Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

Final report. (Two copies in Comm to G.K.Lee - for disposal) 88/12/09

PILOT-SCALE COMBUSTION TRIAL OF SASKATCHEWAN LIGNITE COAL-WATER FUEL

G.N. Banks, J.K. Wong and H. Whaley
Combustion and Carbonization Research Laboratory

November 1988

ENERGY RESEARCH LABORATORIES
DIVISION REPORT ERL 88-87(IR)

This work was supported in part by the
Federal Panel on Energy R&D (PERD)

INTRODUCTION

Under an agreement between the Saskatchewan Department of Energy and Mines and the Department of Energy, Mines and Resources Canada, Canada Centre for Mineral and Energy Technology (CANMET) conducted a pilot-scale combustion evaluation of a coal-water fuel (CWF) produced by the University of North Dakota Energy and Mineral Research Centre (UNDEMRC). The hot-water-dried, coal-water fuel (HWD-CWF) was produced by UNDEMRC using lignite from the Coronach mine in Southern Saskatchewan. A commercial CWF made from Cape Breton coal, which had been previously used in full-scale boiler trials in Chatham, N.B., Charlottetown, P.E.I. and Minas Basin, N.S. as well as in pilot-scale boiler trials at CANMET was used as the reference fuel (Ref-CWF).

COAL-WATER FUEL CHARACTERISTICS

Four 208-litre plastic drums of CWF were delivered to the Energy Research Laboratories (ERL) on March 24, 1988. A letter, received from the University of North Dakota, U.S.A. on March 28, indicated the CWF (732 kg) had a solids content of 58 to 59% by weight and an apparent viscosity of 600-800 cP at 100 sec^{-1}. No flow enhancement reagents had been added to the CWF, however 0.1 wt % formaldehyde had been added in order to minimize biological growth. Examination of these four drums of CWF indicated that the drums ranged from 47 to 81% full and that a considerable amount of solid material had settled out of the suspension (40 to 85 vol %), as outlined in Table 1.

Table 1 - Condition of HWD-CWF delivered to ERL

Drum no.	Drum occupancy vol %	HWD-CWF as a hard solid vol %
1	81.1	40.0
2	70.3	73.1
3	64.9	72.9
4	47.3	85.7

Attempts to produce a pumpable slurry from the product in drum No. 1 were unsuccessful and the Saskatchewan Department of Energy and Mines was informed of our difficulties. A sample of the partially reconstituted product from drum No. 1 was sent for analyses (column A, Table 2).

Dr. M. Wilson of the Technology Branch of the Saskatchewan Department of Energy and Mines arranged for Mr. T. Potas, a slurry preparation specialist from the University of North Dakota and Mr. D. Webster from FENCO Lavalin, Toronto to visit CANMET and determine the correct procedure for reconstituting the four drums of HWD-CWF which had apparently been manufactured in December 1987. Mr. Potas arrived on June 13 and after examining the product, he determined that a high-shear mixer and a chemical stabilizer were required to resuspend and stabilize the lignite particles. A pumpable product was produced on June 14 and stored overnight in a continuously agitated day tank. Table 2 gives an analyses of both the partially reconstituted and the fully reconstituted HWD-CWF's (columns A and B respectively) and the Ref-CWF.

Table 2 - Chemical analyses of coal-water fuels

	HWD-CWF		Ref-CWF
	A*	B**	
Proximate analysis, wt % as sampled			
Total moisture	43.9	51.8	31.4
Ash	11.5	9.7	2.9
Volatile matter	19.7	17.2	24.5
Fixed carbon	24.9	21.3	41.2
Ultimate analysis, wt % dry			
Carbon	58.2	58.4	81.3
Hydrogen	3.4	3.4	5.2
Nitrogen	0.8	0.8	1.5
Sulphur	0.7	0.8	1.8
Ash	20.6	20.1	4.2
Oxygen (by difference)	16.3	16.5	6.0
Calorific value, MJ/kg	22.29	22.46	33.98

A* - This as received material was partially reconstituted with a high-shear stirrer, but was too viscous to pump and atomize in the pilot-scale research boiler. No water was added.

