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COAL COMBUSTION RESEARCH AT THE CANADIAN COMBUSTION RESEARCH LABORATORY

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INTRODUCTION

The coal combustion research activities currently being carried out at the Canadian Combustion Research Laboratory (CCRL) are part of the Minerals and Earth Sciences (MESP) Program administered by the Canada Centre for Mineral and Energy Technology (CANMET) on behalf of Energy, Mines and Resources Canada. These activities form part of a national energy R and D program which encompasses a wide range of research, development and demonstration-scale projects, with major emphasis on techniques to optimize the burning of Canadian coals under environmentally acceptable conditions.

The majority of coal combustion research projects are related to the improved utilization of coal in conventional pulverized-fired boilers and kilns, the use of coal-liquid mixtures CLM as alternate fuels in combustion equipment designed for oil firing; and efforts to accelerate the application of fluidized-bed combustion systems for low-grade coal.

CONVENTIONAL COAL COMBUSTION RESEARCH

The Canadian utilities and industry are rapidly converting from premium liquid fuels to indigenous often low-grade coals in response to federal initiatives to achieve oil independence and energy security under the National Energy Program (NEP). In addition, Canadian coal companies are vigorously attempting to secure a reasonable share of the world market often with newly developed thermal coals of unknown quality and performance. Consequently, these activities have resulted in a collaborative government/industry combustion research program under the CANMET Minerals and Earth Sciences Program, Energy Technology Activity. The objectives of this program are as follows:

1. To develop new or improved techniques for efficiently utilizing pulverized coal and renewable fuels as a substitute for oil in industrial processes.
2. To define and optimize the combustion performance of low-grade coals from new mines or waste materials in pulverized-fired combustion systems.
3. To promote the development, and where feasible, the implementation of coal-liquid mixtures (CLM) as a substitute fuel for oil in existing oil-fired equipment and as an alternative to direct coal firing in other combustion equipment.
4. To conserve and improve the use of fuel oil through operational and design modifications to industrial combustion systems.
5. To keep abreast of national and international combustion R and D and where appropriate, to participate in joint R and D and D projects relevant to Canadian needs.

6. To minimize the environmental effects of the increased use of coal in industrial and utility combustion systems.

Two pilot-scale combustors have been installed at CCRL to conduct coal combustion R and D to meet the above objectives. The membrane-wall pilot-scale research boiler shown in figure 1 is equipped for pulverized coal firing and incorporates two opposed in-shot burners which can be located at several points on a U shaped combustion chamber to vary residence time for low reactivity coals. Rated at 2.5 GJ/h (0.7 MW), the boiler generates 800 kg/h of steam at 690kPa. The coal supply is supplied from a 4.5 tonne hopper mounted on electronic weigh scales, through a variable speed worm feeder to a ring-roller pulverizer with a variable classifier. Secondary air can be supplied to the coal burners at any temperature up to 260°C.

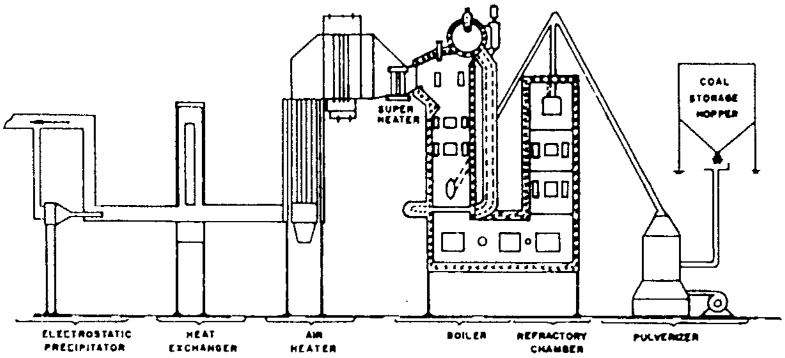

Figure 1 - Illustration of CCRL pilot-scale boiler

The tunnel furnace consists of 28 parallel-connected calorimeters which form a cylindrical combustion chamber 1 metre in diameter and 4.25 metres long. Each calorimeter is part of a coolant circuit containing a flow control valve, a variable area flow meter, and inlet and outlet thermocouples. An axial slot, located along the entire wall of the furnace, allows the use of IFRF combustion probes to measure flame and heat transfer parameters. The furnace is rated at 3GJ/h (.8 MW) and is equipped with an IFRF variable swirl burner. The coal supply is that used for the CCRL pilot-scale boiler. In order to study low reactivity coals in the tunnel-furnace one or two refractory-lined 1 m diameter extensions to the burner front-wall can be added.

