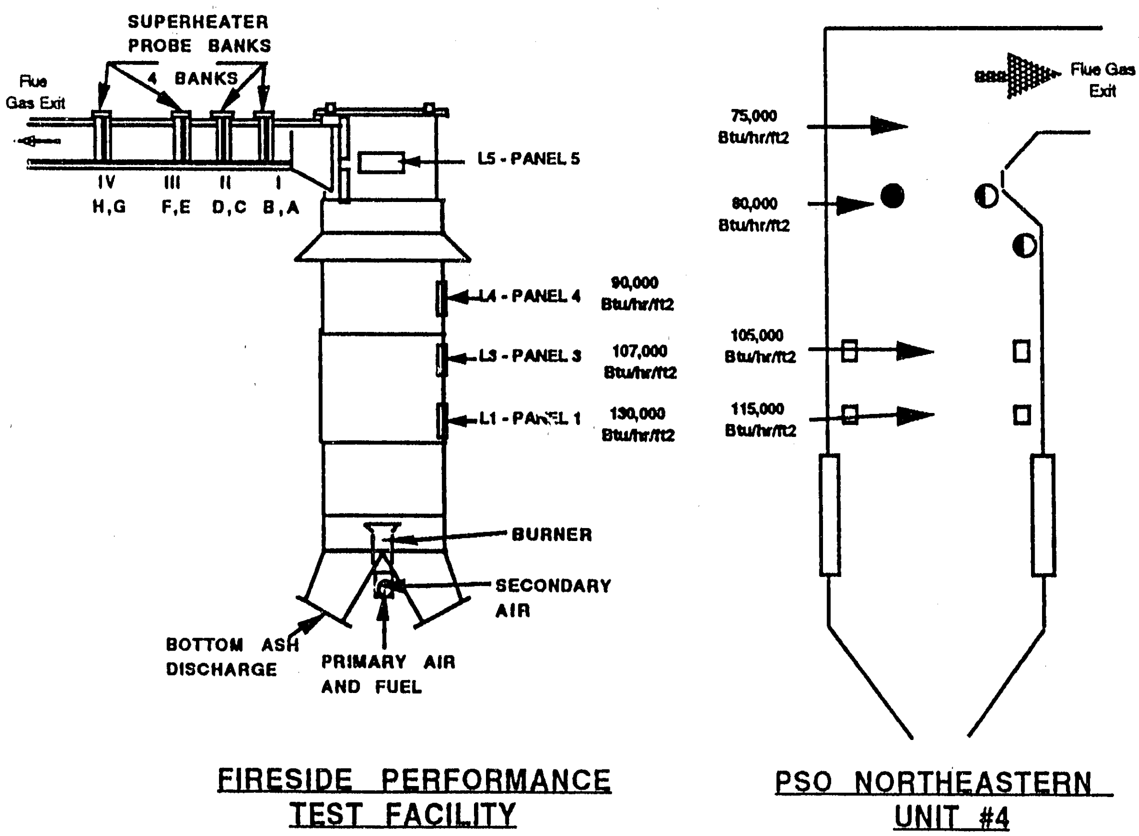

Figure 1. FPTF Schematic and a Heatflux Comparison Between the FPTF and the Full-Scale Boiler

TABLE 1

Analyses of Fuels Fired in the FPTF Combustion Performance Tests

Analysis	100% Bas		90% Bas/ 10% Alt		70% Bas/ 30% Alt		70% Bas/ 30% Alt CLN		100% Alt*	
	As Fired	Dry	As Fired	Dry	As Fired	Dry	As Fired	Dry	As Rec.	Dry
Proximate, wt.%										
Moisture	13.4	-	11.5	-	8.5	-	8.0	-	8.9	-
Volatile Matter	43.8	50.5	43.0	48.6	40.2	43.9	41.4	45.0	28.8	31.6
Fixed Carbon	35.9	41.4	38.2	43.2	43.2	47.2	44.0	47.8	51.0	56.0
Ash	6.9	7.9	7.3	8.2	8.1	8.9	6.6	7.2	11.3	12.4
HHV, Btu/lb	10225	11807	10552	11923	11332	12385	11484	12482	11803	12956
Ultimate, wt.%										
Moisture	13.4	-	11.5	-	8.5	-	8.0	-	8.9	-
Hydrogen	4.4	5.0	4.4	4.9	4.4	4.8	4.7	5.1	4.3	4.7
Carbon	57.9	66.9	59.8	67.6	64.5	70.5	65.5	71.2	65.4	71.8
Sulfur	0.5	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.7
Nitrogen	0.9	1.0	1.0	1.1	1.3	1.4	1.2	1.3	1.6	1.7
Oxygen	16.0	18.6	15.4	17.6	12.6	13.7	13.4	14.6	7.9	8.7
Ash	6.9	7.9	7.3	8.2	8.1	8.9	6.6	7.2	11.3	12.4
Flammability Index, °F	800		780		815		830		-	
Ash Composition, wt.%										
SiO_2	31.7		35.3		37.7		35.4		48.5	
Al_2O_3	15.8		16.2		15.6		16.3		17.6	
Fe_2O_3	5.6		5.8		5.8		6.7		7.2	
CaO	19.5		18.1		16.0		16.5		12.3	
MgO	4.3		3.9		2.8		3.5		1.5	
Na_2O	0.8		0.8		0.7		0.7		0.6	
K_2O	0.5		0.8		1.6		1.1		3.0	
TiO_2	1.2		1.2		1.0		1.2		0.8	
P_2O_5	0.4		0.8		0.5		0.8		0.1	
SO_3	19.0		16.4		17.8		15.1		7.9	
Forms of Sulfur										
Sulfate (dry)	0.02		0.01		0.01		0.04		0.03	
Pyritic (dry)	0.13		0.14		0.16		0.10		0.19	
Organic (dry)	0.45		0.45		0.53		0.46		0.48	
Acetic Acid Leachable										
Na_2O	0.84		0.74		0.53		0.69		0.11	
K_2O	0.15		0.13		0.11		0.26		0.08	
Ratios										
Base/Acid	0.63		0.56		0.50		0.54		0.37	
Fe_2O_3/CaO	0.29		0.32		0.36		0.41		0.59	
SiO_2/Al_2O_3	2.01		2.18		2.42		2.17		2.76	
Ash Fusibility, °F										
I.T.	2108		2120		2115		2100		2138	
S.T.	2131		2169		2147		2165		2210	
H.T.	2140		2186		2170		2184		2258	
F.T.	2158		2203		2194		2224		2320	
Temp. Diff. (F.T. - I.T.)	50		83		79		124		182	

