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ABSTRACT

Eastern Canada is the only region of the country where electricity is generated from oil and it is this region which is most dependent on imported oil. In addition, natural gas is not yet generally available local coal tends to be high in ash and sulphur and in need of upgrading. This scenario has prompted Energy, Mines and Resources Canada, in collaboration with the New Brunswick Electric Power Commission (NBEPC) and the Cape Breton Development Corporation (C.B.D.C.) to undertake a major collaborative initiative in Eastern Canada under the National Energy Program (NEP) to develop coal-water mixture technology for utility boiler application.

The current status of the following main activities of the project are described together with the future potential for CWM's in the Maritime Utility sector:

1) Process development for coal/water mixture fuel preparation.
2) Burner Development for front-wall and tangentially-fired utility boilers.
3) Pilot Plant construction for coal-water fuel preparation.
4) Demonstration trials in a small utility boiler of each configuration at Chatham, New Brunswick.

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INTRODUCTION

Coal-liquid mixtures could replace oil in many stationary combustors and possibly in some mobile uses provided that they can be burned reliably, cleanly, safely and economically. Canada is a net importer of some ten percent of its oil consumption and will become even more dependent on foreign oil unless new ways are found to substitute for the depletion of its limited conventional oil supplies. The chosen approach to reducing reliance on imported oil is a multifaceted one which includes conservation, upgrading of bitumens, heavy oils and residuums and replacement by other indigenous fuels, particulary natural gas and coal. Coal-liquid mixtures (CLM) offer a means of replacing oil by coal where direct substitution of a solid fuel is impossible or economic.

In central and western Canada, natural gas and coal are readily available and can be chosen as replacements for oil depending on price and convenience. However, in eastern Canada, the only part of the country where electricity is generated from oil, natural gas has not been generally available and local coal tends to be both expensive and high in sulfur. The need for oil substitution is thus most urgent where it is most difficult to find an economic substitute.

As the federal government agency responsible for formulating and implementing energy policy for Canada, the Department of Energy Mines and Resources (EMR) has been encouraging the substitution of coal for oil with special emphasis on the four maritime provinces, Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick.

The Canadian National Energy Program (NEP) has established funds under the special Atlantic initiatives in order to accelerate the shift away from dependence on imported oil which is characteristic of the Atlantic region. These initiatives include a coal utilization program designed to identify, develop, demonstrate and then commercialize new technologies that would enhance the local use of indigenous coal under environmentally acceptable conditions. Through this activity, EMR Canada will assume a large share of the technical risk associated with the introduction of new technologies.

The emerging technology of coal-water mixtures (CWM) was identified early as showing special promise for the Cape Breton Coal Industry both to serve local markets and for export purposes. In Eastern Canada the potential for CWM fuel initially relates to oil substitution in utility boilers that are not designed for conventional pulverized coal combustion or cannot readily be converted to that technology.

BACKGROUND

Interest in CLM technology as potential oil replacement fuels has been continuing in Canada since the early seventies when an early research effort [1] led to three phases of a coal-oil mixture (COM) technology demonstration from 1977 to 1980 in a small generating station at Chatham, N.B.[2] It is not fortuitous that the demonstration aspects of the present project will also take place at Chatham later this year. The Chatham generating station is small, with two boilers of 12.5 and 22 MW(e) which are no longer required to supply power to the grid. Thus, it has the operational flexibility necessary for the CWM burner evaluation tests of the present project.

In April of 1982 EMR Canada, the New Brunswick Electric Power Commission (N.B.E.P.C.) and Cape Breton Development Corporation (C.B.D.C.) entered into a collaborative agreement to demonstrate the preparation of CWM and its utilization in utility boilers. In addition, CBDC has signed a licencing agreement with AB Carbogel of Sweden to manufacture and market CWM based on proprietary Carbogel technology with exclusive rights to eastern Canada. The agreement provided for the construction of a 4 tonne/hour CWM pilot plant to be located in Sydney, N.S. It also specified that burners should be developed and tested for the 12.5 MW(e) unit No. 1 front-wall fired boiler and the 22 MW(e) unit No. 2 tangentially-fired boiler at Chatham, N.B. The project was to be administered by a management committee comprising of representatives of EMR Canada, N.B.E.P.C., C.B.D.C., the Nova Scotia Power Commission (N.S.P.C.) and AB Carbogel. (see Figure 1) Technical input to the project is through a technical committee which in addition to management committee members, includes representatives of the National Research Council (NRC), Ontario Hydro, New Brunswick Research and Productivity Council and the Centre for Energy Studies of the Technical University of Nova Scotia.

