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ABSTRACT

The Canadian demand for thermal coal is expected to increase by 35% to about 10 million tonnes over the next 20 years. Most of this coal is targetted for electricity production and the major thrust of Canada's advanced combustion programs is directed toward increasing energy conversion efficiency, reducing environmental impact and improving the economics of coal burning. Utility-scale demonstrations and mission-oriented research projects, now in progress, include work on staged flames, circulating fluidized-beds, coal-liquid mixtures and suppression of NO_x/SO_x emissions. Fundamental studies are being conducted on coal reactivity, ash slagging mechanisms, laser probing of flames and furnace modelling.

INTRODUCTION

In 1983, over 90% of the thermal coal burned in Canada was used for electricity production, with the balance being used for space and process heating. By the year 2005, forecasts indicate that domestic coal demand will increase by 35% to about 60 million tonnes, with thermal coal imports, currently about 9 million tonnes, gradually declining.

It is anticipated that most of the future coal demand will continue to be burned in conventional pulverized-fired utility boilers. However, a substantial portion of the increased production will probably be used to fuel emerging technologies such as fluidized-bed and coal slurry combustion systems.

This paper reviews briefly Canada's coal reserves and markets and gives an overview of federal priorities and activities in advanced coal combustion.

COAL RESERVES

Canada's abundant coal reserves, Table 1, are sufficient to meet all domestic and export requirements for the foreseeable future (1). Thermal coal production, 92% of which was surface-mined in western Canada, reached about 36 million tonnes in 1984. Exports of thermal coal, mostly to the Pacific Rim amounted to 4 million tonnes and thermal imports into central Canada from the United States exceeded 11 million tonnes.

The rank and quality of commercially-available Canadian thermal coals are shown in Table 2. Virtually all of the lignitic, sub-bituminous and eastern bituminous coals are supplied to pithead or regional electrical utilities, whereas the western bituminous coals are mined primarily for export.

TABLE 1

COAL RESERVES AND THERMAL COAL PRODUCTION
1984

Region	Rank*	Coal, 10^6 tonnes			
		Recoverable	Production	Export	Import
Atlantic	hvb	463	3,1		
Central	hvb				11,7
Prairie	lig	1697	9,9		
	sub	918	15,4		
Foothill	hvb	272	7,7	4,0	
Mountain	lvb/mvb	2337			
Pacific	hvb/sub	581			
Total		6268	36,1	4,0	11,7

TABLE 2

QUALITY OF COAL RESERVES

Region	Rank*	Proximate Analysis, % wt					HHV, MJ/kg
		M	VM	FC	A	S	(moist basis)
Atlantic	hvb	1-8	29-36	40-62	3-25	1-10	24-33
Prairie	lig	30-35	26-31	29-32	6-13	,4-,6	14-17
	sub	19-25	24-34	31-40	6-20	,2-,6	16-20
Foothill	hvb	7-16	27-36	37-47	8-25	,2-,5	19-26
Mountain	mvb	6-8	21-27	45-55	20-30	,3-,5	21-26
	lvb	1-5	9-23	55-60	15-20	,3-,4	30-31
Pacific	hvb	6	33	46	14	1,1	26
	sub	23	24	21	32	0,4	12

* hvb = high-volatile bituminous
mvb = medium-volatile bituminous
lvb = low-volatile bituminous
sub = sub-bituminous
lig = lignite

ENERGY ISSUES

Canada is a large and relatively unpopulated country richly endowed with a variety of energy supply options: oil, gas, uranium, wood and water as well as coal. As a result coal's role in the energy economy differs in importance throughout Canada. Over 14% of the total primary energy demand is supplied by coal but this figure ranges from almost 0% in provinces like British Columbia, Manitoba and Quebec whose primary source of energy is hydro electric through to Alberta and Saskatchwan where over 20% of primary energy demand is supplied by coal at the mine mouth. Ontario, the nation's largest coal consuming province located over 2,200 kilometres from 90% of Canada's coal resources, has an energy policy which calls for a combination of its indigeneous resources of hydro and uranium plus coal imported from both the United States, for reasons of distance, and western Canada to service its electrical generating needs. In Atlantic Canada, with 10% of Canada's coal resources, the sulphur content of this high volatile bituminous coal as well as the increased cost associated with underground mining have inhibited maximum domestic utilization of this energy resource. In 1980, for example, oil supplied nearly 50% of the elctric power produced in this region.

Canada is also an exporter of both thermal and coking coal with 40% of its total production exported in 1984, representing over $1.8 billion in revenues. With about 11,000 persons employed by the coal industry, the development of this resource represents not only an important source of energy for Canada but also contributes significantly to the country's economic growth (2).

In this context, the federal government's role with regard to coal has focused on the continuance of a healthy coal industry as a contribution to economic and regional development objectives; concern for the environmentally safe use of coal to meet long term environmental objectives; and on ensuring an increased use of coal, as an abundant energy resource, to meet domestic energy objectives related to energy security and independence (3).

