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COAL SELECTION PROCEDURE FOR GENERIC COAL WATER FUELS - PRELIMINARY REPORT

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ABSTRACT

A coal selection procedure for the manufacture of generic coal water fuels based on desired combustion properties is presented. Important elements of the criteria include carbon/hydrogen ratio, the volatile content, composition and calorific value, higher heating value, and inert macerals. To minimize slagging and fouling in a boiler and high carbon losses, the sintering temperature of the ash and the coal free swelling index are additional parameters in the evaluation criteria. Other properties such as coal porosity, oxygen, nitrogen and sulphur affect the fuel ignition stability and the formation of gas pollutants.

A preliminary evaluation of various coals has been made according to the assessment criteria. However, a more conclusive assessment of coal suitability must await further analysis to determine the volatile composition and calorific value, inert macerals, porosity, free swelling index and the ash sintering temperatures.

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1. INTRODUCTION

Strictly, generic coal water fuels (CWF) describe nonproprietary coal slurries with pH control as a method to attain high solids loadings. In practice this definition has been expanded to include coal slurries made with low concentrations of chemical surfactants, but manufactured using nonproprietary methods. The latter applies to the generic CWF discussed in this report.

The use of surfactants without other chemicals to stabilize the mix produces a CWF with poor storage stability. The surfactants which assist coal suspension in water, and increase the solids loading in the fuel, also increase the settling properties of the coal. However, by maintaining a low residence time with good mixing between fuel production and utilization, gravity settling may be minimized.

The present report examines coal selection parameters for the manufacture of generic CWF for on-site preparation and use in a power plant. This work has been undertaken on behalf of the New Brunswick Electric Power Commission (NB Power) who are pursuing the application of generic CWF in the Coleson Cove generating station. The list of coals described in section 4 was supplied by NB Power.

2. CWF COMBUSTION PROPERTIES

This section describes the fuel properties desired for good combustion and minimal ash fouling and erosion in the boiler. It does not attempt to evaluate the fuel rheological properties necessary for efficient handling prior to its combustion. Fuel atomization behaviour will be discussed when relevant to fuel combustion.

2.1 Ignition Stability

The ignition stability of the fuel is the most critical requirement for its efficient combustion in a boiler. For CWF, the moisture content and coal volatility are the most significant fuel selection parameters for good ignition stability. The fuel moisture delays ignition by retarding droplet drying and heating, whereas the coal volatile content and composition determine the onset of fuel ignition and flame propagation at the burner mouth.

Typically, an increased moisture content in the CWF usually dictates a higher volatile content coal and higher calorific value gaseous products (from devolatilization) for stable ignition. For conventional 70% solids CWF, intermediate rank, bituminous coals with a volatile content > 30 wt % are necessary for the stable ignition of CWF (1). These requirements also vary somewhat with the fuel spray quality, and burner design parameters such as length to diameter ratio of the quarl (2). Due to the absence of a reliable data base on high moisture generic CWF, it is necessary to evaluate ignition behaviour in pilot-scale combustion tests.

2.2 Carbon Burnout

The overall fuel carbon conversion efficiency is determined by gas temperature, excess oxygen and residence time available for char burnout in the boiler. For CWF, the moisture reduces the flame temperatures by 100-200 ^{o}C, and this has a great bearing on char burnout. For retrofit applications in an oil-designed boiler, the higher gas volume required for coal combustion and the smaller boiler volume reduce the char residence time. With these negative effects for which little can be done, it is important to select coals with less stable forms of carbon (1). This selection may be achieved by a petrographic evaluation of candidate coals.

Besides the above parameters, carbon burnout in CWF combustion is also affected by the morphology of the char and ash particles. A recent study has shown that coarse char cenospheres formed in the CWF flame envelope contribute significantly to the unburnt carbon emissions from the boiler (3). This effect was caused by entrainment of the low apparent density chars. It was found that the carbon emissions from the boiler could be improved by coal selection to reduce the free swelling index, and by improved fuel atomization (3).