The major objectives of the project were to build a pilot-plant to produce 6000 tonnes of CWM for burner evaluations to be undertaken in the Chatham units after the necessary preliminary testing had taken place at the manufacturer's test facilities. Since the agreement called for the burner development program to run concurrently with the CWM pilot plant design and construction, 550 tonnes of the CBDC coal were shipped to AB Carbogel in Sweden for design fuel manufacture. This fuel was to be used in burner testing prior to installation in the Chatham units.

CAPE BRETON DEVELOPMENT CORPORATION CWM PREPARATION FACILITY

CBDC is a federal Crown Corporation which was established in 1968 and is located in Sydney, Nova Scotia. At the time of its inception its mandate was two-fold; to phase out the mining operations of the former Dominion Coal Company in the face of declining coal markets; and to attract and establish a broader base of secondary industry in a predominantly steel and coal oriented community to off-set the effects of the unemployment created from mine closures.

Now, due to the dramatically altered position of coal in the world energy picture, CBDC's task now becomes the establishment of a viable coal

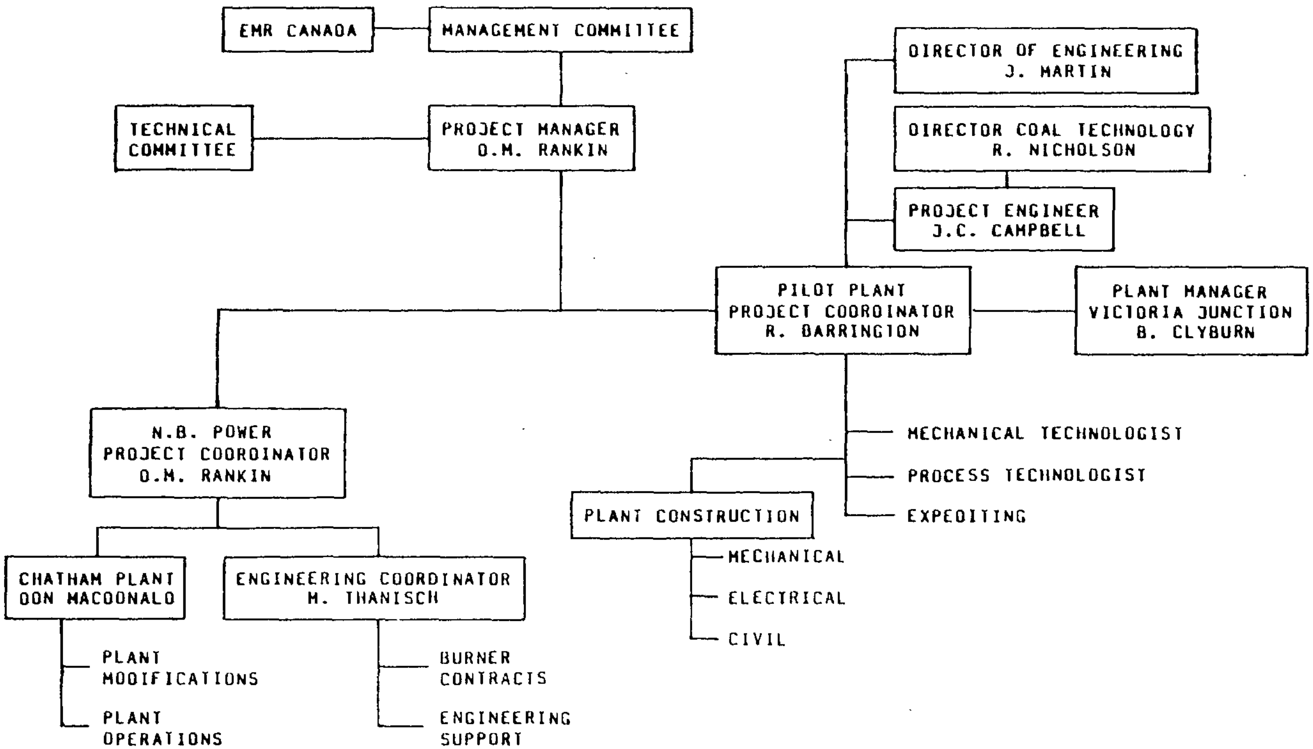


Figure 1 - CWM Project Organization

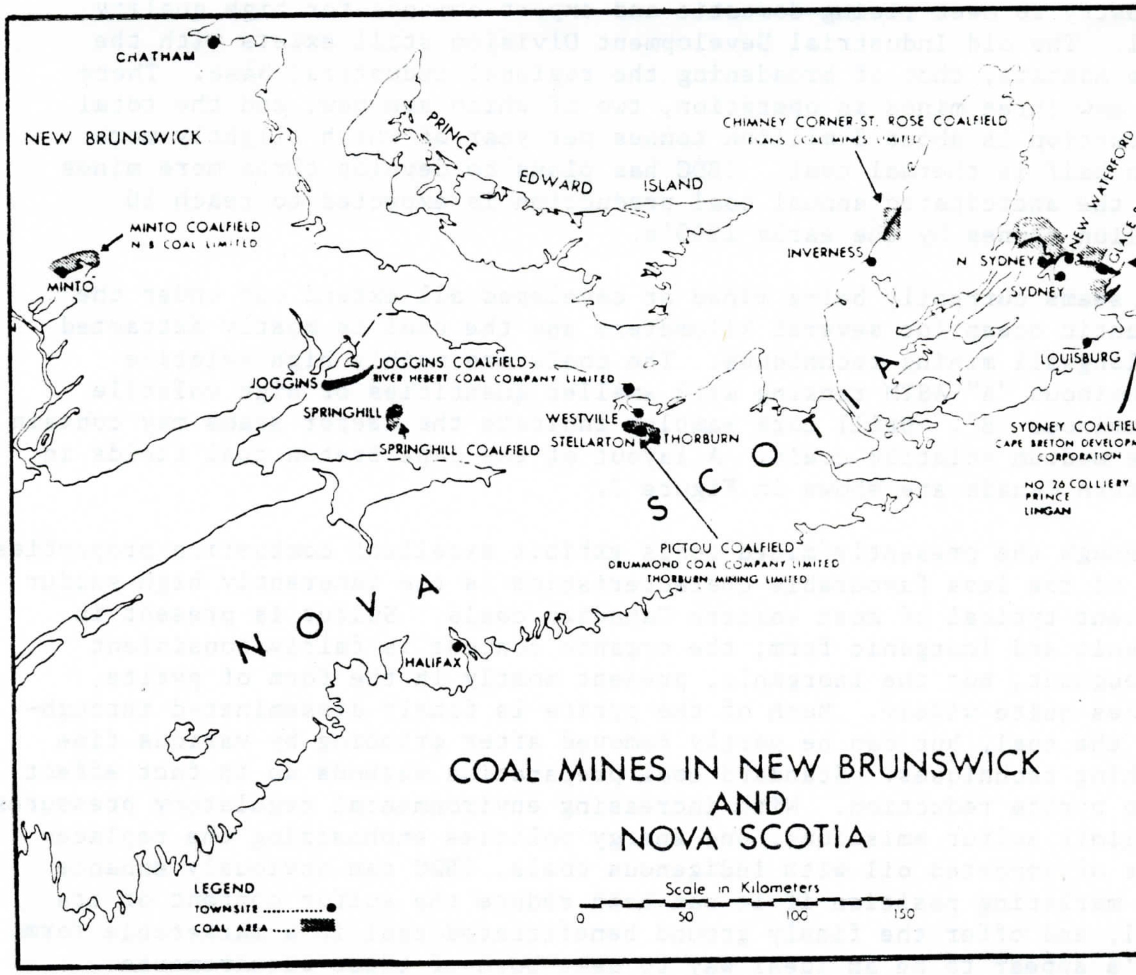
industry to meet rising domestic and export demands for high quality coal. The old Industrial Development Division still exists with the same mandate, that of broadening the regional industrial base. There are now three mines in operation, two of which are new, and the total production is about 3 million tonnes per year of which slightly more than half is thermal coal. CBDC has plans to develop three more mines and the anticipated annual coal production is expected to reach 10 million tonnes by the early 1990's.