COMBUSTION PROGRAM STRUCTURE

The federal Department of Energy, Mines and Resources (EMR), the lead agency involved in funding and encouraging advanced coal combustion initiatives in Canada, sponsors a broad range of activities directed at expanding the use of Canadian coals in both domestic and export markets and operates national combustion research facilities.

The Canada Centre for Mineral and Energy Technology (CANMET), the Department's research and development arm, is responsible for carrying out a comprehensive coal combustion program in response to national energy strategies and industry needs. Major features of the CANMET program include joint projects with outside organizations to accelerate technology transfer, contract research to complement in-house projects, and support of proposals to foster fundamental research at universities.

The Coal Division, which addresses Departmental coal policy issues, administers the Coal Utilization Program with CANMET scientific support. This Program was initiated in 1980, primarily in response to the high proportion of oil in Atlantic Canada's energy mix with its indigenous source of high-sulphur coal, to identify, select and assist in the demonstration and commercialization of improved or new, efficient and environmentally sound coal combustion technologies.

Both the CANMET Coal R&D and the Coal Division Coal Utilization Programs are closely interfaced to ensure an effective, systematic transfer of research results into practical applications. Projects are reviewed quarterly and modified as necessary to reflect evolving needs in energy utilization.

COMBUSTION RESEARCH, DEVELOPMENT AND DEMONSTRATIONS

Priority research, development and demonstration projects, now in progress, for efficiently burning coal with minimal environmental impact

are broadly classified into four combustion technologies - pulverized-fuel, fluidized-bed, slurry firing and pollution abatement.

Pulverized-coal Firing - Research and development in pulverized-coal firing is directed toward the expanded use of coal for both electricity production and for large industrial process and space heating applications. Current EMR projects, many of which are cost-shared with industry, involve studies to:

a) delineate the combustion behaviour of coals from newly-opened mines,
b) determine the feasibility of using coal as a replacement fuel in oil- and gas-fired furnaces and
c) identify possible problems associated with switching from a design coal to an off-specification coal in existing equipment.

A research boiler, capable of duplicating or closely simulating utility furnace operating conditions, is used for evaluating the combustion performance, the ash slagging and fouling propensity and the emission potential of low-quality coals earmarked for pithead generating stations. High quality coals or coal blends destined for export are also evaluated. The boiler, which is rated at 0.7 MWt input, has two roof-mounted burners that can be located to provide extended residence times for improved carbon burn-out of non-reactive, high-ash or high-moisture coals. Auxillary equipment includes a coal drying and blending system, a conventional air preheater, ash deposition probes, continuous flue gas monitoring instruments and an experimental electrostatic precipitator (4).

Studies, using controlled burner aerodynamics to generate stable flames with specific geometries and heat transfer patterns from various coals, are being conducted in a horizontal calorimetric furnace (5). Coal input rates can be varied from 0.4 to 0.7 MWt with a single burner. Data from this furnace are being applied to conversions of industrial furnaces and

kilns from oil to coal and to the validation of a complex computer model for predicting the combustion efficiencies and heat absorption characteristics of flames from coal properties (6).

A catalogue of the combustion and flame properties for a number of Canadian coals, that have been evaluated in the two pilot-scale combustion rigs, is being compiled with the first report of a series scheduled for publication in 1987.

Fundamental research associated with suspension burning of coal includes projects on the role of coal macerals on combustion reactivity, the slagging propensity of ash minerals in lignite, and the development of a laser probing system for non-intrusive flame measurements of temperature and specie concentration. These projects, which are structured to support the applied research effort, have long-term objectives.

The pulverized coal research has demonstrated that (a) a significant deterioration in flame stability and combustion efficiency occurs when furnaces designed for high-quality coals are fired with coals containing over 50% inert macerals or 35% ash and (b) judicious blending with higher reactivity and higher ash-fusion coals can minimize these deficiencies while at the same time avoiding the possibility of ash slagging and poor precipitator performance. Recent pilot-scale studies have been used to generate furnace design criteria and fuel specifications for a 500 MWe boiler capable of burning lignite with a calorific value of 14 MJ/kg.

Coal Slurry - To reduce Atlantic Canada's dependence on off-shore oil, a series of projects has been initiated to demonstrate the feasibility of using coal-liquid mixtures as a replacement fuel in oil-fired utility boilers and process kilns (7). One project embraces the deep cleaning and stabilization of a high-volatile coal from eastern Canada in a water slurry. Another deals with the development of an abrasion resistant, burner atomizer for slurry burning by the National Research Council of Canada.

A third involves three stages: a modelling study to identify the potential de-rating of an oil-fired boiler when coal/water fuels are burned; an evaluation of the ignition, flame stability and heat transfer properties of newly-developed slurry fuels; and the conversion of iron-ore induration and cement-making kilns from oil to slurry firing.