* Not fired in FPTF; included for reference purposes.

The major areas of fireside performance addressed in the FPTF include: slagging, fouling, and superheater tube erosion rates. Furnace slagging characteristics are primarily determined by the ease of deposit removal in response to wall blower cleaning and the thermal properties of deposits accumulated on simulated waterwall surfaces. Critical thermal conditions from an ash slagging standpoint are defined as the maximum furnace heat input and the corresponding furnace gas temperature at the first panel elevation of the FPTF which produce deposits that are marginally cleanable with normal sootblowing techniques. Heat flux recoveries between 60 and 75% are generally used as guidelines for marginal cleanability. Therefore, at gas temperatures where the lower furnace deposits formed are above 75% cleanable (i.e., 75% of the heat flux lost during deposit build up is recoverable with normal soot blowing techniques) the deposit formation is termed cleanable. At gas temperatures where the lower furnace deposit cleanability is lower than 60% are generally termed non-cleanable or uncontrollable by normal soot blowing techniques.

Preheated combustion air is used to offset the greater heat absorption that occurs in a small furnace with a high surface/volume ratio to produce a time-temperature history that is similar to that found in full scale boiler applications. Preheated combustion air also provides flame temperature control which is used to establish a consistent furnace thermal loading. The furnace residence times ranged from 0.9 to 1.1 seconds through the radiant section of the furnace with a cumulative residence time of 1.5 to 1.9 seconds through the convective pass section of the FPTF depending on the furnace heat input and excess air used in the test runs.

Upper furnace fouling characteristics are determined primarily by measuring the force required to remove deposits which accumulated a 2.5 to 3 inch deposit thickness on simulated superheater tube surfaces which are controlled around 1100 °F. A penetrometer is used to measure the force required to break the deposit to tube bond (or deposit to initial deposition layer bond) and completely remove the deposit. Bonding strength measurements coupled with gas temperature and particle loading information during the deposition process, allows a quantitative assessment of upper furnace operational parameters which may limit full scale unit performance.

Fly ash erosion characteristics are determined in a high velocity test section downstream of the FPTF convection tube banks. Tube specimens are exposed to a particulate laden flue gas stream at gas velocities above 200 ft/sec. High gas velocities are used to accelerate wear and provide measurable erosion during each test period. The amount of tube erosion caused by the fly ash is determined using a radioactive surface measurement technique described elsewhere (2). The wear data are then normalized to velocity and ash loading to provide a basis for comparison among various coal tests.

In-flame particulates, waterwall deposits, convection tube deposits and fly ash samples are collected from the FPTF tests for analyses being conducted at the University of North Dakota Energy and Environmental Research Center (UNDEERC). Scanning electron microscopy, Mossbauer, X-ray diffraction, and X-ray fluorescence are to be used to determine the distribution of amorphous and crystalline phases, chemical composition and surface chemistry of the ash components. These analytical data will be related to performance characteristics for all of the coals/coal blends to be tested during this project.

Slag deposits are also collected on sacrificial probes inserted in the lower furnace sections of the FPTF. The sacrificial probes metal surface temperatures are maintained at 700 °F during deposit build up to simulate large scale furnace wall conditions. Once deposits have formed on the tube surfaces, the probes are removed from the furnace on line, effectively quenching the deposits to ambient conditions. After the deposits and probes have cooled to room temperature, the probes with the deposits still bonded to the tube surface, are cast in epoxy and sent to UNDEERC for further analysis. The use of a sacrificial probe allows the analysis of key deposit bonding structures from the surface of the tube through the outer layer of the slag deposit.