The seams currently being mined or developed all extend out under the Atlantic ocean for several kilometers and the coal is mostly extracted by longwall mining techniques. The coals are mainly high volatile bituminous "A" ASTM ranking with smaller quantities of high volatile bituminous "B". Drill core samples indicate the deeper seams may contain some medium volatile coals. A layout of the Cape Breton coal fields in eastern Canada are shown in Figure 2.

Although the presently mined coals exhibit excellent combustion properties, one of the less favourable characteristics is the inherently high sulfur content typical of most eastern Canadian coals. Sulfur is present in organic and inorganic form; the organic content is fairly consistent throughout, but the inorganic, present mostly in the form of pyrite, varies quite widely. Much of the pyrite is finely disseminated throughout the coal, but can be partly removed after grinding by various fine washing techniques. Standard coal preparation methods do in fact effect some pyrite reduction. With increasing environmental regulatory pressures to limit sulfur emissions, and energy policies emphasizing the replacement of imported oil with indigenous coals, CBDC can obviously enhance its marketing position if it can both reduce the sulfur content of its coal, and offer the finely ground beneficiated coal in a marketable form. CWM's appear to be an ideal way to meet both of these requirements.

The agreement signed between the three parties in April 1982 provided for about 500 tonnes of CWM to be made by AB Carbogel in Sweden, which was to be used for preliminary burner tests and for 6000 tonnes of CWM to be made in a 4 tonne/hour pilot plant operated by CBDC. The agreement further provided for two designations of fuel: Design Fuel and Commercial Fuel. The fuel made in Sweden and the 6000 tonnes to be made in the pilot plant were classified as design fuel and were to be made from a mix of Harbour Seam coals (Lingan and No. 26 mines). These coals are normally beneficiated together to produce a metallurgical grade coal, with the middlings going to thermal coal, and are generally the highest quality coals produced by CBDC. Commercial Fuel was to be used for later phases of the program involving larger utility boiler tests and would probably be the fuel that CBDC would develop and sell on a commercial basis. Commercial Fuel will be made from Prince Mine coal (Hub Seam) which is currently sold as a thermal coal and is not beneficiated.

Typical analyses of Harbour and Hub Seam coals are given in Table 1.



