THE PREDICTION OF SLAGGING PROBLEMS AS A RESULT OF COAL BLENDING

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INTRODUCTION

Power generating facilities which use coal face several problems caused by the nature of the fuel. Of these problems, fireside fouling and deposition is of major importance. Fireside deposition affects boiler availability and operating efficiency. Determination of when a coal or blend of coals will cause significant slagging problems is extremely important. The properties and mechanisms behind fireside deposition due to coal blending is the focus here (1).

Such a problem occurred at the Public Service Company of Oklahoma's (PSO's) northeast generating facility. The problem arose when two Wyoming, subbituminous coals were blended. These two coals, Jacob's Ranch (JR) and Clovis Point (CP) cause only moderate fireside deposition when burned separately. Any blend of the two coals causes more boiler deposition and fouling than either pure coal, based on observations by PSO's engineers (2). The blend which results in the most severe fireside deposition is approximately 75% JR-25% CP. Although avoiding blending eliminates this problem, in some circumstances operating conditions require the use of blended coals.

When blending coals, care must be taken to determine if the two (or more) coals are compatible. Lee and Whaley (3) examined the modification of combustion and fly-ash characteristics due to the blending of coals. They concluded that potential operational problems due to the blending can be minimized or avoided by careful determination of coal and coal ash properties before usage. Dooley and Chacinski (4) agreed on not using empirical slagging correlations to predict blended coal slagging propensities. To further support this, a number of the standard slagging indices (5) have been evaluated with the available data on Jacob's Ranch and Clovis Point coals. As Table I summarizes, none of the standard indices describe the problem as observed by PSO's engineers.

As a result, a new approach seems to be necessary. A possible approach, and the one used in this study, is one analogous to reaction order theory.

EXPERIMENTAL DATA

There is certain data that is necessary in evaluating the predictive method to be employed in this study. A proximate analysis of both coals (Jacob's Ranch and Clovis Point) is given in Table II (6). The data that will be of most interest in the approach used here are the coal ash compositions. There are two different sets of coal ash composition data, one is an independent analysis conducted by Williams Brothers Laboratory (6), the other is the analysis at OSU. This data is presented in Table III. The analysis of the ash from different blends of the two coals is presented in Table IV.

GENERAL APPROACH

The approach selected to predict the observed problem is similar to reaction rate theory. If one coal is rich in component A and the other coal is rich in component B, then a reaction analogy applies. An interaction between two components is modeled as if it were a reaction with a rate equation given by: aA + bB → Products (reaction or interaction); Rate $\alpha\ [A]^n\ [B]^m$ (rate expression). Where n and m are exponents on the concentrations of reactants A and B, respectively. The order of the interaction is given by n + m. There are certain unknowns here that need to be selected or determined by trial and error.

DISCUSSION

The general description of the deposition problem leads immediately to a conceptual form of the desired slagging correlation (Figure 1). The problem is how to predict such a dramatic change in the slagging properties of the coal burned as the %Jacob's Ranch in the blend changes with the numerous variables that are as of yet undefined. The most pressing problem is the selection of the data to be used as concentrations. Finding actual concentrations in such a situation is impossible, so some means of finding relative or pseudo concentrations is necessary. The weight percents of oxides in the ash represent relative concentrations. Using these values as the concentrations in the rate equation resolves two of the unknowns. The problem of interaction order needs to be addressed, since it has been shown that overall first order involving either sodium or iron (historically the most important elements in slagging) has not been successful. An overall second order has been selected for application in this study. The most reasonable values for n and m in this scheme are one. The final problem is in determining A and B, the coal and coal ash constituents. The selection of A and B is not obvious and will be determined via trial and error with those resulting in the desired profile considered further. The interactions will be plotted as a function of the percent Jacob's Ranch in the blend. Where available the actual blend data points will also be included on the graph to compare the predicted value with the actual data.