FPTF TEST MATRIX

Six, 12-hour tests were conducted on each coal/coal blend tested in the field for a total of 18 pilot-scale tests. To address the effects of cleaning the Alternate coal, a fourth test series (consisting of 3 individual 12-hour tests) was conducted on a 70% Baseline/30% Alternate cleaned coal blend. The first three tests conducted on each coal/coal blend were at 20% excess air. These tests were used to establish the critical thermal conditions for each coal/coal blend. Once the critical thermal conditions were established, a low excess air, 12.5% EA, and a high excess air, 30% EA, were conducted to address the effects of excess air on the critical thermal furnace conditions. The final test for each coal test sequence was performed at the critical thermal furnace conditions and 20% excess air. The final test was conducted to collect deposit and ash samples to be sent to UNDEERC for further analysis.

FIELD TESTING

Full-scale testing at PSO's Northeastern Unit #4 was completed for 3 of the 4 coal/coal blends tested in the FPTF. The coals tested included: 100% Baseline, 90% Baseline/10% Alternate and 70% Baseline/30% Alternate. Comprehensive testing was performed at full load conditions for each coal in an attempt to replicate firing conditions from fuel to fuel. Full-scale testing was performed by Electric Power Technologies (EPT), Energy and Environmental Research Corporation (EERC), Southern Research Institute (SRI), Combustion Engineering (CE) and Southern Company Services combined with a major support effort from PSO's Northeastern Plant personnel.

RESULTS

Furnace Slagging Characteristics

Critical thermal conditions varied significantly from fuel to fuel, indicating that the different concentrations, or mixtures of Baseline and Alternate coals produced a range of furnace deposit characteristics. Table 2 shows the critical thermal conditions found for the lower furnace deposits. The 100% Baseline coal and the 70% Baseline/30% Alternate coal blend resulted in similar thermal limiting conditions in the lower furnace. The 90% Baseline/10% Alternate and the 70% Baseline/30% Alternate cleaned coal blends also resulted in similar limiting conditions for lower furnace slagging characteristics but showed a greater tolerance to higher gas temperatures before deposit cleanability became questionable.

Table 2

FPTF Critical Thermal Conditions

Fuel Description	Firing Rate (MBtu/hr)	Ave. Gas Temp at Level 1(°F)
100% Baseline	3.3	2825-2850
90% Baseline/10% Alternate	3.8	2950-2975
70% Baseline/30% Alternate	3.2	2800-2825
70% Baseline/30% Alternate CLN	3.9	2975-3000

Figure 2 provides a comparison of the cleanability of the lower furnace deposits, at similar firing conditions, for the four fuels tested as evidenced by the heat flux recoveries following soot blowing of the deposits. Heat flux recoveries on the 90% Baseline/10% Alternate and 70% Baseline/30% Alternate cleaned were notably higher than those resulting from the 100% Baseline and the 70% Baseline/30% Alternate fuels.

Examination of the relevant field data has substantiated results from pilot scale testing with regard to lower furnace ash deposit effects (3). Figure 3 shows the furnace outlet temperatures as a function of location across the width of the commercial unit at similar loads and firing conditions for the different fuels as indicated. Gas temperature measurements were taken through Port 9S and its counterpart

