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CANADIAN INITIATIVES IN COAL-LIQUID MIXTURE COMBUSTION AND DEVELOPMENT

Horace Whaley
Canadian Combustion Research Laboratory

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Canadian Combustion Research Laboratory
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The Canadian National Energy Program (N.E.P.) and the recently negotiated oil pricing agreements between the major oil producing provinces have established that the cost of fuel oil in Canada will rise substantially in the next few years. This fact, together with the removal of fuel-oil subsidies, has caused considerable interest in coal-liquid mixtures (CLM) as an alternative to fuel oil in industrial and utility applications where conventional coal and natural gas are not feasible.

This paper describes current initiatives being undertaken by Energy, Mines and Resources Canada under the N.E.P. to develop and demonstrate coal-water slurry fuel combustion technology in utility boilers. In addition, the CLM technology support role of the Canada Centre for Minerals and Energy Technology, CANMET, will be detailed, together with a description of the Atlantic CLM working group and International Energy Agency (I.E.A.) activities.

Introduction

The interest in coal-liquid mixtures (CLM) as potential oil replacement fuels has been continuing in Canada since the early part of the seventies. The initial work begun in Energy, Mines and Resources Canada's CANMET laboratories which led to R and D and contract activities which have been described at the previous COM symposia and elsewhere, see Whaley (1,2,3,4). The motives for this interest are apparent, the rapidly rising cost of crude oil coupled with an insecurity of supply, both of which have caused the western industrialized nations to seek feasible alternatives for petroleum-based derivatives. For the past few years, Canadian industry has been somewhat sheltered from the direct impact of escalating oil prices by an oil subsidy program which resulted in the domestic cost of crude oil being about half that of the world market price. However, this picture is in the process of change with the announcement of the November 1980 National Energy Program (5) and the recently negotiated oil-pricing agreements between the federal government and the major oil-producing provinces. Thus, the driving force to seek alternatives to petroleum-based liquid fuels will be intensified by the above measures, which will progressively raise the price of crude oil by more than fourfold over the next decade.

BACKGROUND TO FEDERAL GOVERNMENT INITIATIVES

Energy, Mines and Resources Canada has identified coal-liquid mixture technology development as a priority for funding under the National Energy Program (N.E.P.). Specifically these developments fall into three main areas:

(1) Coal/water slurry fuels for utility boiler applications
(2) Coal-liquid mixture fuels for industrial applications
(3) R and D support to CLM technology development

As mentioned in previous status reports by the author (2,3,4) the maritime provinces of Canada (that is Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick) are particularly dependent on offshore oil. Therefore it is specifically to this region of eastern Canada that the Special Atlantic Initiatives sub-program of the National Energy Program is addressed. The major objective of the sub-program is to assist the power utilities in the maritime provinces to convert from fuel oil to alternative fuels wherever it

proves to be feasible. The development of coal/water slurry fuels for utility boilers is being funded under the Special Atlantic Initiatives Sub-program and the technical and economic feasibility of converting utility boilers greater than 100 MW(e) to coal/water slurry fuels will be determined during the course of the next three years.

Although not as well advanced, a similar initiative is being developed to apply CLM technology to industrial boilers. It must be noted here that COM's or any hybrid fuels containing fuel oil have generally been ruled out for utility application in Canada but this is not the case for industrial applications. This latter activity and the R and D support of CLM technology will not necessarily be restricted to the maritime provinces under N.E.P. funding.

Useful background reports which describe the various coal substitution technologies and R and D on coal in the maritimes have been prepared by the Atlantic Coal Institute of Sydney, N.S. (6) and the New Brunswick Research and Productivity Council (7).

Coal/Water Slurry Fuels for Utility Boiler Applications

A major initiative under the N.E.P. has been undertaken by Energy, Mines and Resources Canada which will establish the feasibility of utilizing coal/water slurry fuels in utility boilers that are currently using fuel oil and cannot be readily converted to alternative fuels. It is envisioned that the greatest potential for coal/water fuel relates to fuel-oil substitution in boilers that are not originally designed for conventional coal combustion. The coal policy group of the department has initiated N.E.P. funding support for the four following main activities:

(1) Process selection for coal/water slurry fuel preparation.
(2) Burner development for front-wall and tangentially (corner) fired boilers typical of Canadian utility practice.
(3) Pilot plant construction to produce coal/water slurry fuels.
(4) Demonstration trials in small utility boilers of front wall and tangentially-fired configurations.

