OPEN FILE REPORT 89-02

COAL WATER FUELS FROM LOW-RANK COALS

By
W. (Bill) Irwin, Todd A. Potas, and
Warrack G. Willson
October 23-27, 1989

COAL WATER FUELS FROM LOW-RANK COALS

By

W. (Bill) Irwin, Canadian Pacific Consulting Services, Ltd.,
Calgary, Alberta, Canada

Todd A. Potas, Energy & Mineral Research Center(EMRC), University
of North Dakota, Grand Forks, North Dakota, USA

Warrack G. Willson, EMRC and the Mineral Industry Research Lab.,
University of Alaska Fairbanks, USA

For Presentation

1989 International Conference on Coal Science

Tokyo, Japan

October 23 - 27,1989

CWF 10-89

COAL WATER FUELS FROM LOW-RANK COALS

W. (Bill) Irwin, Canadian Pacific Consulting Services, Ltd., Calgary, Alberta, Canada; Todd A. Potas, Energy & Mineral Research Center (EMRC), University of North Dakota, Grand Forks, North Dakota, USA; and Warrack G. Willson, EMRC and the Mineral Industry Research Lab., University of Alaska Fairbanks, USA

KEYWORDS: Low-Rank Coal-Water Fuels, Hydrothermal Processing

INTRODUCTION

Low-rank coals (LRCs), brown, lignitic, and subbituminous coals comprise about half of the world's coal reserves. In many developing countries they constitute the majority, and in some cases, the only carbonaceous reserves in sufficient supply to be of economic significance. While LRCs are as varied in composition as the countries in which they are located, they share one major impediment to widespread commercial use - high inherent moisture which ranges from 25 to 65%. This makes transportation costs prohibitive and has relegated LRCs mainly to local use or to mine mouth power generation. These moisture levels have also, until recently, excluded these feedstocks from consideration in the developing coal-water slurry or more appropriately, coal-water fuel (CWF) applications, despite the fact, that LRCs almost always are far cheaper and far more reactive than their bituminous counterparts.

There are numerous low temperature drying technologies available commercially. Most use hot flue gases to evaporate the coal moisture. The final product moisture is dependent on feed size and residence time at temperature.(1) Due to the low temperatures used, these processes are the least expensive and are preferred if the dried product is to be used immediately. However, since the drying temperatures are too low to cause permanent changes in the coal structure, the dried coals are porous and hydrophilic, and readsorb the lost moisture.(1) The untreated dried product is also susceptible to spontaneous heating and excessive fines generation.

If LRCs are dried at temperatures above about 240 C, the basic chemical and physical coal characteristics begin to change. Decarboxylation occurs and CO_2 is evolved.(1) Much of the coal's additional volatile matter, tars and oils, are also liberated and migrate to the coal's surface. If the tars are not stripped during drying, they remain on the coal further reducing the coal's ability to hold water. Product stability especially towards fines generation and spontaneous combustion is also of concern. Methods for mitigating these problems include: coating the coal with residual tar or oil; drying only larger lump coal; or producing briquettes or pellets from dried pulverized coal.

A new non-evaporative drying technique in which the structure of LRC is altered, has been developed by the Energy and Mineral Research Center (EMRC), University of North Dakota. Hydrothermal processing, more commonly known as hot-water drying (HWD), represents a major breakthrough in the science of coal drying while solving the stability problems by producing a safe, easily transported liquid.

EXPERIMENTAL

The initial studies and coal specific HWD tests were performed in autoclaves. (1,2) Proof of concept and technical feasibility was been demonstrated in the EMRC 2.5 tpd process development unit (PDU) described previously.(3) LRCs from the U.S. coal producing regions of the West, Gulf Coast and Alaska, along with those from Australia, Canada, the Phillipines and Yugoslavia have been converted into CWFs. In the PDU a utility grind of LRC (90% minus 200 mesh) is treated as a dilute slurry at coal specific temperatures beginning as low as 240 C and the corresponding saturated steam pressure for less than 5 minutes.(3) The dilute slurry is depressurized prior to concentration via a commercial continuous solid bowl centrifuge.

