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Selecting and implementing a fuel blend for scrubbed units at a pulverized coal power plant

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ABSTRACT

The DTE Power Plant includes four boilers, each generating up to 5.7 million lbs/h of supercritical steam, and each supporting the generation of up to 800 MW_e (net) of electricity. At the time of the testing two units were equipped with both scrubber and selective catalytic reduction systems in addition to electrostatic precipitators. Over a two year period, the Plant modeled and tested a wide variety of fuels and fuel combinations with a base fuel of Wyoming Powder River Basin (PRB) subbituminous coal and Central Appalachian bituminous coal. Fuels incorporated into the blend included petroleum coke, northern PRB subbituminous coal, and northern Appalachian bituminous coal. Various blend combinations were considered and/or tested. Operation with 100% PRB was also tested. The objective was to optimize the fuel blend from both technical and economic perspectives. The blend proven to be optimal from both technical and economic perspectives included 10% petroleum coke with PRB coal and, as necessary, Central Appalachian coal. This blend was implemented.

1. Introduction

During 2012 and 2013, a number of fuels and fuel blends were evaluated in an effort to combine technical and economic performance; the objective was to define the most effective fuels for various loads at the plant. The process started with limited thermodynamic modeling to evaluate the potential performance of a wide variety of blends with emphasis on both boiler efficiency and the behavior of inorganic matter in the fuels. Coupled with the modeling was a review of past tests, including tests conducted 20–30 years previously as remembered by current and retired shift supervisors and engineering personnel. The suite of candidate fuel blends, then, became as follows:

- 100% southern Powder River Basin subbituminous coal (LSW88)
- 90% LSW88/10% petroleum coke (PC) [for units equipped with scrubbers]
- 75% LSW88/15% Central Appalachian (MSE)/10% PC [for scrubbed units]
- 15–30% Northern Appalachian (HSE)/70–85% LSW88 [for units 3 and 4]
- 55–65% LSW88/25% MSE/10–20% Montana-based PRB coal (LSW94).

When the tests were conducted, two units were equipped with scrubbers; since that time all four units have been equipped with scrubbers. Three of the four units are also equipped with selective catalytic reduction (SCR) systems as well.

The blend alternatives were chosen based upon economic potential with technical limitations. Technical limitations, which were converted into criteria, included attention to unit capacity, boiler efficiency, and ease of operations. Among the technical limitations were attention given to slagging and fouling – deposition – and corrosion potential. While attention was given to emissions, the presence of SCR and wet scrubber technology along with electrostatic precipitators made these issues less critical. At the same time certain emission criteria including impact on the scrubbers and the potential for forming SO_3-based "blue plume" were of significance.

1.1. Background

The fuels being burned in the various blends or combinations shown above are characterized in Table 1.

The blending also was performed recognizing that, for some properties, coal blends do not function as the weighted average of their constituent fuels, but reflect interactions between and among the parent materials [3]. Rather, there is significant interaction between and/or among the fuels in the blend that causes altered performance characteristics. Mathematically the results of this interaction as shown for 2 solid fuels can be expressed by two equations:

The first equation which establishes a base for understanding calculates the weighted average of a given property following formula for coals i and j:

$$V_{ij} = x_{ib}V_i + (1–x_{ib})V_j \quad (1)$$

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Table 1
Generalized compositions of the fuels tested.

Parameter	Fuel				
	LSW88	LSW94	HSE	MSE	Pet coke[a]
Proximate analysis (wt.%)					
Moisture	26.45	23.95	5.89	6.55	6.29
Ash	4.92	4.38	7.74	8.52	1.06
Volatiles	32.34	31.41	35.59	32.99	3.07
Fixed carbon	36.30	36.654	50.53	51.91	89.59
Sulfur	0.25	0.35	2.38	1.40	5.96
HHV (Btu/lb a/r)	8818	9479	13,111	12,739	14,364
(MJ/kg a/r)	(20.51)	(22.05)	(30.50)	(29.63)	(33.41)
Ultimate analysis (wt.%) (a/r)					
Carbon	50.94	54.41	72.27	70.79	81.29
Hydrogen	3.51	3.70	4.83	4.67	3.17
Nitrogen	0.68	0.77	1.37	1.40	1.60
Sulfur	0.25	0.35	2.38	1.40	5.96
Cl (ppmw, mg/kg)	80	127	940	1480	100
Moisture	26.45	23.95	5.89	6.55	6.29
Ash	4.92	4.38	7.74	8.52	1.06
O [by difference]	13.33	12.32	5.49	6.58	0.393
Ash elemental analysis					
SiO_2	34.39	36.05	46.08/	50.12	13.8
$Al2O_3$	17.10	8.32	22.83	28.68	5.9
TiO_2	1.31	1.25	1.00	1.34	0.3
Fe_2O_3	5.85	5.46	14.97	11.28	4.3
CaO	21.79	15.42	5.56	2.35	3.6
MgO	5.04	3.99	1.09	0.94	0.6
K_2O	0.55	0.73	1.55	2.28	0.3
Na_2O	1.58	7.16	0.98	0.57	0.4
P_2O_5	1.30	0.78	0.57	0.41	–
SO_3	10.23	12.61	5.05	1.65	1.6