B** - This material was fully reconstituted on June 14, 1988 by Mr. T. Potas through addition of water, a chemical stabilizer and a high-shear stirrer.

TRIAL PROCEDURE AND OBSERVATIONS

The combustion trial was conducted in the CCRL pilot-scale research boiler using the roof-fired "J_1" configuration shown in Fig. 1. A qualitative assessment of combustion performance was obtained from:

(a) ignition stability
(b) flame shape and size
(c) sparkler density
(d) bottom-ash quantity and characteristics
(e) carbon in fly ash

In the early stages of the combustion trial, a support flame (No. 2 fuel oil) was used to maintain a visible flame in the furnace combustion zone in order to assure safe combustion of volatile gases. At the request of the UNDEMRC representative, this support flame was withdrawn after 30 minutes and the trial was continued using the HWD-CWF alone. Unlike the luminous stable flame produced by the Ref-CWF, no visible flame could be seen when the HWD-CWF was fired, although some sparklers were observed at the base of the furnace. During the burn, a steady build-up of what appeared to be coke accumulated on the refractory walls immediately below the burner quarl. This build-up continued until the view port, located below the south-side burner, was about 50% covered. The CWF feed rate, which varied from 122 to 160 kg/h, averaged 148.9 kg/h. This variation in feed rate was chiefly due to coarse particles or agglomerates (>2 mm) of feed material rapidly plugging the strainer on the burner feed-line. About 2 h into this trial the north-side burner plugged and attempts to open the feed line were unsuccessful. The trial was continued using only the south-side burner until the fuel was consumed. The average results of this trial are given in Table 3 together with the results of the Ref-CWF trials.

Table 3 - Boiler operating conditions

	HWD-CWF	Ref-CWF	
Fuel rate, kg/h	148.9	87.3	87.8
Thermal input, MJ/h	1612	2035	2047
Atomizing air			
Temperature, °C	34	25	21
Flow rate, kg/h	29	30	23
Combustion air			
Temperature, °C	200	235	201
Flow rate, kg/h	454	784	629
Furnace exit temperature, °C	770	903	879
Flue gas analysis, volume			
O_2 %	2.6	5.0	2.0
CO_2 %	17.2	14.2	16.0
CO ppm	34	31	47
NO ppm	358	656	728
SO_2 ppm	642	1296	1269
Combustible in fly ash, wt %	4.4	10.2	28.5
Bottom ash, approximate depth, cm	>10	<0.5	<1
Distribution of ash, wt %			
Furnace bottom	81.5	24.7	10.5
Furnace wall	3.8	11.8	15.8
Superheater tubes	0.2	1.2	1.1
Flue pipes and heat exchangers	14.5	62.3	72.6
Total ash collected, kg	51.9	8.5	9.5

The day following the combustion trial, the residue in the furnace bottom was stirred with a steel rod and found to be burning. This indicated that the furnace bottom ash contained a high level of unburned carbon 20 hours after the burn had been completed. At the request of Mr. T. Potas, samples of ash collected from various sections of the furnace, were sent by courier to the University of North Dakota for examination under their electron microscope. The results of this examination, which were to have been included in this report, have not been received.

CONCLUSIONS

1. The reconstituted slurry feed contained agglomerates or particles that were too coarse (>2 mm) for good atomization. This non-homogeneous slurry caused frequent interruptions in fuel feed and finally resulted in one burner becoming plugged.

2. More than 80% of the ash produced in the trial remained in the furnace bottom, which would cause some concern in a utility boiler.

3. The atomization characteristics of this fuel should be evaluated before further burn tests are contemplated. Priority consideration should be given to ensure that the maximum size of the particles or agglomerates is less than 2 mm.

4. It is strongly suspected that this material had settled into a cohesive agglomerate during storage and subsequent transit. Even after being reconstituted by UNDEMRC, particles greater than 2 mm were present in the mixture.