It has been mutually agreed that the major coal producer of the maritime provinces, the Cape Breton Development Corporation (C.B.D.C.) and the New

Brunswick Electric Power Commission (N.B.E.P.C.) will collaborate with the department in a three-party agreement to complete the four above-mentioned activities over the next two years.

C.B.D.C. has signed a memorandum of understanding with AB Carbogel of Sweden in November 1981 and jointly these companies will cooperate in the design and construction of a preparation facility for coal/water slurry fuels in Sydney, N.S. This facility will prepare the fuel for the burner testing phase of the program.

The burner development program which will be managed by N.B.E.P.C. will lead to demonstration of coal/water slurry fuels in combustion trials in the front-wall and tangentially fired boilers at Chatham, N.B. The three phases of the program are:

Phase 1: Design, testing and evaluation of a burner rated at approximately 30 GJ/h (thermal input), of a type suitable for coal/water slurry fuel combustion in the 12 MW(e) front-wall fired Chatham Unit No. 1. A testing and evaluation program for the burner together with boiler performance assessment will be developed for the anticipated trials in Chatham Unit No. 1 to be undertaken during Phase II.

Phase II: Installation of four burners and coal/water slurry supply system and completion of about 200 h combustion trials in Chatham Unit No. 1. An evaluation of boiler performance will be conducted, followed by the design, scale-up and testing of a prototype burner for a boiler in the 100 to 150 MW(e) capacity range.

Phase III: Conceptual design of a conversion to coal/water slurry fuel firing of a selected oil-fired design front-wall fired boiler in the maritimes of the 100 to 150 MW(e) generating capacity range.

During the implementation of these three phases a program of similar scope will commence leading to the development of burners for a small tangentially-fired unit. Phase II of this latter program will include combustion trials on N.B.E.P.C. Chatham Unit No. 2, a tangentially-fired unit of 22 MW(e) generating capacity.

In its role of new technology development and support for the coal/water slurry fuel initiatives being undertaken for utility boilers applications, the Canada Centre for Mineral and Energy Technology, CANMET, of Energy, Mines and Resources Canada will provide input to the Technical Steering Committee which coordinates the project. Other participating agencies are shown in Figure 1. It is anticipated that key technical areas will be:

(1) Burner development for slurry fuels
(2) Assessments of potential loss of capacity (derating) caused by switching from fuel oil to coal/water slurry fuels.
(3) Slagging and fouling assessments.
(4) Design parameters for upgrading of environmental control equipment.
(5) Combustion and heat transfer characteristics of coal/water slurry fuels.
(6) Upgrading of coal quality by advanced beneficiation methods.

COAL-LIQUID MIXTURE FUELS FOR INDUSTRIAL APPLICATIONS, R, D AND D

CANMET has a continuing involvement in the research, development and demonstration of coal-liquid mixtures as viable fuels for industrial and utility boilers and process combustors. This involvement generally takes the form of participation in technical steering committees, management of contracts and research into the preparation, combustion and heat tansfer properties of coal-slurry fuels and the demonstration of them in industrial applications. Some of these activities were described by Whaley and others (4,8,9,10) at previous COM symposia; those still ongoing and new projects are shown in Figure 2. Coordination of the Canadian CLM Program takes place through cooperative interaction or technical seminars such as that organized by the Atlantic coal-liquid mixtures working group (11). Canada is also involved with other countries in many of the activities related to the International Energy Agency (I.E.A.) coal-liquid mixtures cooperative agreement.