There is more than one basis to calculate these interactions. The first and simplest is to assume that the relative amounts of ash contributed by each coal are the same. This means that the interaction is just the product of the values determined for the percentages of the oxides in the ash. A more realistic approach is to employ an ash correction factor to account for the two coals have differing ash contents. This correction factor is based on equal weights of the coals (or blends) being burned. A further correction may be used to account for differing heating values for the coals to produce the same heat output. A linear relationship between the pure coal heating values for the heating values of blends has been used. The actual effect of this correction factor will be to shift the curve towards the Clovis Point axis (0% JR).

Those curves with the desired profile are shown in Figures 2 through 5. Table V summarizes the interactions that showed the desired profile for any one of the above methods. Those interactions that are of most interest involve sodium or iron. These elements have been considered most influential in the formation of fireside deposits. Hence, these interactions support work done with pure coals.

CONCLUSIONS

This work is preliminary and involves only the two coals used at PSO where the blending problem was observed. Further work in this area is clearly necessary. However, the results clearly indicate that an overall second order reaction analogy can show an optimum as a function of coal blend which previous slagging prediction methods could not do. Efforts are continuing to evaluate interaction for other blending problems in hopes of obtaining a correlation which will be predictive for any coal blend.

REFERENCES

1. Zecchini, E. J., Masters Thesis, Oklahoma State University, 1986.

2. Lehman, D., "Slagging Experiences while Blending Wyoming Coal," Internal Report, Public Service Company of Oklahoma, Northeast Station, Oologah, Oklahoma, 1983.

3. Lee, G. K. and H. Whaley, Journal of the Institute of Fuel, 190, 1983.

4. Dooley, R. B. and V. Chacinski, Proceeding of the American Power Conference, 43, 106, 1981.

5. Raask, E., Mineral Impurities in Coal Combustion, Hemisphere Publishing Corp., New York, 1985.

6. Personal Communication from Williams Brothers Laboratory, Analysis of Jacob's Ranch and Clovis Point Coals, 1984.

TABLE I
STANDARD SLAGGING CORRELATION SUMMARY

	Williams Brother Data			This Study HTA Data		
Index	JR	Blends	CP	JR	Blends	CP
Silica Ratio	MS	MS	MS	HS	HS	HS
%Na_2O	MS	MS/HS	HS	MS	MS/HS	HS
%Fe_2O_3	LS	LS	LS	LS	LS	LS
Na Equivalent	LS	LS	LS	LS	LS	LS
$R_{b/a}$	LS	LS	LS	SS	SS	SS
Fy	MS	MS	MS	MS	HS	HS
Fs'	LS	LS	LS	LS	LS	LS

ND = Not Determined
LS = Low Slagging
MS = Medium Slagging
HS = High Slagging
SS = Severe Slagging

TABLE II
PROXIMATE ANALYSIS OF PURE COALS

Jacob's Ranch			
Analysis (wt%)	As Received	Moisture Free	Moisture and Ash Free
Moisture	25.44	****	****
Vol Matter	36.55	49.02	53.95
Ash	6.81	9.13	****
Fixed Carbon	31.70	41.85	46.05
H.H.V. Btu/lb	8,863	11,886	13,081
Clovis Point			
Analysis (wt%)	As Received	Moisture Free	Moisture and Ash Free
Moisture	31.32	****	****
Vol. Matter	33.85	49.28	54.11
Ash	6.14	8.94	****
Fixed Carbon	28.69	41.78	45.89
H.H.V. Btu/lb	8,014	11,668	12,813

Data from Williams Brothers Laboratories

TABLE III
JACOB'S RANCH ASH ANALYSIS

Component	Williams Brothers	This Study HTA
Iron as % Fe_2O_3	7.15	5.93
Calcium as % CaO	14.22	19.43
Magnesium as % MgO	3.15	4.75
Sodium as % Na_2O	0.68	0.76
Potassium as % K_2O	1.37	0.33
Silicon as % SiO_2	46.38	45.45†
Aluminum as % Al_2O_3	13.81	15.04
Titanium as % TiO_2	1.15	N.D.
Phosphorus as % P_2O_5	1.11	N.D.
Sulfur as % SO_3	6.05	N.D.
% Ash in the Coal	6.81	6.40