2.3 Ash Properties

The sintering temperatures (or ash fusion temperatures) in an oxidizing and reducing environment are important in determining the slagging and fouling propensity of the ash. High sintering temperatures minimize the tendency to slag on furnace panels, and in forming hard sintered deposits on heat transfer tubes that may be difficult to remove by soot blowing. The sintering temperatures are often determined by the chemical composition of the ash, and increase with the acid oxide ratio, i.e., the fraction of SiO_2/Al_2O_3 and decrease with the base percent, i.e., the total fraction of Fe_2O_3, CaO, MgO, Na_2O and K_2O. Usually, a minimal tendency for ash slagging and fouling established in a pulverized coal firing environment would be an adequate criterion for safe application as a coal water fuel. However, due to the fundamentally different morphology of the CWF ash (3), pilot scale combustion tests to evaluate the ash properties are recommended. Where practical, the fuel ash content must be minimized to reduce the risk of erosion damage in the boiler, for improved heat transfer and reduced frequency of operation of soot blowers.

3. COAL SELECTION AND ANALYSIS

3.1 Coal Type

The optimum choice for the manufacture of generic coal-water fuels is a medium rank, high-volatile bituminous coal. This criterion is dictated by the need for good ignition stability. However, in terms of ability to disperse coals with low additive consumption, the optimum choice would be a high-rank coal but high-rank coals often have a high carbon to hydrogen ratio, low concentrations and calorific values for the coal devolatilization products (1).

Since it is difficult to clearly delineate natural coals by rank, coal selection may be achieved by an evaluation of the following parameters:

a) fixed carbon, hydrogen, and carbon to hydrogen ratio,
b) combustible, volatile content,
c) composition and calorific value of the volatiles evolved in an inert atmosphere,
d) higher heating value,
e) inert maceral content, i.e., stable forms of carbon,
f) oxygen content,
g) free swelling index

Coals deemed appropriate in terms of the above criteria and other properties described in sections 3.2-3.3 should then be evaluated in pilot-scale tests to assess their combustion performance as a generic CWF (4).

3.2 Physical Properties

The skeletal (material) and apparent densities of candidate coals should be measured mainly to determine porosity. The porosity usually affects the distribution of surface and pore moisture in the coal water fuel (1). A higher porosity, and hence a greater concentration of pore moisture would reduce the solids loading and ignition stability of the CWF. Because porosity is often linked to a tendency for increased oxidation, the oxygen content may also serve as an indicator. In addition, the oxygen content increases the amount of chemical additive required to produce a CWF with an acceptable rheology. In most cases, a high oxygen content will also reduce the calorific value of the coal volatiles that are so crucial to the ignition stability of the fuel.

3.3 Coal Nitrogen and Sulphur

Nitrogen and sulphur contents are secondary parameters in the coal assessment criteria. A low nitrogen content will minimize fuel NOx emissions during combustion. Coals having a greater concentration of ash as opposed to chemically bound sulphur are also preferred. With the inevitable fine grinding of coals during CWF production, there is a greater potential to reduce SOx emissions by incorporating an oil agglomeration process to separate the coal from the sulphur-bearing iron pyrites (5).

4. PRELIMINARY ASSESSMENT OF SPECIFIC COALS

Tables 1 and 2 show the ultimate and proximate analyses of coals of interest to NB Power. A 60 wt % solids CWF made from the Cape Breton Development Corporation (CBDC) coal has been successfully fired in a pilot-scale boiler at the Energy Research Laboratories (4). The CBDC coal therefore serves as a useful guide for the selection of other coals. Some of the fuel evaluation parameters listed in section 3 are currently unavailable (see Table 3). These include the petrographic, porosity, free swelling index and the volatile composition and calorific value analyses.