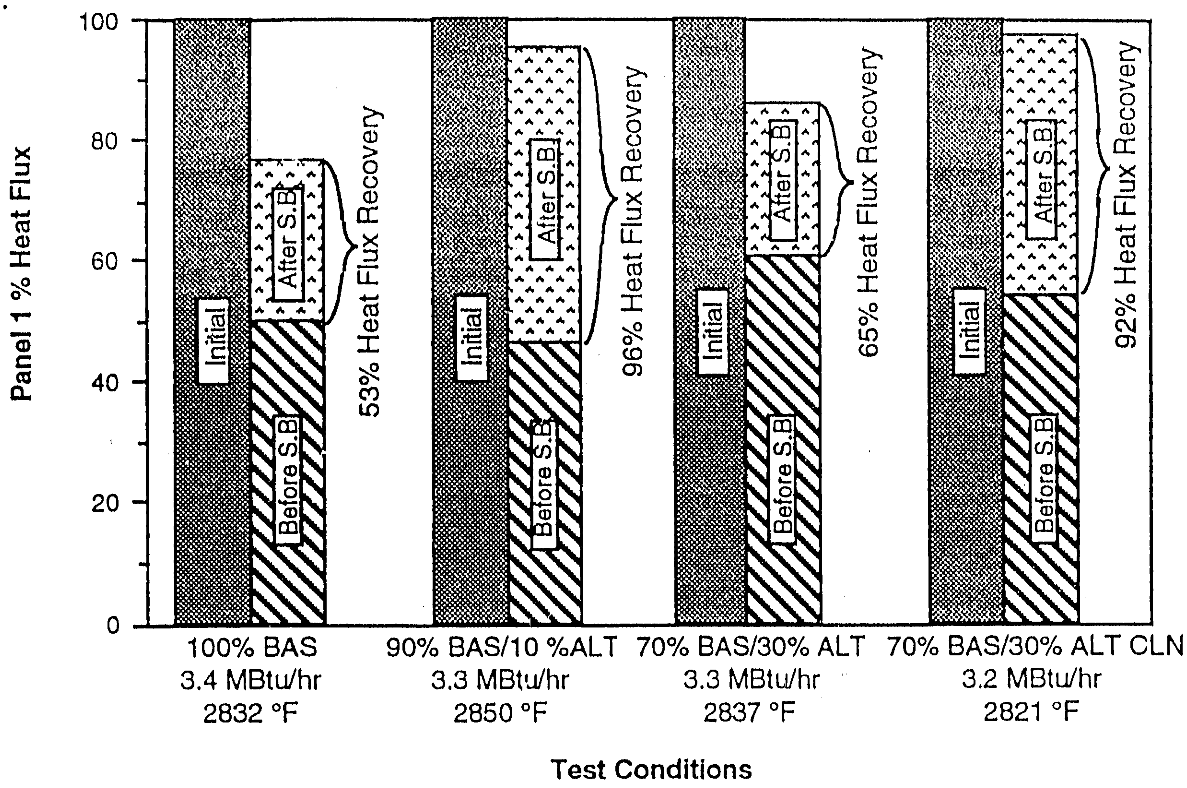

Figure 2. A Comparison of Heat Flux recoveries at Similar Firing Conditions

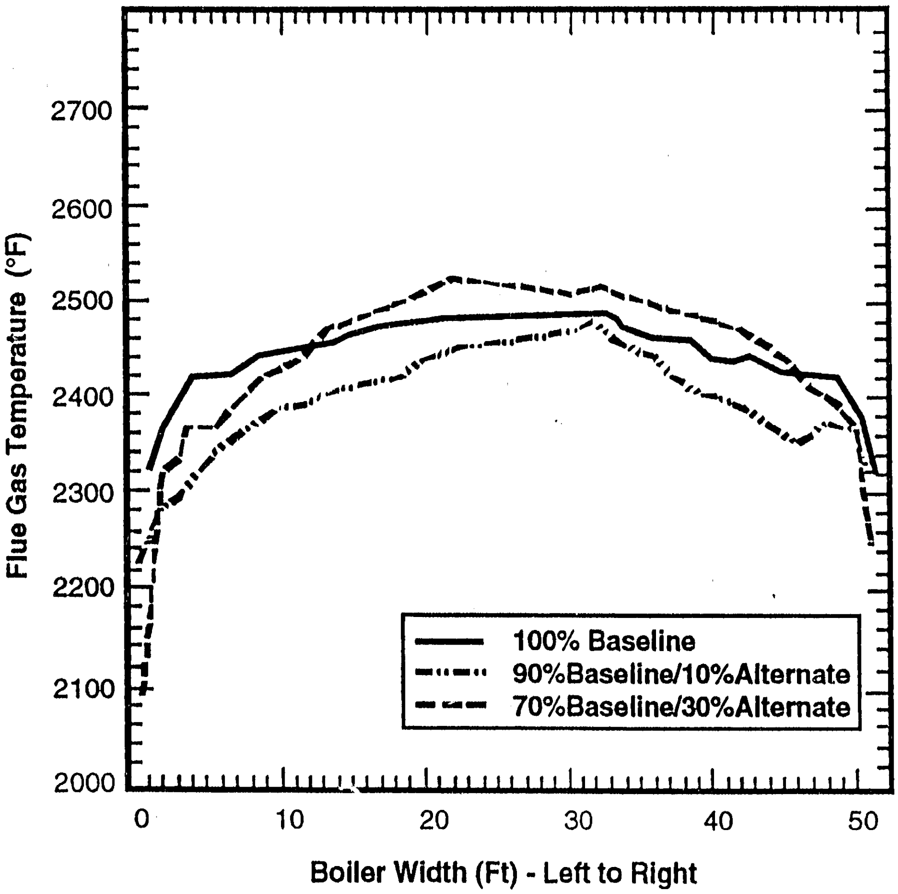

Figure 3 A Comparison of Furnace Outlet Gas Temperatures Under Similar Furnace Loadings for the Coal/Coal Blends Tested in the Field (3)

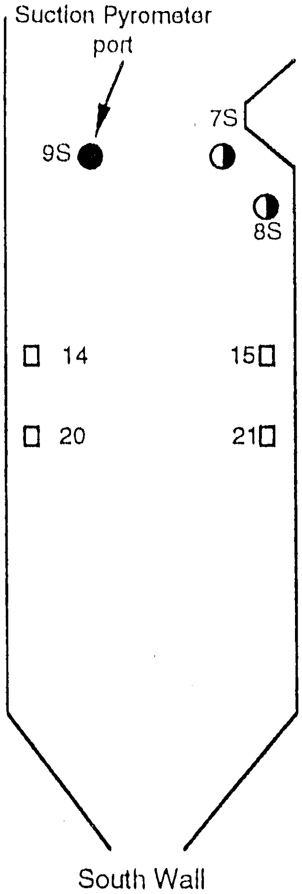

Figure 4 Schematic Elevational View of Northeastern Unit #4 Showing the Location of the Furnace Outlet Temperature Measurements

on the opposite wall (see Figure 4). As expected the gas temperature drops off near the side walls for each test case. The average gas temperatures across the width (52 feet) of the furnace are approximately the same for the 100% Baseline and the 90% Baseline/10% Alternate fuel tests which is somewhat higher than for the 70% Baseline/30% Alternate coal test. Furnace outlet temperatures, at the same firing rate and excess air, are determined primarily by lower furnace heat absorption and to a lesser extent by the fuel reactivity. In the case of the Baseline and Alternate coal/coal blends, the fuel reactivity is very similar; differences in furnace outlet temperature (Figure 3) can be ascribed to the differences in deposit characteristics, specifically the resistance to heat transfer. Examination of ash deposit thermal conductances as measured in the FPTF shows values that directly correspond to the furnace outlet temperatures as measured in the field. Table 3 shows the thermal conductance ($k/\Delta x$) of FPTF generated deposits at various elevations as well as an average $k/\Delta x$ of the three elevations.