N.D. = Not Determined
† = By Difference

TABLE III
(Continued)

Clovis Point Ash Analysis

Component	Williams Brothers	This Study HTA
Iron as % Fe_2O_3	4.29	3.94
Calcium as % CaO	14.64	21.93
Magnesium as % MgO	3.12	5.58
Sodium as % Na_2O	1.08	1.66
Potassium as % K_2O	1.45	0.10
Silicon as % SiO_2	50.24	44.71†
Aluminum as % Al_2O_3	13.55	15.04
Titanium as % TiO_2	0.95	N.D.
Phosphorus as % P_2O_5	1.56	N.D.
Sulfur as % SO_3	4.53	N.D.
% Ash in the Coal	6.14	7.0

N.D. = Not Determined
* = Negligible
† = By Difference

TABLE IV
ASH COMPOSITION OF SELECTED BLENDS

a) High Temperature Ash (HTA)

Component	100%JR	75%JR-25%CP	50%JR-50%CP	25%JR-75%CP	100%CP
Fe_2O_3	5.93	4.72	4.49	3.94	3.94
CaO	19.43	20.14	20.62	21.15	21.93
MgO	4.75	5.15	5.25	5.35	5.58
Na_2O	0.76	1.04	1.18	1.44	1.66
K_2O	0.33	0.27	0.22	0.16	0.10
SiO_2	45.45†	46.21†	45.52†	45.40†	44.71†
Al_2O_3	15.04	14.76	15.04	15.04	15.04
TiO_2	N.D.	N.D.	N.D.	N.D.	N.D.
P_2O_5	N.D.	N.D.	N.D.	N.D.	N.D.
SO_3	N.D.	N.D.	N.D.	N.D.	N.D.

* = Negligible
† = By Difference

TABLE V
POSSIBLE INTERACTIONS FOR SLAGGING PREDICTION

Interaction	Williams Brothers Data			This Study HTA		
	Uncorr.	Ash Corr.	Heat Corr.	Uncorr.	Ash Corr.	Heat Corr.
Na * Fe	DP	DP	DP	NP	NP	NP
Na * K	NP	NP	NP	DP	DP	DP
Fe * P	NP	NP	NP	DP	UP	UP
Na * S_{coal}	NP	DP	NP	NP	NP	NP
Na * S_{ash}	NP	UP	NP	NP	ND	NP