Only a preliminary assessment is possible at this time. Cerrejon coal clearly has the worst properties in terms of the higher heating value, despite having the highest volatile content and the lowest fuel and carbon/hydrogen ratio (Figures 1-4). The low heating value of this coal stems from the high ash and oxygen contents. The higher ash and oxygen will also increase the additive concentration required for coal suspension. Due to the high oxygen, the coal may have a high porosity, which will reduce its solids loading and hence the net heating value of the CWF.

Farrel coal has the highest carbon/hydrogen ratio and the second highest oxygen content. This suggests that the volatiles may also have the lowest calorific value among the four coals, but this must be verified by an analysis of the composition and calorific value of the volatiles. With the possibility of a high porosity (oxygen), the combination of a more dilute slurry and the high oxygen volatiles may affect the fuel ignition stability.

Maturin and the CBDC coals seem to be the most acceptable choices among the four coals on the basis of the currently available data. However, the CBDC blend has the highest sulphur content of the four coals and may require additional processing to reduce the sulphur by coal beneficiation.

Subject to further tests and supplementary information on the ash slagging and fouling properties, coal selection for the generic CWF may be ranked in the following order:

1. Maturin
2. CBDC Blend
3. Cerrejon, Farrel

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TABLE 1. PROXIMATE ANALYSIS OF COALS (DRY)

COAL TYPE	ASH %	VM %	FIXED CARBON %	HHV Btu/lb
Cerrejon (Columbia)	9.87	38.63	51.50	11, 637
Maturin (Columbia)	7.59	36.51	55.90	13, 251
Farrel (W. Virginia)	6.97	37.05	55.98	13, 722
Lingan/Phelan (CBDC)	6.11	37.29	56.61	13, 590

TABLE 2. ULTIMATE ANALYSIS OF COALS

COAL TYPE	Carbon %	Hydrogen %	Nitrogen %	Sulphur %	Oxygen %
Cerrejon (Columbia)	65.56	4.87	1.68	1.40	6.29
Maturin (Columbia)	74.77	5.79	1.77	0.77	4.45
Farrel (W. Virginia)	77.42	5.26	1.82	0.98	5.13
Lingan/Phelan (CBDC)	76.17	5.90	1.71	2.60	3.27

TABLE 3. MISCELLANEOUS COAL EVALUATION PARAMETERS

COAL TYPE	C/H Ratio	Fuel Ratio	Vol. Composition	Vol. Calorific Value	% Inert Macerals	Porosity %	FSI
Cerrejon (Columbia)	13.46	1.33					
Maturin (Columbia)	12.91	1.53					
Farrel (W. Virginia)	14.72	1.51					
Lingan/Phelan (CBDC)	12.91	1.52					