Table 3

Thermal Conductance of Deposits Generated at Various Elevations in the FPTF (Btu/hr-ft^2 °F)

Fuel	100% Bas	90% Bas/10% Alt	70% Bas/30% Alt
Panel 1	38	49	42
Panel 3	32	48	32
Panel 4	37	48	35
Average $k/\Delta x$	35.7	48.3	36.3

Furnace outlet temperatures during the 90% Baseline/10% Alternate field test were lower than the furnace outlet temperatures for the other two coals (Figure 3); correspondingly the 90% Baseline/10% Alternate fuel had an average $k/\Delta x$ of 48.3 (better heat transfer) compared to the other two coals which had $k/\Delta x$'s of approximately 36.

Deposit cleanability and hence heat flux recovery as measured in the FPTF was found to be more favorable for the 90% Baseline/10% Alternate fuel than for the 100% Baseline and 70% Baseline/30% Alternate fuels which is in direct correspondence to the furnace outlet temperature measurements for these fuels during field testing.

The effects of excess air were also evaluated in the FPTF as well as during field testing. It is recognized that changing excess air in a commercial unit has two possible influences on deposit characteristics: (1) the chemical effects of lower oxygen partial pressures on deposit properties, and (2) the thermal effects on the furnace environment. As oxygen partial pressures are decreased, mineral matter transformations to flyash can be affected; for example the time that it would take for pyrites to be converted to iron oxide. When excess air is decreased, gas temperatures will increase because of the lower thermal diluent effect; the opposite is true when excess air is increased. Testing in the FPTF has the advantage of separating these two effects , i.e., excess air can be varied while maintaining the same gas temperatures. Figure 5 shows the effect of excess air on lower furnace deposits at a relatively constant temperature, hence the chemical effects of variable oxygen partial pressures are being evaluated. Figure 5 shows that the 20% and 30% excess air cases for the 100% Baseline coal are very similar in terms of the heat fluxes before soot blowing and in terms of the heat flux recoveries after soot blowing. The 12.5% excess air test showed a modest decrease in the heat flux before soot blowing and a significant decrease in the heat flux recovery after soot blowing. These data strongly suggest that the chemical effect of excess air on the 100% Baseline coal will alter the nature of the deposit and it's cleanability, despite the relatively low iron content and even lower pyritic iron content.

Excess air testing conducted on the 90% Baseline/10% Alternate and the 70% Baseline/30% Alternate fuels in the FPTF did not show the same effect on lower furnace deposit characteristics as the 100% Baseline fuel. Pilot-Scale data suggests that increasing the excess air resulted in little or no effect on deposit cleanability. The average peak gas temperatures for the 90% Baseline/10% Alternate and 70% Baseline/30% Alternate were not significantly similar to permit an interpretation of chemical versus thermal effects.

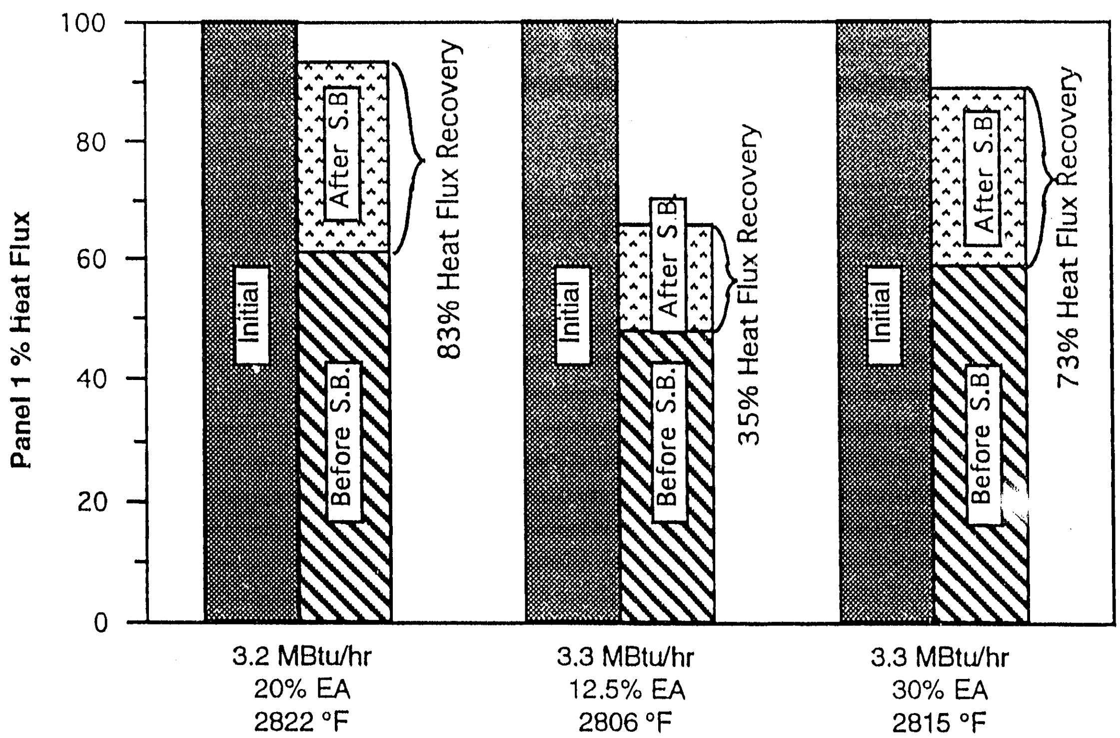

Figure 5 A Comparison of Heat Flux Recoveries for Baseline Coal at Various Excess Air Levels

