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FUTURE TECHNOLOGY NEEDS FOR CANADIAN FOSSIL FUEL DEVELOPMENT

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Output for the Canadian mineral industry was valued at $33.9 billion in 1986; $10.8 billion less than in 1985. The fuel sector, including crude petroleum, natural gas and coal accounted for most of this decrease because of the decline in demand for these resources (The Canadian Mineral Industry Monthly Report, EMR, December 1986). In spite of this somewhat downward trend with respect to Canadian fossil fuel resources, it is generally acknowledged that Canada will increasingly depend on high molecular-weight fossil fuels - oil sands, heavy oils, coal - supplemented with natural gas, for its future energy needs.

In October 1986, the National Energy Board projected Canadian energy supply and demand to the year 2005, assuming that overall awareness of energy conservation will continue and that energy demand will grow less rapidly than the overall growth rate of the economy. A continued shift off oil is projected with its use being increasingly confined to the transportation sector. At the same time the proportion of natural gas and electricity in total energy use is increasing. The NEB noted that conventional crude oil constitutes only 10% of Canada's oil resource base (half in Western Canada and half in frontier regions). The remainder constitutes bitumen.

Thus, a key question is: "What engineering requirements will be needed to develop the new technologies required for the production of liquid fuels from non-conventional sources". Also, the increasing shift to electricity by industry will underline the clean use of coal as a primary energy source for which new technologies are also required.

A set of fundamental questions remains, the answers to which are the subject of debate but which make the prediction of future requirements just that - a prediction. Examples are:

- How much light oil is really left and how long will it last?
- Will liquids be made from coal in Canada?
- How much primary energy (electricity) will be nuclear-based?
- What is going to be done about acid rain, depletion of the ozone layer, and CO_2 and the "greenhouse" effect?
- How will we react to another oil embargo?

This paper does not attempt to debate such issues but to describe developing technologies which are providing new engineering challenges. Development of many of these was accelerated after the 1973 Arab oil embargo and when it was recognized that coal-derived energy has to be extracted cleanly. Also, the paper catalogues fossil energy development programs at the Energy

Research Laboratories, Canada Centre for Mineral and Energy Technology (CANMET), Energy, Mines and Resources Canada.

To clarify these technologies they are considered in two groups, i.e., production of liquid fuels and advanced coal-to-electricity processes.

Production of Liquid Fuels

Declining western North American conventional crude resources dictate the following possible optional supply sources:

- frontier (North Slope; Beaufort; Hibernia);
- oil sands mining and upgrading;
- heavy oil enhanced recovery and upgrading;
- single and two-stage coal liquefaction;
- bitumen/heavy oil and coal coprocessing;
- oil shales.

In the context of the above list the upgrading of synthetic crudes has presented a particular opportunity for Canadian technology. The NEB Canadian Energy 1985-2005 Supply and Demand Forecast in its high oil price scenario ($27 US in 1986 dollars as opposed to $18 US in the low price case) allows for the construction of two upgraders in addition to that now under construction in Saskatchewan.

The CANMET Hydrocracking Process, which uses a low-cost additive, comprising coal impregnated with an iron compound has been demonstrated in a 5000 BPD demonstration unit at Petro-Canada's Montreal refinery. More than 50000 h of pilot plant operations at CANMET's Energy Research Laboratories proved that remarkably high conversion rates can be achieved for a wide range of feedstocks including oil sands, heavy oils, and refinery residua. The key was the low-cost additive which inhibited coke formation in the reactor. Results from the 5000 BPD unit both in the hydrovisbreaking and hydrocracking modes have been encouraging. Partec Lavalin (Calgary) is actively marketing this advanced technology.

Continuing technological development such as coal liquefaction could improve the economic feasibility of the supply sources. However, conventional wisdom in Canada at present seems to preclude coal liquefaction as an option although the opportunity exists for using Canadian coals in emerging two-stage coal liquefaction technology in Japan.

Intermediate between heavy oil upgrading and direct liquefaction is the coprocessing of coals with bitumen/heavy oils/residua, which eliminates the need for costly recycle solvent common to all direct liquefaction technologies. Special opportunities exist in Canada which may make the coprocessing route attractive, especially when high-sulphur heavy crudes and low-rank coals occur in close proximity in Western Canada. High-volatile Eastern Canadian bituminous coals present greater difficulties. A technical and economic evaluation of synthetic crude oil production using coprocessing technology has just been completed for CANMET. Under the terms of the study, CANMET hydrocracking is always superior to coprocessing. However, strong evidence suggests that given the right set of circumstances, coprocessing could be a viable Canadian option. A 2 BPD pilot plant is in the final stages of construction at CANMET and other interests are actively promoting different coprocessing routes with Canadian applications.