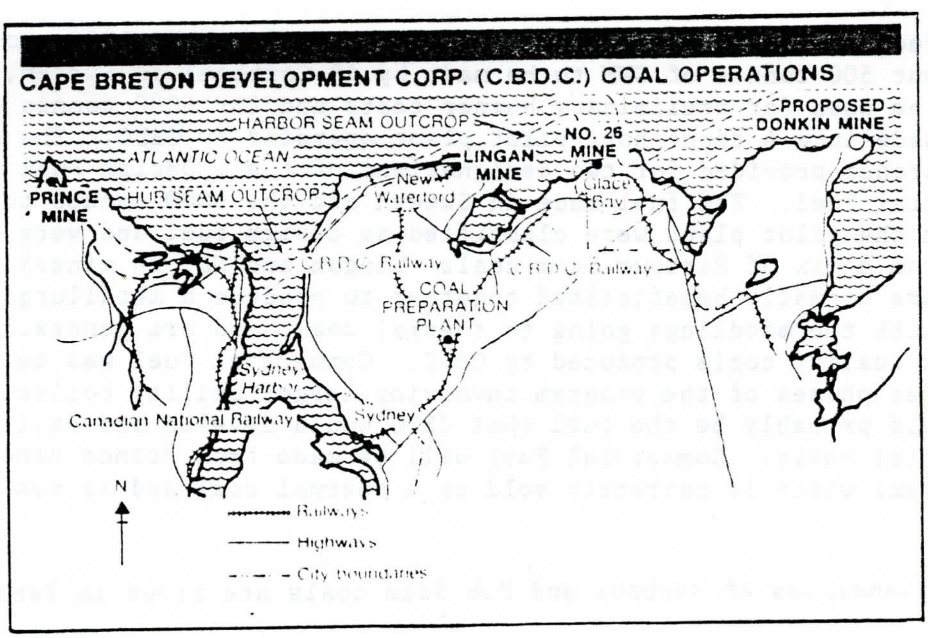


Figure 2 - Map of CBDC's Sydney NS Coal Fields

Table 1

	Harbour Seam			Hub Seam
(% dry basis)	As Mined	Beneficiated	CWM	As Mined
Ash	15.0*	2.8	1.7	16.0
Sulfur	1.8	1.2	0.9	4.5

* - Includes rock from mining operations; in-seam coal analyses show 5.0% ash.

The properties of the Hub Seam commercial CWM are still under investigation by AB Carbogel and the University of Minnesota and the final quality projections have yet to be made. It is expected that comparable reductions in ash and sulfur to that achieved with the Harbour Seam, will be obtained.

Upon signing of the agreement, a CBDC project team was formed from representatives of coal preparation operations, engineering, and coal technology. A basic process flow sheet and material balance was developed with Carbogel engineers, and basic equipment requirements determined with Carbogel and Boliden, a part-owner of A.B. Carbogel and a large mineral processing company in Sweden and internationally. Because it was impractical to locate the CWM plant in the existing Victoria Junction coal preparation facilities, a separate building was planned in an adjacent area. The site choice was logical since Victoria Junction is at the junction of rail lines serving the Lingan and Glace Bay mines, and the shipping docks at Sydney. Thus the plant has ready access to road, rail or water transportation as well as to the coal mines.

The CWM plant building of sectional prefabricated steel was erected in December 1982 with overall dimensions of 38m x 18m.

Initially, operation of the pilot plant was scheduled to be on a single shift a day, 5 days per week operation. However, growing concern about the time necessary to produce the 6000 tonnes for the NBEPC burner evaluations, and the subsequent effects on operating costs of spreading the tests over a long period, and the lack of capacity to meet a perceived demand for similar tests in other locations, led to a decision to increase the production capacity of the plant and also to increase the number of operating shifts. Consequently, in January 1983, it was decided to increase the capacity to 7 tonnes/hour and to operate on a 3 shift per day basis, effectively increasing the theoretical output from about 6000 tonnes per annum, at 80% availability, to about 38,000 tonnes per annum.

An examination of the flow sheet illustrated in Figure 3 and equipment capacities showed clearly that the limiting factor in the production rate was the vacuum filter. Most of the other items of equipment specified had excess capacity, but the filter was limited to the 4 tonnes/hour original design specification. Since there was sufficient space and floor support to install a second filter in parallel to the first, and feed piping from the flotation unit could be split to feed both units simultaneously, the plant capacity could be increased by about 75%, for the relatively modest cost of the second vacuum filter.