A plot of average furnace outlet temperatures (FOT) versus oxygen concentration from field testing shows increasing FOT with decreasing oxygen for the three fuels tested (Figure 6). Interestingly the slope of the 100% Baseline test is steeper than that of the 90% Baseline/10% Alternate and 70% Baseline/ 30% Alternate fuels, suggesting a greater chemical effect in the 100% Baseline case compared with the other fuels which show less sensitivity. The suggestion of a greater chemical effect in the case of the 100% Baseline coal corresponds directly with data/interpretations from pilot scale testing.

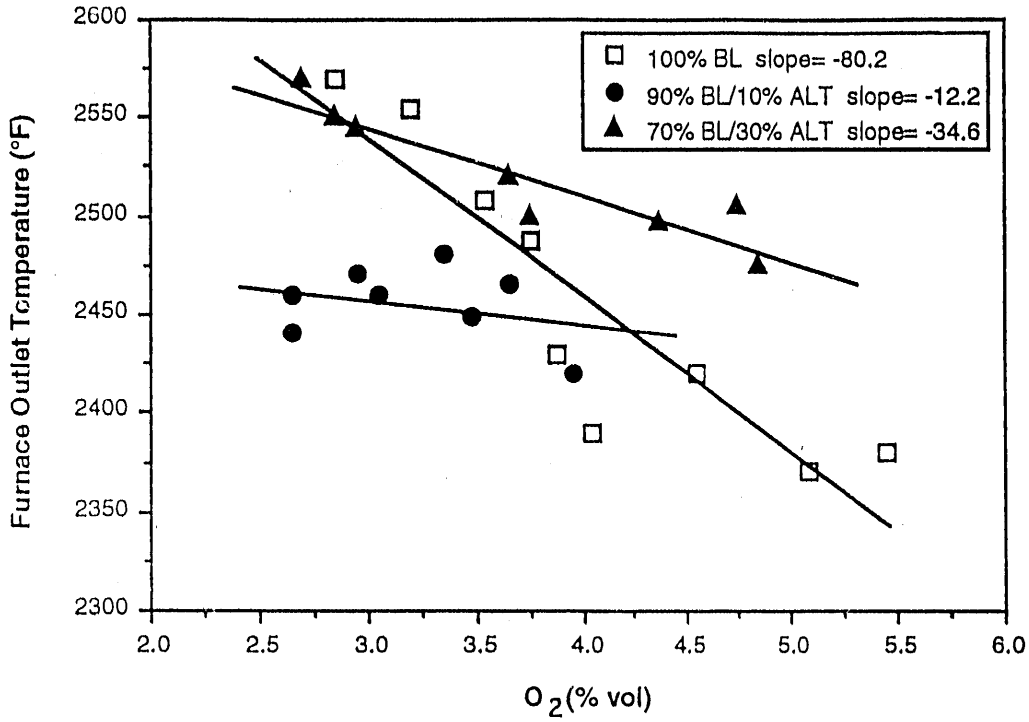

Figure 6 Furnace Outlet Temperatures as a Function of Excess Air for Fuels Tested in Northeastern Unit #4 (3)

Convection Pass Fouling Characteristics

Fouling characteristics, specifically bonding strengths found during pilot-scale testing are summarized in Figure 7. In general the bonding strength increased with increasing furnace outlet gas temperatures and increasing quantities of the Alternate coal. There were no significant differences between the 70% Baseline/30% Alternate blend and it's cleaned counterpart at temperatures which were above 2200 °F. Deposits which formed on simulated superheater tube surfaces in the convective section of the furnace were generally sintered at gas temperatures in the 2100 to 2300 °F range and transitioned to a molten outer surface at higher gas temperatures (above 2300 °F). Deposit bonding strength increased significantly with increasing gas temperature for each coal/coal blend fired, resulting in deposits which exceeded the cleanability level in the blended coal cases. It is generally considered that bonding strengths of 15 or less mean that deposits are cleanable with conventional sootblowers.

In terms of limitations the 100% Baseline coal produced deposits which were cleanable under all conditions tested, i.e., up to a temperature of 2260 °F.

In the case of the 90% Baseline/10% Alternate coal, non-cleanable deposits occurred when temperatures exceeded 2360 °F. There did not appear to be a significant difference between the 70% Baseline/30% Alternate and the 70% Baseline/30% Alternate clean blends in terms of critical temperatures; for both coals the critical temperature is probably slightly above 2200 °F. Significantly, the blend with the cleaned coal showed higher bonding strengths at lower gas temperatures than did blends with the uncleaned coal. However, because of the lower ash content in the clean coal blend the deposition rate (under equivalent firing conditions) was lower and soot blowing frequency could be commensurately decreased.