Scotia Liquicoal

The Scotia Liquicoal coal-oil emulsion preparation facility located in Dartmouth, N.S., incorporates two developing Canadian technologies. The feed coal is beneficiated, using the National Research Council (N.R.C.) spherical agglomeration process, (4,12) after being milled to about 15 μm mean diameter in a Szego mill developed by General Comminution Inc. of

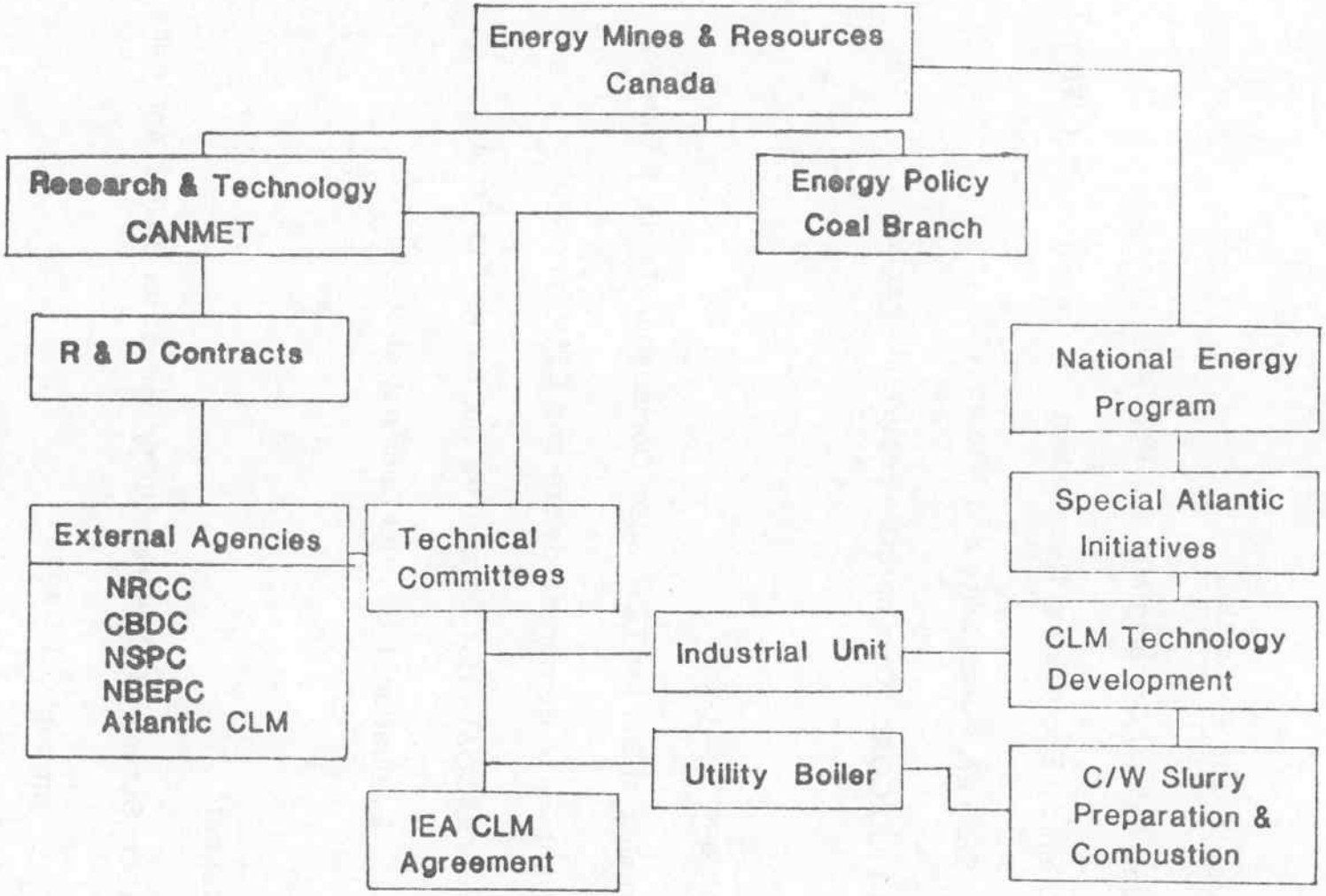


Figure 1. Agencies involved in Canadian coal liquid mixtures program.