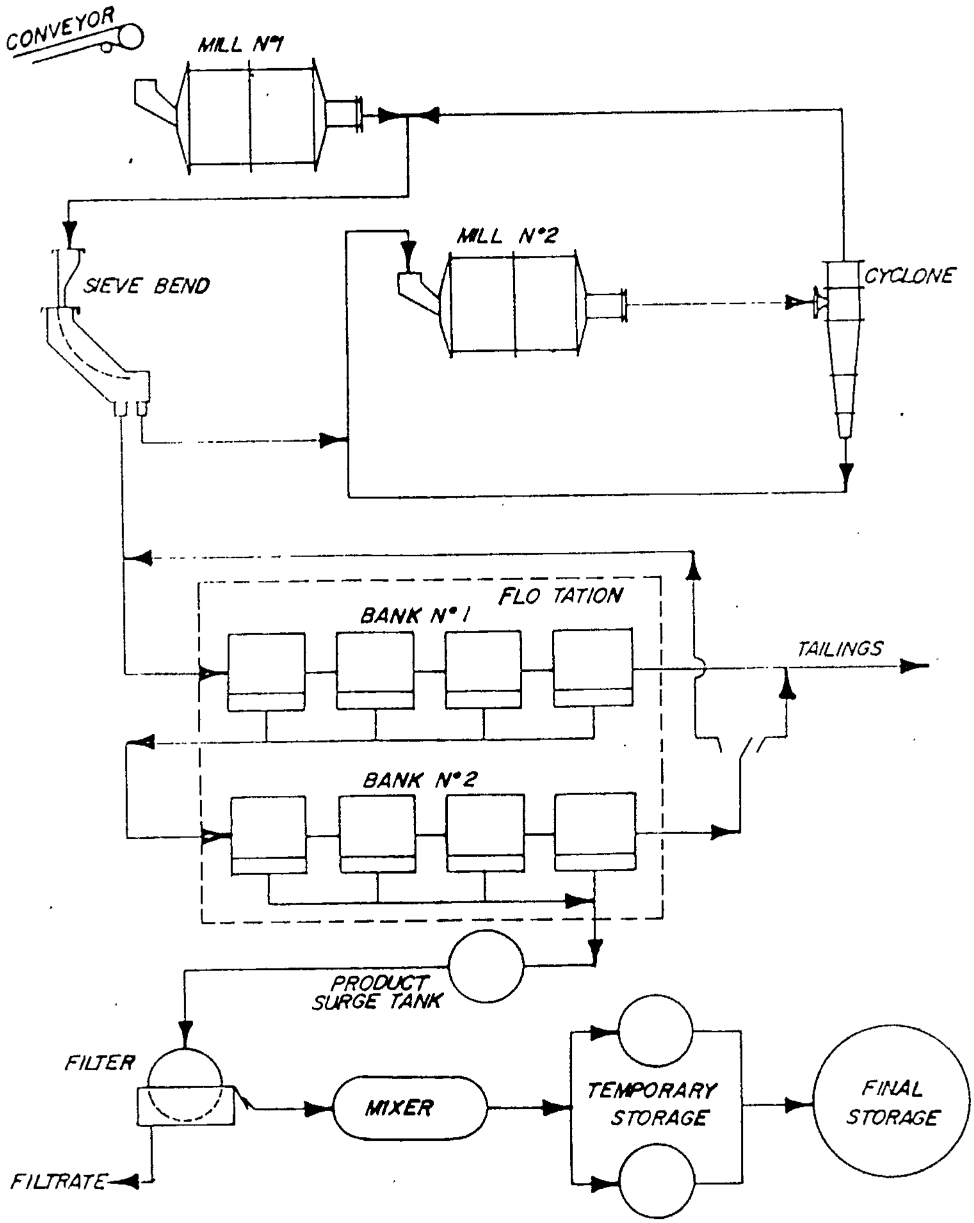


Figure 3 - Schematic Illustration of CWM Preparation Plant Flow Sheet

At the time of writing this paper the CWM plant is on schedule, see Figure 4. Equipment procurement is being monitored by expeditors and delivery schedules are being maintained. It is still anticipated that the first CWM fuel will be produced by the plant in June 1983.

