Combustion of Coal Washery Rejects in a Circulating Fluidized Bed

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INTRODUCTION

The CANMET Energy Technology Centre, sponsored by Luscar Ltd and the Alberta Government, carried out a series of combustion trials on a number of washery rejects, to determine whether they could be burned in an environmentally acceptable manner using both conventional and advanced combustion technologies - namely fluidized bed combustion (FBC). The facilities used were a pilot-scale research boiler (PSRB) and CANMET's 0.8 MWth circulating fluidized bed boiler (CFBC). The program was sponsored by the Alberta Government (Western Diversification) and Luscar Ltd. This paper presents details of the CFBC pilot plant trials only.

EXPERIMENTAL

Test Materials

The three fuels burned in the reactor were: raw coal (Obed No.4), Obed Jig Rejects (Obed No.7) and Obed Jig Middlings (Obed No. 10). These fuels required a sorbent, Cadomin limestone (Genstar Cement Ltd), to achieve the allowable SO_2 emissions levels recommended under the National Guidelines for Stationary Sources. This particular limestone had been previously tested by CANMET using a TGA and was shown to be only a moderately reactive sorbent. As some difficulties were experienced in achieving adequate sulphur capture under the test conditions employed, a trial was also carried out using Havelock limestone (a relatively reactive eastern Canadian limestone).

Test Methods

The pilot-scale CFBC unit used has been described extensively elsewhere [1]. The major features of this versatile facility include a refractory lined combustor 405 mm in diameter and 7 m high, a refractory lined hot cyclone and an inclined L-valve loop seal system for recirculation of solids (Fig. 1). Four retractable bayonet type vertical cooling tubes permit the control of the combustor temperature during operation at various test conditions. It is complemented by a comprehensive instrumentation and control system, which is described elsewhere [1]. The combustor is designed to operate at temperatures up to 1100 °C and at a superficial gas velocity of up to 8 m/s.

CFBCs typically operate at combustion temperatures between 800 °C and 950 °C. Lower temperatures normally reduce combustion efficiency to unacceptable levels, decrease sulphur capture and increase products of incomplete combustion. Higher temperatures by contrast, run the risk of producing bed agglomeration, increasing NO_x emissions to unacceptable levels, and also reducing sulphur capture.

Initial operation of the facility has demonstrated a satisfactory performance of the combustor and ancillary equipment. In addition, the unit has been successfully used with high sulphur petroleum coke and pitch. The unit has also been used to generate ash from the CFBC combustion of high sulphur coals in order to study various ash management applications.

The research facility generates a database useful for the design and process optimization of full-scale units, study of emissions of pollutants, and prediction of the combustion performance of feedstocks.

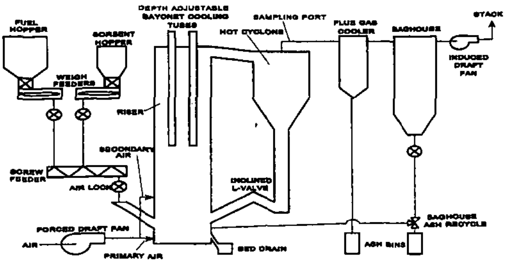

Figure 1. Schematic of CANMET's 0.8 MW(th) CFBC pilot plant

RESULTS

Table 1. Combustion results

Test and Date	Bed Temperature (°C)	Ca/S	NO_x (ng/J)	SO_2 (ng/J)	Sulphur Capture Efficiency (%)	Combustion Efficiency (%)
Obed No. 4 Oct. 29-30/ 92	850	0	155.3 ± 8.7	370.3 ± 31.9	26	99.0
	850	2.2	151.8 ± 7.7	354.1 ± 53.7	28	-
Obed No. 7 Nov. 3-4/92	850	0	149.5 ± 10.1	562.5 ± 34.9	14	98.2
	850	4.9	144.9 ± 11.7	377.9 ± 74.3	32	98.9
	800	4.9	100.9 ± 5.5	224.1 ± 31.5	49	97.7
Obed No. 10 Nov. 5-6/92(*)	850	0	117.8 ± 8.6	422.0 ± 69.0	14	99.0
	850	2.8	107.2 ± 5.1	313.5 ± 25.2	30	98.8
	800	2.8	72.7 ± 8.0	185.7 ± 9.2	63	98.0
	900	2.8	135.1 ± 4.1	395.2 ± 24.4	38	99.1
Obed No. 4 Nov. 10/92	800	0	103.6 ± 10.4	316.8 ± 65.6	26	98.5
	800	2.7	97.6 ± 10.4	264.3 ± 62.4	31	98.3
Obed No. 7 Nov. 12/92	800	0	113.2 ± 14.7	218.4 ± 79.2	-	-
	900	5.5	187.9 ± 4.9	403.7 ± 50.4	44	99.0

(*) Trial with Havelock limestone

Table 1 (above) presents results from the CFBC combustion trials.