NP = No Peak
DP = Desired Profile
UP = Undesired Profile

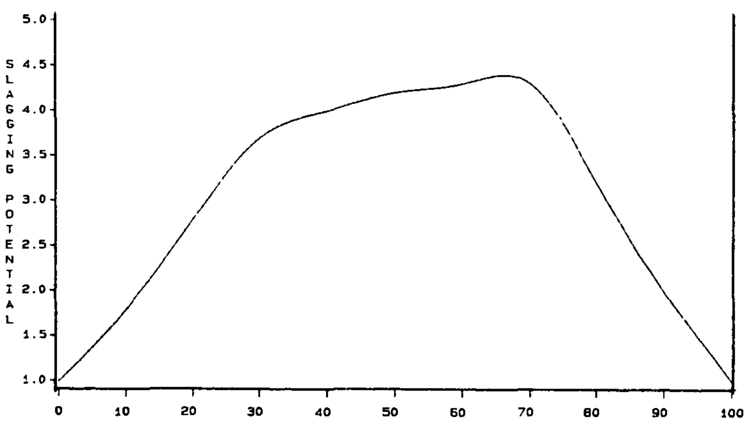


Figure 1. Desired Slagging Index Profile as a Function of Blend

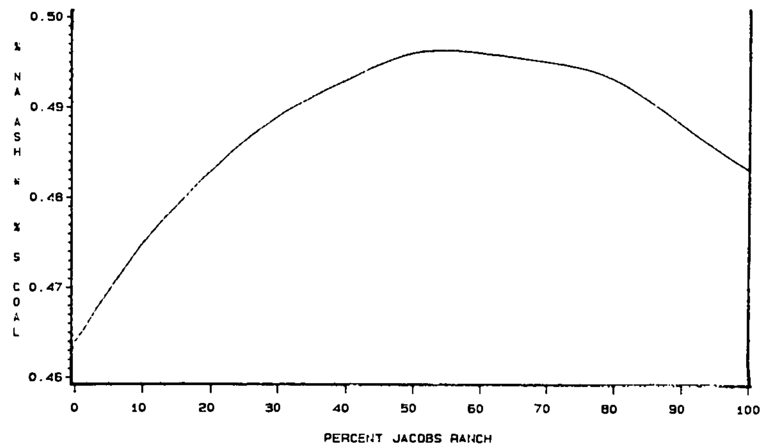


Figure 4. Ash Corr. 2nd Order Interaction of Na and S(coal)
(Williams Brothers Data)

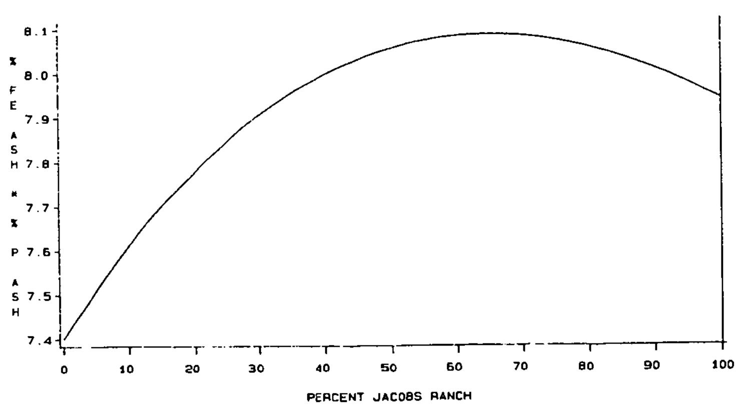


Figure 5. Heat Corrected 2nd Order Interaction of Fe and P
(Williams Brothers Data)

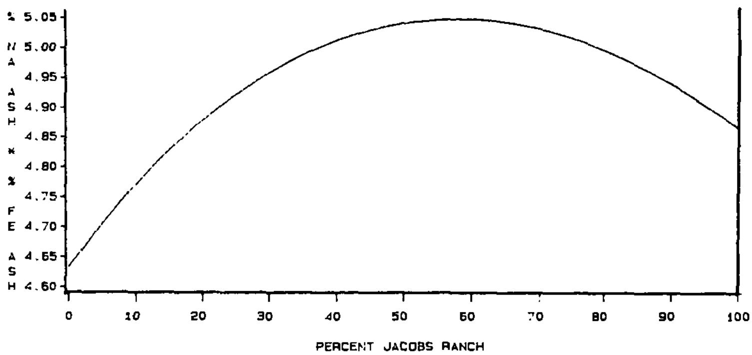
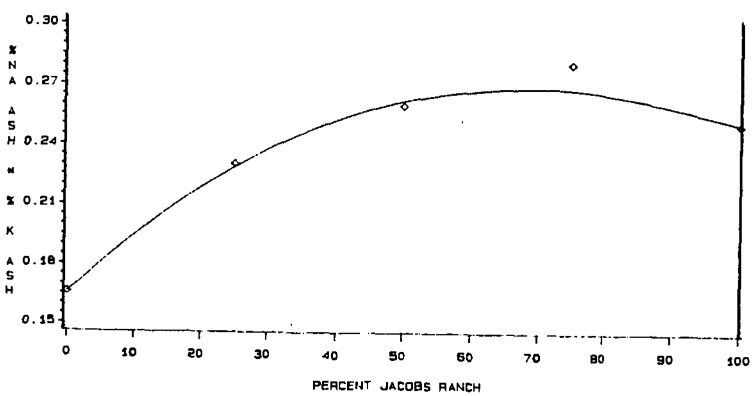


Figure 2. Uncorrected 2nd Order Interaction of Na and Fe
(Williams Brothers Data)



Solid line- This Study Predicted
Diamond- This Study Actual Data

Figure 3. Uncorrected 2nd Order Interaction of Na and K