Data on CWFs made from four North American LRCs following hydrothermal processing are presented in Table 1. All of these coals are from active mines and represent some of the largest potential resources in North America. These coals are typical of high quality low sulfur LRCs. All responded favorably to HWD producing CWFs with energy densities over 50% higher than possible with the raw coal. The maximum solids concentration was the dry solids loading in a CWF that would flow without assistance.

Table 1. HWD, LRCs and their CWF properties (dried at ~330 C)

COAL MINE		Indian Head	Martin Lake	Usibelli	Blk.Thunder
LOCATION		N. Dakota	Texas	Alaska	Wyoming
RANK		Lig.	Lig.	Subbit.	Subbit.
COAL ANALYSES					
Equil.Moist.	(Raw)	33.0%	31.6%	24.1%	26.4%
"	(HWD)	12.1%	8.5%	9.2%	8.7%
Fuel Ratio	(Raw)	1.10	0.99	1.12	1.21
"	(HWD)	1.09	0.97	1.10	1.25
Carbon	(Raw)	60.3%	61.3%	64.8%	67.2%
"	(HWD)	64.6%	66.3%	71.1%	72.1%
Hydrogen	(Raw)	3.8%	4.3%	5.0%	4.6%
"	(HWD)	4.6%	4.6%	5.1%	4.7%
Sulfur	(Raw)	1.0%	1.3%	0.2%	0.5%
"	(HWD)	0.7%	1.1%	0.1%	0.5%
Ash	(Raw)	15.6%	16.1%	8.6%	8.8%
"	(HWD)	13.9%	13.8%	8.1%	6.4%
CWF ANALYSES					
Max.Conc.%	(Raw)	40.5%	43.0%	44.0%	44.6%
"	(HWD)	58.3%	62.0%	62.0%	63.1%
CWF(Btu/lb)	(Raw)	4,100	4,500	4,900	5,200
"	(HWD)	6,300	6,800	8,000	7,900
MASS & ENERGY BALANCES (MAF Basis)					
Dry Coal Rec.(wt%)		87%	92%	86%	93%
Energy Rec. (%)		94%	98%	99%	97%

RESULTS AND DISCUSSION

Water is present in LRCs in basically three forms, free water on the surface and in the pores, chemically bonded to carboxyl or cationic moieties, and hydrates of mineral matter, Fig. 1. During HWD, water is removed via expansion and expulsion by CO2. Decarboxylation not only removes hydrophyllic sites but leads to an increased energy density of the CWF by ridding the coal of oxygen functionalities.(1) The largest contributors to a stable, non-readsorbing particle are the evolved tars/oils. Tars are mainly hydrophobic and in a pressurized aqueous environment tend to remain on the coal in a uniformity not possible with any other means of coating the dried coal's reactive surface. The uniform tar coating effectively seals the pores against moisture readsorption, Fig. 1.(1,2) The overall process, which simulates or induces coalification, can be represented as removing the inherent moisture and reusing this moisture as the vehicle solvent. For some high moisture coals the process may even become a net producer of water. In general there is little ash reduction during HWD. However, in coals with high alkali concentrations, the alkalis associated with the carboxyl groups are released into the aqueous phase and can be removed by washing during the final mechanical dewatering step, giving a product with a much lower fouling potential.

Advanced applications, such as in combustion turbines and/or diesel engines place new demands on the fuel's combustion characteristics due to the greatly shortened residence times allowable for combustion. Instead of the usual seconds available in conventional combustors, reaction times in heat engines are measured in milliseconds. Thus, to achieve complete carbon burnout with bituminous coal water fuels, suppliers have gone to more costly fine grinding to produce "micronized" CWFs. The smaller size and much narrower particle size distributions negate any advantages bituminous coals might have held over LRCs in producing more concentrated CWFs, since concentrations in the low 50%s are the rule. For advanced applications, the higher reactivity of low-rank CWFs could prove to be a decided advantage over bituminous CWFs by requiring less grinding to reach a size for complete carbon burnout or to enable use in higher speed engines.