DISCUSSION

Sulphur Capture Results

As indicated in Table 1, the natural Ca/S molar ratio of all of the fuels tested is relatively high. These high levels of alkali metals versus fuel sulphur content could potentially result in a significant inherent capture if the calcium was present in a suitable form. Sulphur removal without limestone addition observed by CANMET for FBC combustion of Canadian fuels appears to average about 28% [2], and captures of over 90% have been observed for one Western Canadian subbituminous coal using both circulating and bubbling FBC technology [3,4]. Similar data have been reported elsewhere, e.g., inherent captures of up to 75% have been reported for British coals [5].

However, one important difference between capture due to ash components and limestone in FBC systems was that the optimum capture temperature for ash appears to be about 750 °C. This is a full hundred degrees below the optimum temperature for most limestones [5].

Combustion Efficiency

The combustion efficiency data follow the expected trend increasing with increasing bed temperature. No other experimental parameter over the range used in this test series seems to have a significant effect on the combustion efficiency. The variation in combustion efficiency from 97.7 to 99.1% is very small, with typical combustion efficiency being about 99% for bed temperature of 850 °C.

Nitrogen Oxides Emissions

NO_x emissions vary from 73 to 188 ng/J, which are well below levels typically seen from conventional combustion. Surprisingly there appears to be no effect associated with the addition of limestone, which might have been expected to increase NO_x emissions. Limestone is well known to be able to increase NO_x emissions in CFBC's due to its ability to catalyze NH_3 oxidation (from fuel volatiles) [6]. Perhaps the explanation is that limestone is simply not present in sufficiently high absolute quantities to have a significant impact, despite the high Ca/S molar ratios used in this study. However, the data clearly show that NO_x appears to increase with bed temperature which is as expected.

Sulphur Dioxide Emissions

For the most part, the National Guideline for Stationary Sources (258 ng/J) is exceeded (Table 1). However, the use of Cadomin limestone with Ca/S molar ratio of greater than 5 does allow this guideline to be met at 800 °C and SO_2 emissions should not be a problem for sufficiently high Ca/S molar ratios.

CONCLUSIONS

Three fuels, Obed No. 4, Obed No. 7 and Obed No. 10, have been burned in a CFBC combustor. All of these fuels are highly reactive and at typical CFBC operating conditions (850 °C and 3% O_2), it appears that combustion efficiency (based on unburned carbon loss) is 99.0% which is typical of such very reactive fuels. Inherent sulphur capture was shown to be small and to decrease with bed temperature, and appeared to be directly related to the degree of pyritic sulphur in the fuel which suggests that the "apparent capture" is due to carryover of unreacted pyritic sulphur. Cadomin limestone is only likely to be effective in achieving emission guidelines when it is used at Ca/S molar ratios of greater than 5. NO_x emissions are all below the current guidelines. Other emissions such as CO and N_2O appear to be low and are unlikely to pose problems. CO and N_2O emissions decrease with increasing bed temperatures as expected and interestingly, limestone appears to have a small positive effect in reducing CO levels. CFBC appears to be an entirely satisfactory technology for burning these fuels and based on these results would have no problem in achieving good combustion performance and low emissions.

REFERENCES

1. Desai, D.L. "The 0.8 MWth circulating fluidized bed combustion research facility at the Combustion and Carbonization Research Laboratory, CANMET: Its design and initial operating experience", Proceedings of the 1991 CANMET CFBC Management Seminar, eds. E.J. Anthony and F. Preto, Halifax, Nova Scotia, July 2-3, 1991.

2. Zhang, J.Q. and Jones, W.E. "Evaluation of SO_2 and NO_x emissions in fluidized bed combustion ", Final Report to Energy, Mines and Resources under contract 007SQ-234400-8-9213, August 1990.

3. Grace, J.R., Brereton, C.M.H., Lim, C.J., Legros, R., Zhao, J., Senior, R.C., Wu, R.L., Muir, J.M. and Engman, R. "Circulating fluidized bed combustion of Western Canadian fuels", Final Report to Energy, Mines and Resources Canada under contract 52.SS23440-7-9136, August 1989.

4. Becker, H.A., Code, R.K. and Stephenson, J.R. "Pilot scale trials on atmospheric fluidized bed combustion of a Western Canadian Sub-bituminous coal (Highvale)", Final Report to Energy, Mines and Resources Canada QFBC.TR.87.3, March 1987.

5. Raymant, A.P. "Sulphur capture by coal and freeboard processes during fluidized bed combustion", Proceedings of the Tenth International Conference on FBC, ed. A. Manaker, pp. 597-602, San Francisco, CA, April 30-May 3, 1989

6. Lyngfelt, A. and Leckner, B. "The effect of reductive decomposition of $CaSO_4$ on sulphur capture in fluidized bed boilers", Proceedings 10th International Conference on FBC, p. 675-684, San Francisco, CA, 1989.