FIGURE 1. COAL HEATING VALUE

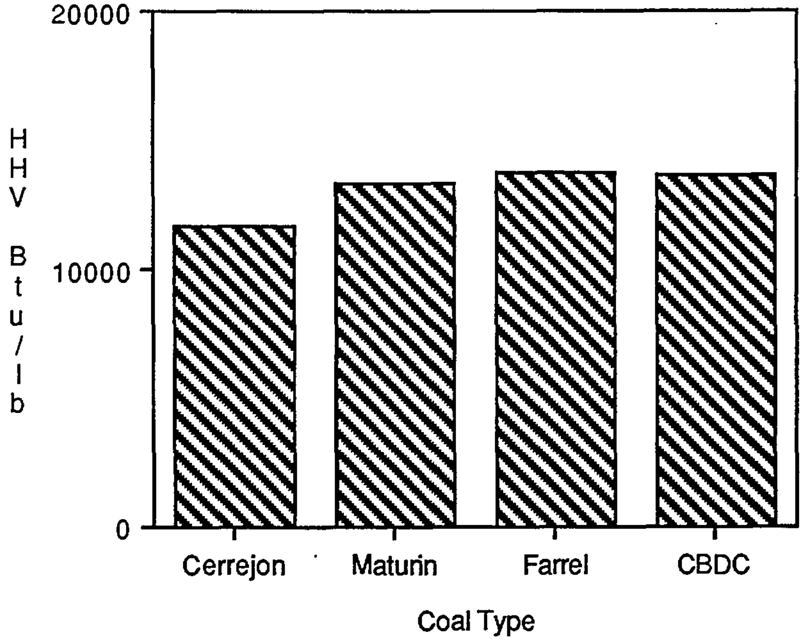

FIGURE 2. COAL VOLATILES

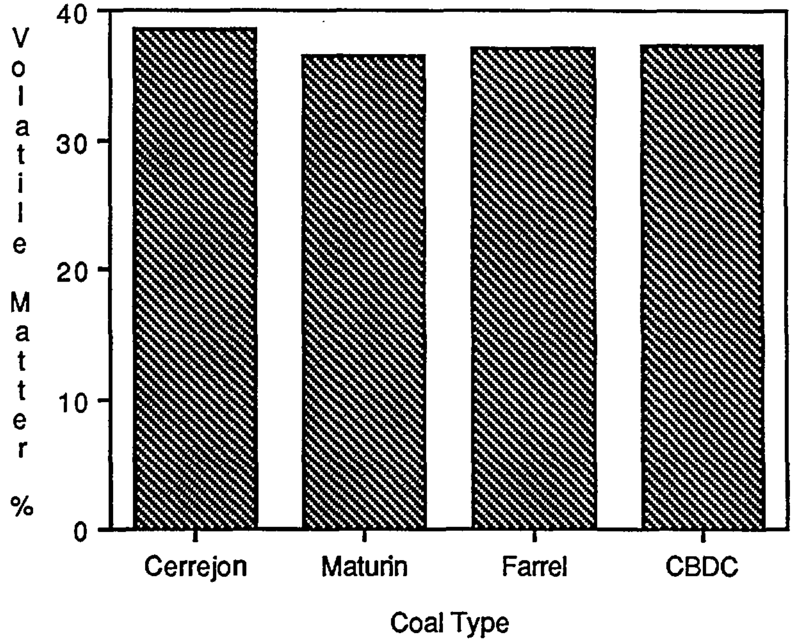

FIGURE 3. COAL FUEL & C/H RATIO

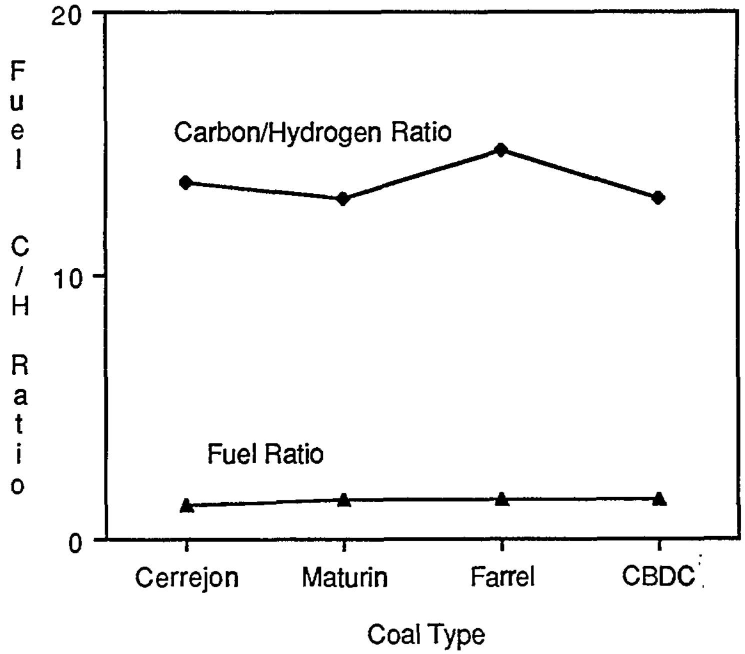

FIGURE 4. COAL N, S, OXYGEN