Upgraded heavy fossil fuels require further upgrading (hydrotreating) to make refinery-acceptable feedstocks. Programs are underway to develop new catalysts to hydrotreat synthetic crude distillates, e.g., to make octane enhancers, which will be required as lead is phased out of motor gasoline. Also, a key issue in the economics of any upgrading process is pitch utilization. Options being looked at include asphalt blending, gasification and combustion especially using circulating fluidized bed technology.

Oil shales, e.g., from New Brunswick do not seem to be an attractive source of liquid fuels under current world oil prices. However, the New Brunswick Research and Productivity Council in Fredericton is maintaining a program on oil shale pyrolysis.

A discussion on future sources of liquid fuels would be incomplete without mentioning natural gas. The goal is to convert natural gas to a liquid fuel directly rather than through the traditional route of reforming to carbon monoxide and hydrogen followed by Fischer-Tropsch synthesis, a process which is not energy efficient because of the endothermic-exothermic reaction sequence.

Coal to Electricity

Although the future for heavy oils and bitumens in Canada remains bright in terms of liquid fuels, the fossil fuel business, for example in terms of coke from metallurgical coals for ironmaking will increasingly feel the competitive threat of electrotechnologies. Electricity is expected to take a greater share of the energy demand but, in the context of the present discussion, coal will retain its place as a source of primary energy for electricity production. The engineering challenge is to obtain higher energy conversion efficiencies and to burn coal cleanly.

Of the advanced power generation schemes which use coal for fuel, the integrated coal gasification combined-cycle (gas plus steam turbines) system is considered one of the most important for the future. Such systems are flexible in terms of coal feed, they have a high efficiency rate (about 43%) and are envisaged to have a high unit capacity (250 MWe). The Southern California Edison Cool Water Program is demonstrating the ability to fire a medium-BTU gas in a 65 MW unit that normally runs on natural gas. One Western Canadian utility company is actively pursuing developments in this technology.

Another combined-cycle power generation option is to use a coal-fired pressurized-fluidized bed on the front end of the system. The advantage of a PFB system operating at, say, 10 atm, is that of small plant size compared to an equivalently sized pulverized-fuel fired system.

The clean use of coal requires the elimination of emissions of sulphur dioxide and nitrogen oxides. Whereas sulphur removal can be assisted by coal preparation prior to combustion or by flue-gas scrubbing after combustion, progress is being made in the efficient burning of coal with minimum environmental impact using bubbling and circulating fluidized bed combustion and staged-mixing (low-NO_x) burners. The use of coal-water mixtures permits the substitution of heavy fuel oil particularly in industrial applications such as cement kilns and small boilers.

A 20 t/h steam heating boiler has just come on stream at Canadian Forces Base, Summerside, PEI, burning 3% sulphur coal with limestone. NO_x and SO_x have been reduced to more than 90% and 50% respectively of a comparable pulverized-fuel system at a combustion efficiency of over 99%. A 22 MWe circulating fluidized bed is in the start-up phase at Chatham, New Brunswick, to burn 6% sulphur coal co-fired with oil shale to use its heat value and limestone as sulphur absorbent (90% sulphur removal at a Ca/S ratio of 1.5). Also, staged-air injection should give NO_x emissions of less than 200 ppm. Smaller scale FBC and CFB (50 kg coal/h and 100 kg/h, respectively) are also available at CANMET/EMR for cost-recovery work.

A 50% NOx/SO_x reduction has been achieved with 3% sulphur coal in a staged-mixing burner retrofit demonstration at Canadian Forces Base, Gagetown in New Brunswick. TransAlta Utilities in Alberta plan to retrofit a 30 MWe boiler with Rockwell/TransAlta slagging low-NO_x burners (based on a rocket engine principle) to burn subbituminous coals. Pilot-scale research has indicated that 65% sulphur reduction and NO_x levels below 150 ppm are attainable with no sorbent using Alberta subbituminous coal. A 300 MWe burner at Saskatchewan Power Corporation's Boundary Dam Power Station has been retrofitted for staged combustion with limestone injection to give 40% NO_x/SO_x reduction with 0.7% sulphur lignite. The latter project is sponsored by the Canadian Electrical Association.

Coal-water slurries, as a substitute for oil, are being tested at Maritime Electric's Charlottetown power station to assess combustion performance. A major problem has been burner wear, for which a superior CANMET-designed burner using a ceramic nozzle developed at the National Research Council is being tested. A coal-water mixture is now being used by a Western Canada cement company to fire cement kilns instead of using more costly natural gas.

Concluding Remarks

Fossil fuels (bitumens, heavy oils, or coal) will continue to contribute to Canada's transportation fuel requirements and also to the primary energy mix. New technologies are being developed to extract and process synfuels and to burn coal cleanly. These technologies will provide new and challenging engineering opportunities. Aspects of the future lend themselves to crystal ball gazing. How long will reserves of light and medium conventional crudes last? Will nuclear power regain momentum? If, or when, there is another oil shock within the next few years, will we be ready? Should more emphasis be placed on natural gas based technologies for Canada's future energy requirements?