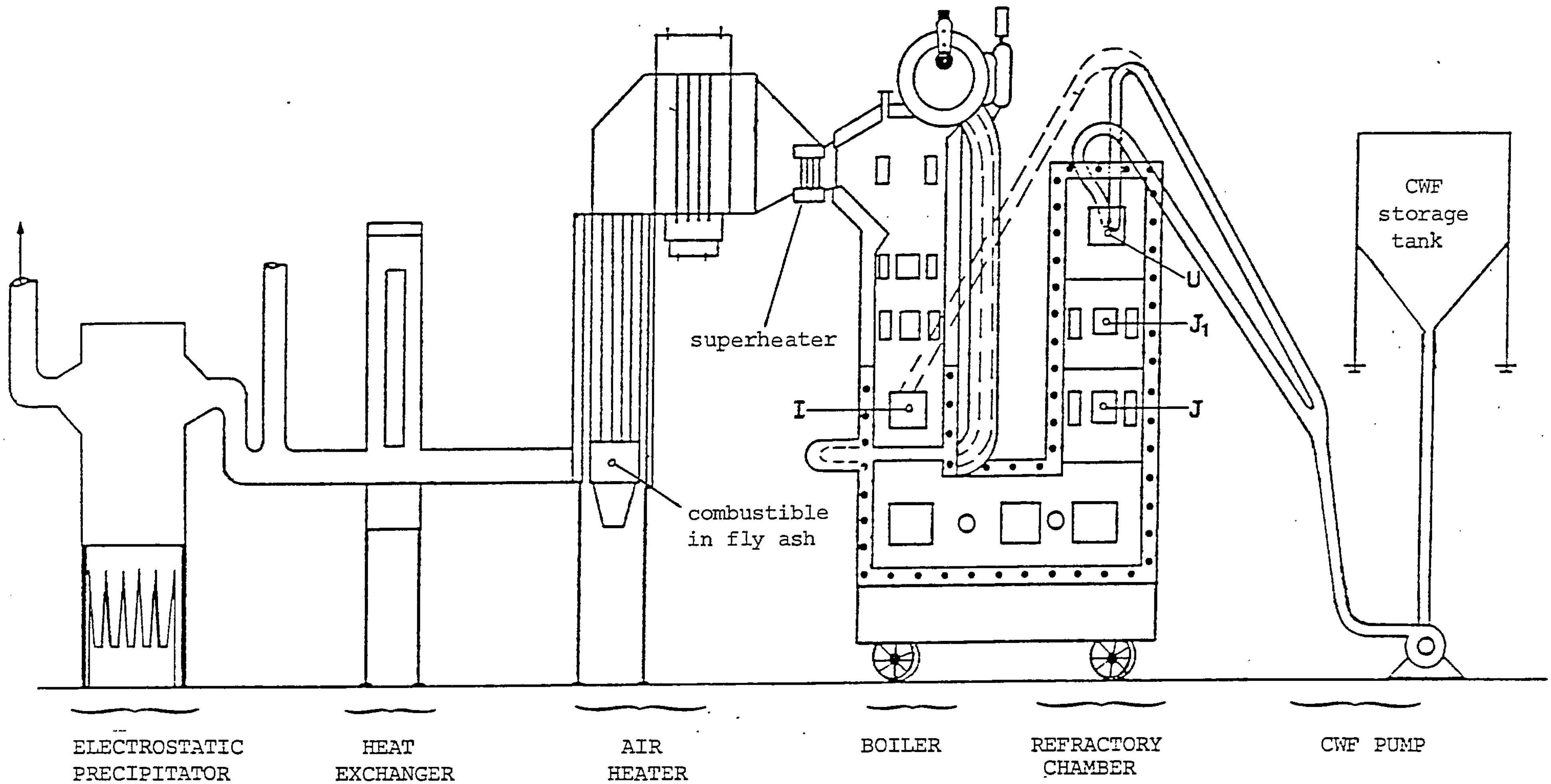

Fig. 1 - Schematic of CCRL pilot-scale boiler with CWF handling system