Initial combustion test results support the higher reactivity of LRC CWFs, which leads to complete carbon burnout in short residence times and higher flame stability.(4,5) Part of the enhanced reactivity is shown schematically in Figure 2.(5) High rank coals go through an agglomerating phase as the water is evaporated and combustion begins. During this time micronized coal particles can agglomerate into slower burning lumps many times their original diameter, which was attained through costly micronizing. The reverse is true for LRCs whose enhanced friability after HWD yields particles that literally break into numerous smaller dried coal particles upon further heating. These highly reactive coal particles ignite readily, producing a stable flame.(4) Tars that seal the pores against moisture readsorption are volatilized at the inception of combustion and contribute fuel to the flame, while leaving behind the high surface area dried LRC. The fact that the HWD LRCs should have excellent combustion properties is also indicated by their low fuel ratios, Table 1, which in some cases are even improved over those in the raw coal.

CONCLUSIONS

Induced coalification occurs when coal is heated to coal specific temperatures, typically above 240 C in an aqueous phase at pressures slightly above the saturated steam pressure. Key advantages of hydrothermal processing include, uniform distribution of tars over the coal's surface, irreversible water removal without vaporization, elimination of much of the LRC hydrophilic oxygen functionality, removal of soluble, boiler fouling alkali cations, and adaptability to continuous processing. The resulting CWF will retain the excellent combustion characteristics inherent in LRCs and will disintegrate rather than agglomerate during combustion giving enhanced flame stability. The EMRC and Canadian Pacific Consulting Services, Inc. will be assessing the application of this technology to a Phillipine LRC in pilot-scale tests, and if the results are favorable, will conduct a small commercial demonstration program in the Philipines.

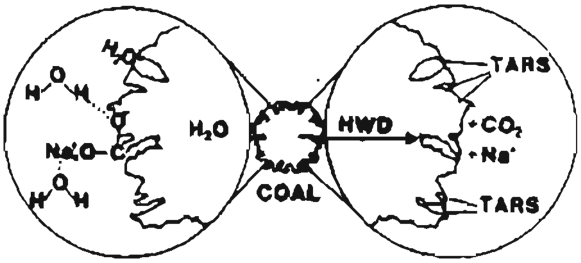

Figure 1 Moisture in LRCs and removal via HWD.

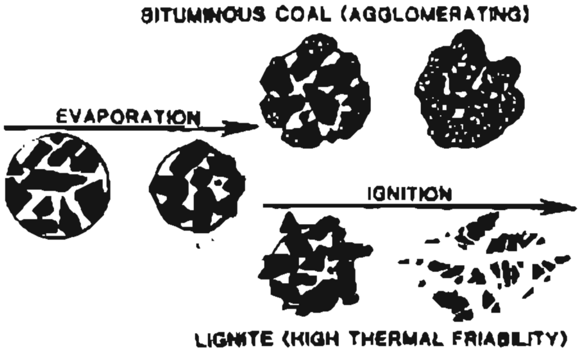

Figure 2 Evaporation and ignition sequence of CWF droplets.

REFERENCES

1. Willson, W.G., et al., "Low-Rank Coal-Water Slurries for Gasification", Fuel Proc. Tech., 15, pp. 157-172 (1987)
2. Willson, W.G., et al., "Low-Rank Coal Water Slurries for Gasification", EPRI Report No. AP-4262 (Nov. 1985)
3. Potas, T.A., et al, "Pilot-Scale Preparation of Low-Rank Coal-Water Fuels, J. Coal Qual. (April 1987)
4. Germane, G.J. and Smoot, L.D., "Fundamental Combustion Studies of Hot Water Dried Low-Rank Coals", DOE/FC/10614-2259 (Sept. 1986)
5. Hauserman, W.B., et al., "Production and Combustion of HWD Lignite Slurries", Preprints 7th Annual Symposium on Coal Slurry Fuels Preparation and Utilization, New Orleans, LA (May 1985)