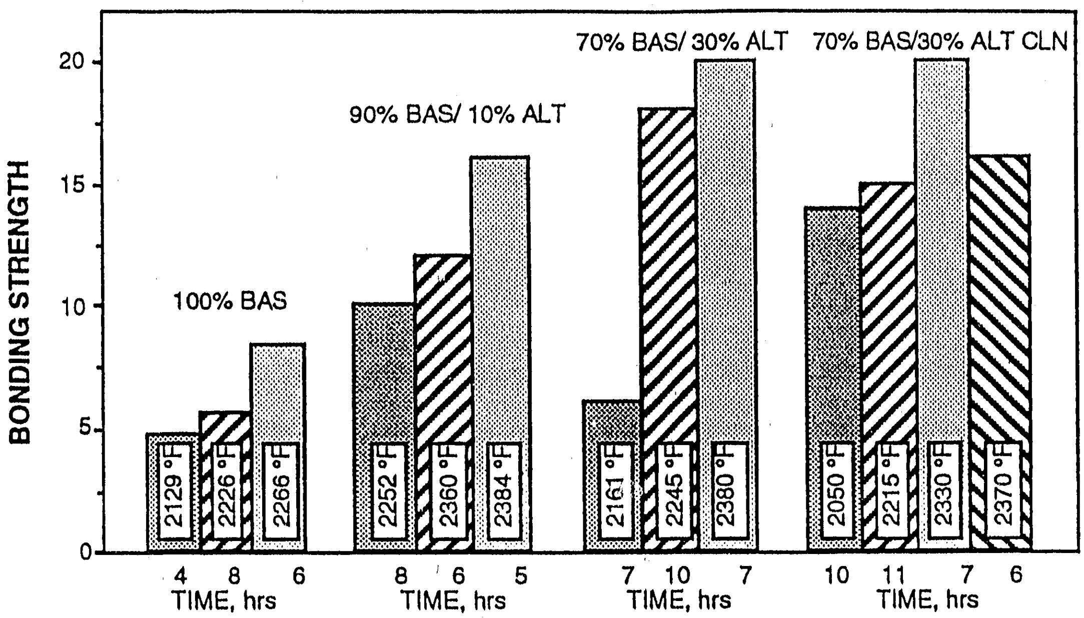

Figure 7 Convection Pass Deposit Bonding Strength Summary

Discussions with plant personnel revealed that the main load limiting factor for the Northeastern Unit was deposit formation in the convection pass of the furnace. It is clear from Figure 7 that from a fouling deposit stand point alone, the 100% Baseline coal would have the best performance. However, in the full-scale furnace application, the temperatures at which convective pass deposits are formed are largely a function of excess air and wall conditions existing in the lower furnace. Full-scale operating data shown previously in Figures 3 and 6 indicate that the 100% Baseline coal must be fired at greater than 4.0% excess O_2 or the temperatures in the convection pass will be sufficiently high to form deposits which cannot be removed. As the deposition continues to build, sections of the convection pass which have limited spacing will become plugged, causing a large pressure drop and flow pattern disturbance. Firing this fuel requires normal soot blowing practices in the lower furnace to maintain heat absorption and lower FOTs brought about by higher excess air.

The 90% Baseline/10% Alternate fuel did not show a significant variance in the FOT with changes in excess O_2. This blend also gave the highest lower furnace heat absorption resulting in the lowest average FOT. The 90% Baseline/10% Alternate fuel could be fired under similar conditions as the 100% Baseline fuel without operational problems.

The 70% Baseline/ 30% Alternate fuel also did not display a large variance in the FOT with excess O_2, however, the slagging tendencies in the lower furnace always maintained the highest overall FOT's. Results from the FPTF indicated that the fouling tendencies of the 70% Baseline/ 30% Alternate fuel would produce convection pass deposits which cannot be removed at temperatures higher than 2200 °F (100 to 150 °F lower than the other fuels field tested). Firing this fuel would require increased lower furnace wall blowing and increased upper furnace retractable soot blowing to control deposits.

<u>Fly Ash Erosion</u>

Flyash erosion rates were measured for the 90% Baseline/10% Alternate and the 70% Baseline/30% Alternate clean blends; though the erosion rate of the former blend was three times that of the latter (see Figure 8), both values of 0.9 and 0.3 mils/10,000 hrs are very low. It is generally considered that an erosion rate of 2 mils/10,000 hrs is typical for U.S. coals; the values measured for the subject fuels do not present a problem in terms of tube wastage due to erosion.