CCRL, through the MESP, has made a commitment to develop non-intrusive probing techniques to be applied to the combustion environments encountered in the pilot-scale equipment. These techniques include laser doppler anemometry (LDA) for gas velocity and particle size distribution and coherent anti-stokes Raman spectroscopy (CARS) for gas temperature and species concentration. The LDA set-up will be a four beam two-component system using frequency shifting for flow reversals. The visibility parameter will be used for the particle size distribution. The CARS equipment will include a doubled Nd-YAG laser and a broadband dye laser in a collinear BOXCAR arrangement. The shape of the spectra of the Q branch vibrational transitions of nitrogen will be used to measure gas temperatures. A holographic grating and diode array detector will be used on the detection side. These laser tools will be made fully portable for use in a variety of experiments. Both laser probes will be used in the drop furnace to study the axial variation of temperature, concentration and velocity profiles. The probing techniques can handle turbulent measurements and so can be used in flame studies in the tunnel furnace. Finally LDA will be used to study swirl phenomena in industrial-scale burners.

A controlled mixing history furnace has been installed at CCRL to study coal reactivity and ignition phenomena. With this furnace it will be possible to simulate heating rates of 10^4K per second and residence times of up to 2 seconds. Various stages of burn-out can also be simulated. Two types of experiment can be conducted with this furnace; the reactivity of coals can be determined at different heating rates and different residence times and pyrolysis and combustion mechanisms of coal can also be studied. This information together with bench-scale data on differential thermographic analysis (DTA) and thermogravimetric analyses (TGA) is expected to lead to a better understanding of non-reactive coal combustion performance in large scale equipment.

FLUIDIZED BED COMBUSTION

Fluidized-bed combustion research at CCRL is carried out in support of a national FBC demonstration program through contract R and D and in the laboratory.

A laboratory-scale FBC with a diameter of 10 cm has been built to screen various Canadian coals. In addition, it is anticipated that the unit can be used to develop a test to estimate the relative reactivity of poor quality coals in anticipation that the test could have general validity for large scale FBC.

A 5 cm diameter laboratory-scale FBC has been built to test various Canadian limestones to both measure their relative effectiveness as sulphur sorbents and to develop information to be used in predictive models for sulphur capture in industrial-scale equipment.

A laboratory-scale recirculating FBC is also being designed. This will be used to study the effectiveness of various Canadian limestones in capturing vanadium and nickel when they are used as sulphur sorbents with petroleum coke from the refining of heavy bitumen (tar sands).

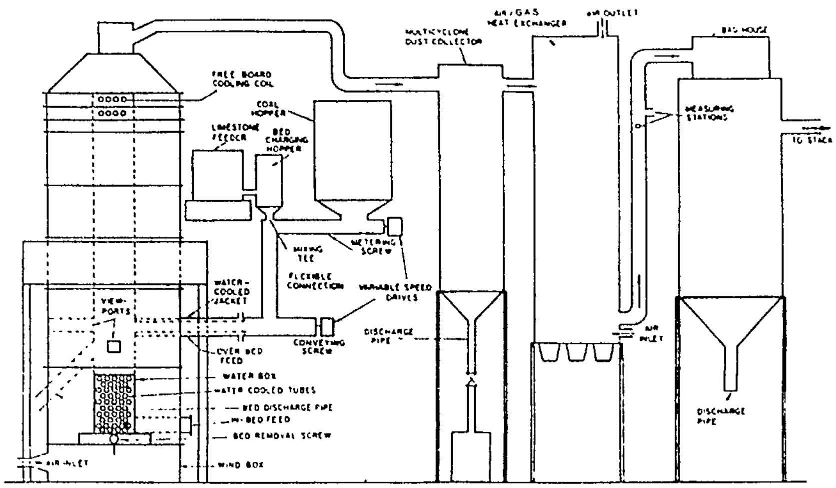

Figure 2 - Schematic diagram of CCRL AFBC

A 380 by 410 mm AFBC, 3.5 GJ/h (1MW) thermal input was built to study the performance of Canadian coals and limestones. The current test program includes research on the performance of two Nova Scotia coals and petroleum coke. The first two are high sulphur bituminous coals which will be utilized in the first industrial FBC in Canada at CFB Summerside and the petroleum coke is high sulphur (.8%). A schematic of the CCRL AFBC unit is shown schematically in Figure 2.

INDUSTRIAL UNITS

A series of exploratory combustion tests were carried out with petroleum coke in an atmospheric recirculating fluidized bed (ARFBC) at the combustion test facility at the Hans Ahlstrom Laboratory in Finland with Swedish limestone as the sulphur sorbent. The program was designed to generate information on combustion efficiency, sulphur and vanadium capture, using a Canadian limestone from the Athabasca region which could then be used to design an industrial ARFBC to burn petroleum coke for process steam at the refinery site.

A pilot-scale AFBC of similar design to that of CCRL has also been built at Queen's University, Kingston. This unit together with a half-scale cold model and a circular cold model used for elutriation studies, is being used to generate data for the development of mathematical models of coal combustion, and fundamental studies on the behaviour of various Canadian coals and limestones in FBC's. The behaviour of large single particle (5 cm) is also being studied at Queen's Unversity using a 10 cm diameter laboratory-scale FBC.

A contract has also been let to provide a detailed design for an ARFBC at CCRL. This unit would be used to complement the existing AFBC facility for research on Canadian fuels and limestones.

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