CLM Preparation and Properties

GCI Szego Orbital Grinding Mill and Rheology

TUNS Chemical Engineering Department Stabilisation of C/W Slurries, Pumpability and Rheology

SCOTIA LIQUICOAL Commercial Preparation Facility

Combustion and Wear

ORF Erosion of Burner Tips, 300h Combustion Trials, 2 Burners

CES Inventory of Burner Hardware and CLM Experience

SCOTIA LIQUICOAL Hot Spray Testing, Burner Tip Erosion, Evaluation, Industrial Demonstration

CLM Potential

MONENCO Survey of Oil-Fired Utility, Industrial Boilers and Kilns throughout Canada

Figure 2. Coal liquid mixtures, R & D activities in Canada

Toronto (9). The Dartmouth facility which will produce about 6 t/h of fuel was developed from scale-up data provided by a small pilot-scale facility operated by Scotia Liquicoal on the premises of the Technical University of Nova Scotia in Halifax, N.S. The project has largely been funded to date by the Canada-Nova Scotia Oil Import Substitution Agreement, administered jointly by Canada and the province to find viable alternatives to fuel oil in Nova Scotia.

At the present time, funding is being provided by the National Research Council, Atlantic Research Laboratories and CANMET to develop a burner which will resist the abrasiveness of the fuel and withstand a 1000 h combustion trial in a 20 GJ/h industrial boiler.

General Comminution Incorporated

General Comminution Incorporated (G.C.I.), a company affiliated with the University of Toronto, Department of Chemical Engineering has undertaken a joint project with CANMET to develop operating data and scale-up information on a small 1t/h Szego orbital grinding mill.

The mill offers attractive advantages in size, power requirements and its ability to grind coal in oil or water to very fine sizes (mean diameter 15 μm). Since the N.R.C. spherical agglomeration process requires very fine coal to give high ash removal, the combination of the Szego mill and the NRC process in the the Scotia Liquicoal project should provide much information on the commercial long-term feasibility of the mill. Having just completed the CANMET project, G.C.I. is now seeking an industrial user for its own commercial feasibility studies.

CENTRE FOR ENERGY STUDIES, TECHNICAL UNIVERSITY OF NOVA SCOTIA

The Centre for Energy Studies (C.E.S.) of the Technical University of Nova Scotia, is in the process of constructing a facility for the combustion testing of CLM burner hardware. This flame tunnel furnace combined with access to two small industrial boilers located near the University, will give C.E.S. and the Atlantic region a much needed combustion test facility for evaluating burner hardware and fuels.

In a collaborative project with CANMET, C.E.S. has been contracted to survey and evaluate commercially available oil-burning equipment and to

assess its potential for CLM combustion. In this review, major oil burner suppliers in both the utility and industrial fields were contacted for the information available on their equipment. In addition those manufacturers known to have experience in handling CLM's were requested to supply such information, whenever possible. The final phase of the project was a review of oil nozzle testing methods for use with CLM fuels. The final report (13) is expected in early 1982, and will be available from CANMET.

Department of Chemical Engineering, Technical University of Nova Scotia

Affiliated with C.E.S., the Chemical Engineering department is involved in the more fundamental aspects of CLM technology such as rheology, pumpability and erosion testing. Initial work in 1979/80 on coal beneficiation and preparation of COM, funded by the National Science and Engineering Research Council, N.S.E.R.C., has led to the development of an accelerated stability testing instrument which has been described elsewhere by Al Taweel (8). Further developments of this method and some of the results are the subjects of two papers at this symposium.

Ontario Research Foundation

The CLM technology development program which has been underway in eastern Canada since 1977 has resulted in some areas of concern as noted by Whaley (4). The major impediment to the acceptance of colloidal fuels by industry in the Maritimes has been the abrasiveness of the eastern Canadian coals used in the test programs, resulting in premature and unacceptable failure of nozzle components, see Figure 3 (14). In order to provide some quantitative data on this problem the Ontario Research Foundation and CANMET have undertaken a joint project to study the erosive behaviour of burner tips when burning CLM made from eastern Canadian coal. Two 300 h combustion tests have been undertaken in a small 10 GJ/h boiler in which a Y jet internal-mix burner of typical design was compared with a highly turbulent externally mixed burner. Both burners were steam atomized and had been tested in previous COM evaluations, as reported by Brandstatter (15). The details of the test program will be reported in another paper at this symposium, but it is sufficient to say that erosion rates are more than halved in the externally-mixed burner when compared to the Y jet burner (16). In addition the test data indicated an initial period of accelerated wear for both burners, occurring within the

first few hours of use. This can be attributed to a "breaking-in" of the nozzles from the polishing action of the coal and ash particles in the fuel.