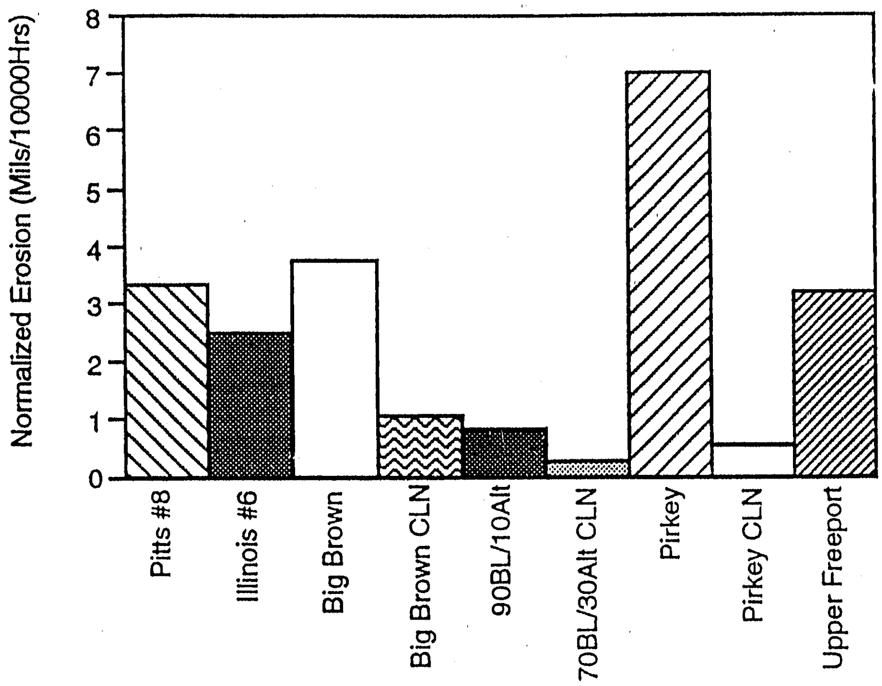

Figure 8 Erosion Comparison between PSO's Northeastern Coal Blends and Other Coals/Coal Blends

CONCLUSIONS

Results from pilot scale testing serve several purposes including: (1) quantitative ranking of the fireside performance of the specific coal/coal blends tested, (2) detailed performance data for input into boiler models to predict boiler operation and performance, and (3) the generation of specific physical and thermal properties of coal ash deposits as a function of furnace operating parameters for slagging and fouling algorithm development as part of the Coal Quality Expert. Importantly, pilot scale testing has been carried out in concert with field testing conducted at Public Service of Oklahoma's Northeastern Station. The correspondence of data from pilot scale and field testing is very good.

The blend of 70% Baseline/30% Alternate cleaned coal resulted in lower furnace deposits which remained cleanable at temperatures up to a 2975 to 3000 °F range. Deposits in the lower furnace from the 90% Baseline/10% Alternate blend were cleanable up to temperatures only slightly below the former coal. The 100% Baseline and 70% Baseline/30% Alternate fuels, by contrast, produced lower furnace deposits which were cleanable only up to a 2800 to 2850°F temperature range. Interestingly, of the three coals which were field tested the 90% Baseline/10% Alternate coal blend resulted in the lowest furnace outlet temperature, the inference being that resistance to heat transfer,due to deposits, was less in this case. Thermal conductance ($k/\Delta x$), as measured in the FPTF, was significantly higher for the 90% Baseline/10% Alternate fuel compared to the 100% Baseline and 70% Baseline/30% Alternate fuels.

Low excess air was shown to have a more significant effect on the nature of lower furnace deposits with the 100% Baseline fuel, from both pilot-scale and field data. Specifically lower excess air reduced the critical temperature for adequate deposit cleanability to a greater extent in the 100% Baseline case than for the other fuel blends tested.

It should be noted that the general operation for the Northeastern Unit No. 4 is MCR (maximum continuous rating) during day time hours when load demand is high and typically drops load by 25 percent or greater as load demand decreases. This type of operation is conducive to "slag shedding," a process not completely understood which involves thermal forces, probably differential thermal contraction between deposit and tube which ultimately weakens the deposit bond. Load cycling operation would generally permit a unit to operate at conditions that are in excess of critical conditions for either the lower furnace or convective pass regions.

Bonding strength of deposits in the convective pass generally increased with increasing concentrations of the alternate coal. However, only with the 70% Baseline/30% Alternate and the 70% Baseline/30% Alternate cleaned coal blends did the deposit bonding strength clearly begin to exceed the ability for conventional soot blowers to remove deposits; such conditions generally occurred at gas temperatures of 2250°F or higher.

Though erosion rates of fly ashes from the 90% Baseline/10% Alternate was three times that of the 70% Baseline/30% Alternate cleaned, both blends showed very low erosion relative to other U.S. coals.

Pilot scale testing affords an opportunity to obtain bonding strength and thermal properties of ash deposits over a wide range of thermal conditions. Furnace heat inputs can be increased until a limiting condition, termed critical conditions, are achieved where deposits can no longer be removed with conventional soot blowers; this type of determination is usually not possible to obtain during field testing. The coal or coal blend is tested without the concerns of uncontrollable operational conditions sometimes associated with full scale plant operation, allowing fireside characteristics to be assessed as a function of known, consistent operating conditions.

A sound set of cause and effect relationships, both fundamentally and empirically based, which require the intelligent integration/use of data from bench, pilot, and field testing will provide the foundation for slagging and fouling algorithm formulation for the CQE.

REFERENCES

1. Levasseur, A.A., et.al., "Combustion Characterization of EPRI cleaned Coals," Co-author, Engineering Foundation Conference on "Fine Coal Cleaning," Santa Barbara, CA, February 1987.

2. Raask, E., Erosion Wear in Coal Utilization, Hemisphere Publishing Corporation, New York, 1988.

3. Taken from a preliminary internal report issued by the EPT, EER, FERCo team.

4. Borio, R.W., Levasseur, A.A., "Overview of Coal Ash Deposition to Boilers," American Chemical Society Annual Meeting, August 1984.

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END

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