Field trials in a 22 MWe corner-fired and a 12 MWe front-wall-fired utility boiler have demonstrated that superfine (85% < 200 mesh), high-volatile coal, blended with 30% water, can be burned successfully. Refractory quarls were necessary for stable ignition and wide-angle, fuel sprays with high momentum were necessary to minimize high carbon carry-over. Work has also recently started on defining the rheological and combustion properties of a water slurry being formulated with a low-volatile, low-swelling Canadian coal under a joint Federal Republic of Germany/Canada Science and Technology Agreement and on evaluating the flame characteristics of several slurries prepared by different beneficiation techniques under an International Energy Agency (IEA) Agreement.

Fluidized-bed Combustion - Fluidized-bed combustion is viewed as an important technology option for expanding the use of thermal coal in Canada, because of its potential for reducing NO_x and SO_x emissions and its relative insensitivity to swings in coal quality.

Two full-scale boiler projects have been funded by EMR to demonstrate the feasibility of burning high-sulphur coals with low emissions. The first, a 15 MWt bubbling or conventional fluidized-bed (BFB) heating boiler at the Summerside Canadian Armed Forces base in Prince Edward Island is being fired with a 5% sulphur coal blended with limestone (8).

The BFB plant is performing at rated load and the SO_x, NO_x, smoke and particulate emissions are well below Canadian guidelines for new sources. During the 1985/86 heating season, the boiler performance while burning other coals and sorbents, will be explored. The second project,

a 22 MWe circulating fluidized-bed (CFB) utility boiler is being designed to co-fire a 7% sulphur coal with local low-grade oil shale at Chatham in New Brunswick. Sulphur oxides will be neutralized by utilizing limestone in the oil shale and by adding extra limestone as required. NO_x emissions will be controlled by the low (850°C) combustor temperature and by staging the combustion air. This facility is under construction and commissioning is scheduled for late 1986. A two-year experimental program, designed to provide reliable data on both the costs of electricity production and the operational flexibility of this technology, will be carried out during 1987 and 1988.

Research to optimize the performance of selected fuels, sorbents, operating conditions and heat transfer materials is proceeding in the following areas:

a) corrosion behaviour of in-bed cooling tubes during 10,000 h pilot-scale BFB studies. Preliminary metallurgical examinations of tube specimens after 8000 h exposure, indicate that erosion is the dominant mechanism of wastage for cooled ferritic alloys and that high-corrosion rates are being experienced by uncooled austenitic steels. Cooled austenitic steels have been unaffected by the bed environment.
b) determination of the combustion properties of different rank coals in pilot-plant experiments
c) mathematical modelling of BFB operating parameters
d) characterization of sulphur capture efficiency by Canadian limestones in BFB and CFB bench-scale reactors
e) construction of a CFB pilot-plant rated at 100 kg/h of coal to complement the 22 MWe demonstration project and to optimize operating parameters for low-reactivity coals; and
f) utilization of spent sorbent from fluidized-bed combustors.

Abatement of Acid Rain Emissions - This project is directed toward control of NO_x and SO_x emissions from pulverized coal flames by combustion process modifications. It includes fundamental and applied research elements as well as full-scale demonstrations.

Canada, under an IEA Agreement with Sweden and Denmark, is co-funding a three-phase investigation of staged flames for suppressing NO_x and SO_x during combustion. Phases I and II, now completed, identified the overriding role of fuel nitrogen in producing NO_x emissions and established that burner air staging with limestone injection can be used to reduce substantially acid gas emissions. Stage III, if implemented, will involve validation trials in an operating boiler with a staged burner concept developed by the US Environmental Protection Agency.

A low NO_x/SO_x burner design that has been the subject of extensive research in Europe and the United States is being demonstrated in Eastern Canada. Two burners, each rated at 12 MWt, are retrofitted to a hot water, heating boiler and commissioning trials with a 3% sulphur coal are in progress. Preliminary results indicate that NO_x and SO_x emissions have been reduced by 50% with no change in boiler efficiency. Other coals and sorbents will be evaluated during the 1985 and 1986 heating seasons (9).

EMR also contributes to two low NO_x/SO_x combustion studies being sponsored by the Canadian Electrical Association, a consortium of electrical utilities. One study, which addresses burner/furnace staging with limestone injection in a 300 MWe, corner-fired boiler, has resulted in SO_x reductions of up to 40% and NO_x reductions of 50% while burning a 0.5% sulphur lignite (10).

The second involves a 6 MWt slagging combustor in which both SO_x and NO_x are prevented from forming in the reducing zone of the multi-staged burner. Trials with a sub-bituminous coal indicate that over 60% sulphur capture without limestone addition, and NO_x levels below 150 ppm are achievable.

CLOSURE

Canada's advanced coal combustion activities are directed toward encouraging and expanding the use of coal in the primary energy mix. Improvements in coal utilization, energy recovery, equipment reliability and environmental control are being addressed, and a selected range of technology options is being examined through an integrated program of research and development, technology transfer and commercial demonstrations.

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