Atlantic Coal-Liquid Mixtures Working Group

The Atlantic CLM Working Group is a coordinating body for CLM technology developments in the maritimes and was formed in early 1981 to review research proposals before submission to the various funding agencies. The early meetings took the form of informal information exchanges, but later the group organized and sponsored a successful workshop on CLM combustion technology which was held in December 1981 in Halifax, N.S. The working group is comprised of interested participants from the maritime utilities, coal producers, industry, universities and other research agencies as well as CANMET and the coal branch of Energy Policy Sector of EMR. It is noteworthy that this group will provide input to the technical committee of the coal/water project being undertaken by EMR in the Maritimes.

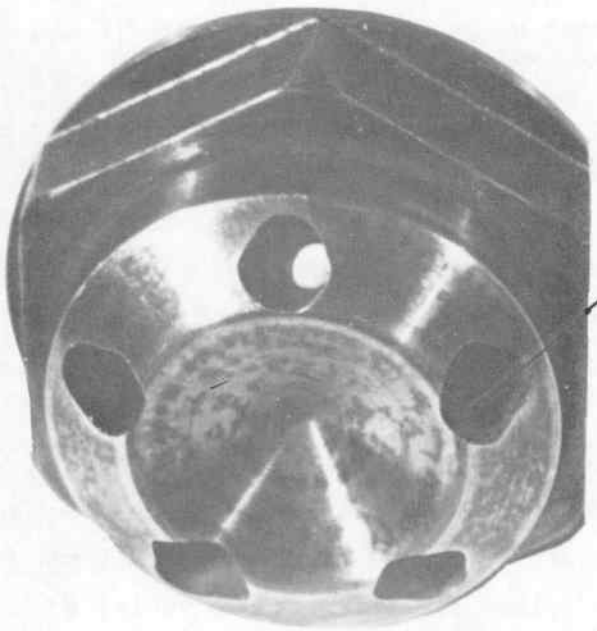
Canadian Combustion Research Laboratory

As part of a continuing involvement in the ongoing CLM projects in Canada, the Canadian Combustion Research Laboratory (C.C.R.L.) of CANMET, will conduct a research program on the flame and heat transfer characteristics of commercial coal-liquid mixtures as they become available in Canada. The first such fuels to be studied will be a typical Scotia Liquicoal product and a coal/water slurry from the coal/water utility development program in the Maritimes. The objectives of the program are:

(1) To determine the aerodynamic requirements for a stable CLM flame;
(2) To evaluate the flame and heat transfer characteristics of the CLM's under controlled aerodynamic and combustion conditions;
(3) To assess the gaseous and particulate emissions produced during the tests; and
(4) To compare the performance of the CLM with No. 6 fuel oil.

The program will be carried out in the C.C.R.L. pilot scale tunnel furnace, maximum thermal input 3 GJ/h and comprised of 28 individual calorimetric sections. Residence time and flame stability can be varied by the addition of an adiabatic pre-ignition section, if necessary. The test procedures and equipment have been described in detail by Friedrich et al (17).

New Burner



After 154h Firing with COM (10-20 % by wt.)

Figure 3. Illustration of Burner Wear by Coal-Oil Mixture.

Tests on the Scotia Liquicoal fuel are scheduled to begin in February 1982 and on the coal/water slurry fuel toward the end of 1982.

INTERNATIONAL ENERGY AGENCY

Canada is a participant in the International Energy Agency (I.E.A.) Coal-oil Mixtures Implementing Agreement. This is a co-operative agreement in which the participating countries agree to technical cooperation and exchange in various annexes dealing with specific areas of CLM technology development. At the present time 5 countries have signed; Sweden, Holland, Japan, U.S.A. and Canada. The U.K. is expected to sign the agreement in the near future.

Annex 1 of the agreement is an assessment within each participating country of the potential for CLM conversions, fuel resources and of support R and D activities. Other annexes that are in the process of development deal with utility and industrial CLM demonstration, R and D base technology support and coal beneficiation/CLM preparation.

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