[a] Note: the petroleum coke pile was moved 3 different times and was contaminated, from a sampling perspective, with some portion of coal. Consequently typical petroleum coke values are shown in this table. The ash values shown do not add to 100 because they do not include vanadium or nickel. Sources: [1,2].

where V_{ij} is the calculated weighted average of any parameter or value (V), and x_{ib} is the proportion of coal i in the blend. The second equation then calculates the difference (d_{ij}) between the measured value (V_m) and the calculated weighted average for any given parameter (V_{ij}), as follows:

$$d_{ij} = (V_m - V_{ij})/[x_{ib}(1-x_{ib})]. \tag{2}$$

The term, d_{ij} is the measure of the magnitude or consequence of the interaction between two solid fuels—typically coals—in the blend. The measure of the interaction can be expanded to a multi-fuel blend by summing the d values for the blend as a whole using a third equation [4]

$$d_{blend} = \sum_{j=i+1}^{n} \sum_{i=1}^{n} x_i x_j d_{ij}. \tag{3}$$

The most prominent issues for significant interaction between and among fuels include fuel reactivity and ash reactivity (slag and fouling formation). Fuel reactivity is reflected in devolatilization and char oxidation kinetics, ignition temperatures (see Fig. 1), and—as a consequence of char oxidation kinetics—unburned carbon in the flyash. Increased volatility can have a dramatic impact on ignition temperatures as is shown. Since Fig. 1 relates to subbituminous (PRB)/bituminous blends, one can project that the curve between subbituminous coal and petroleum coke will be significantly steeper based upon the kinetics of both fuels. Decreased volatility beyond a threshold value can have a moderately disproportionate impact on unburned carbon.

The interaction among inorganic/ash components is typically associated with calcium (Ca)/iron (Fe) interactions forming eutectics (see Fig. 2). Other interactions of significance include those with alkali metals—sodium (Na) and potassium (K). Iron/calcium eutectics are notorious for forming severe slagging deposits and alkali metals interact with silica and alkali earth elements (Ca, Mg) to form severe fouling deposits.

2. Materials and methods

2.1. Program methodology

Test plans were written for each major fuel test effort. These included the PC/LSW88/MSE blend, the LSW88/LSW94/MSE blend, the LSW88

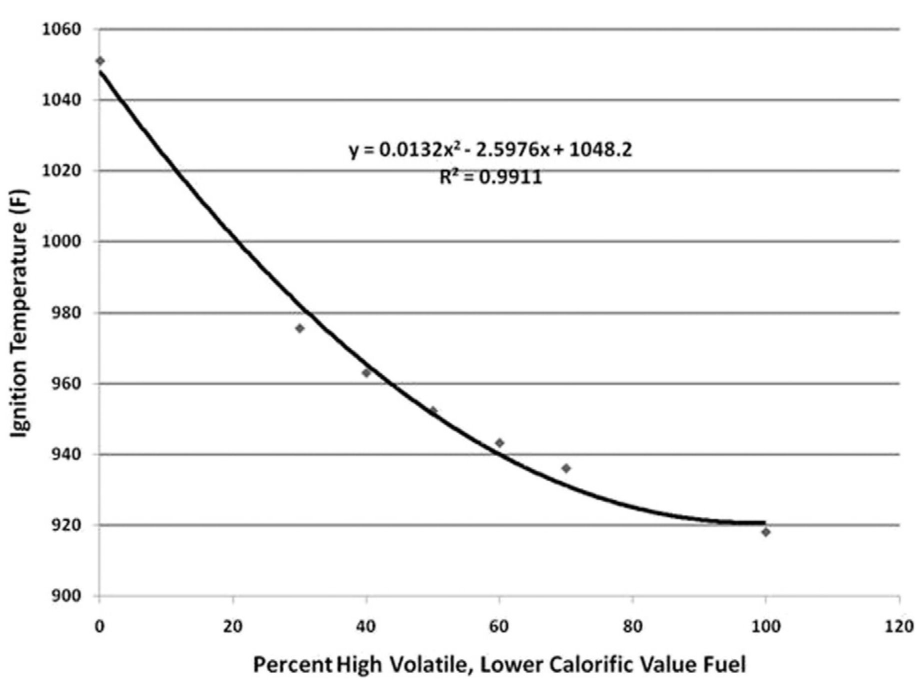

Fig. 1. Ignition temperature as a function of reactive subbituminous coal in a coal blend. Adapted from data presented in [5]).