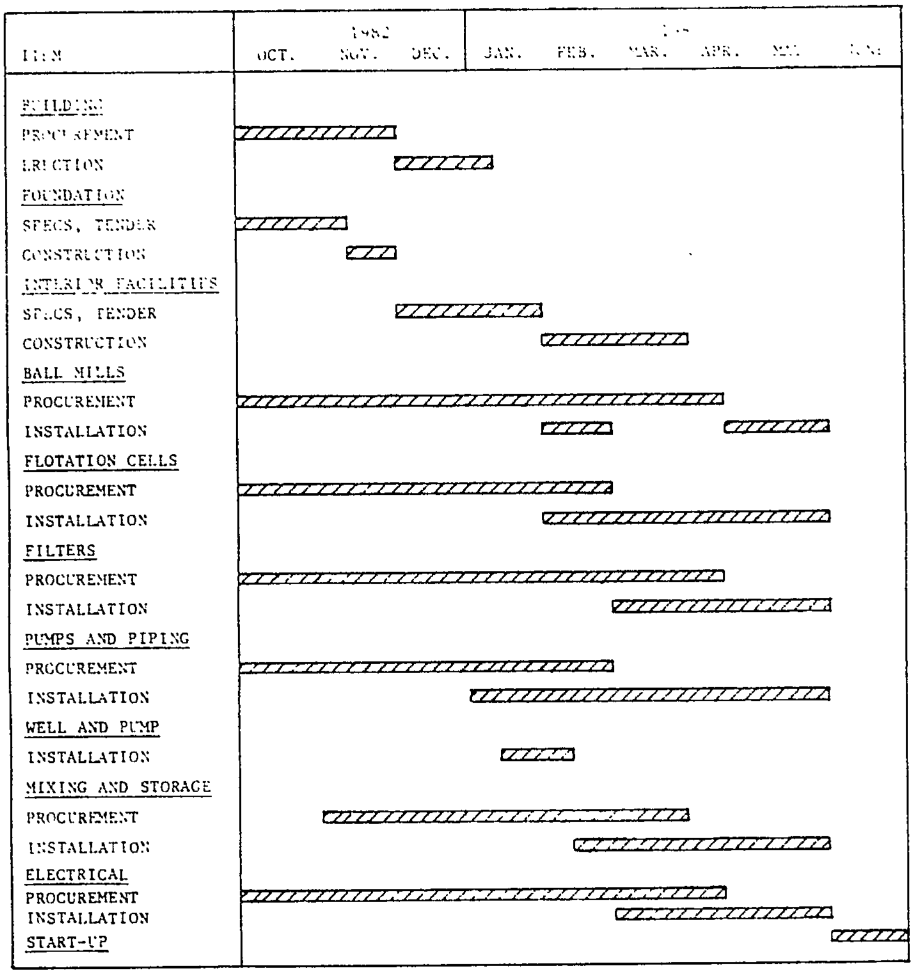


Figure 4 - Schedule for CBDC CWM Pilot Plant Combustion

CWM BURNER DEVELOPMENT

The tripartite agreement provided for the development and evaluation of CWM burners for the two units of the Chatham, N.B. generating station. Consequently, under the management of NBEPC two CWM burner development contracts have been awarded, one to Foster Wheeler Canada Ltd. for the development of burners for the front-fired boiler, unit No. 1, and one to Combustion Engineering Canada for the development of burners for the tangentially-fired boiler, unit No. 2. As mentioned earlier, about 500 tonnes of CWM design fuel have been produced in Sweden for these burner manufacturers to utilize in this stage of the burner development program. Specifically this stage consists of the design, testing and evaluation of a burner rated at approximately 30 GJ/h thermal input and of a type suitable for CWM firing in a front-wall boiler. A parallel activity will address the tangentially-fired boiler. At the time of writing (February 1983), the burners for the front-wall fired unit No. 1 have been tested by Forney Engineering of Dallas and four burners are being manufactured ready for installation by July 1983. The tangentially-fired CWM burner has not yet been finalized and tested, but atomization tests have been conducted by CE. It is expected the burner test evaluation will take place in late February 1983. (see Figure 5). The second phase of the CWM burner development activity is the installation and testing of the burners in the boilers at Chatham, N.B.

Chatham unit No. 1 is a front-wall fired Foster Wheeler balanced draft boiler 12.5 MW(e) designed to burn coal but converted to burn No. 6 fuel oil. This boiler was used in earlier COM tests as noted previously[2]. The main specifications of the boiler are given in the Appendix.

Unit No. 2 is a tangentially-fired CE balanced draft boiler 22 MW(e) also designed to burn coal but converted to No. 6 fuel oil. The specifications of unit No. 2 are given in the appendix.

Figure 5 shows that burner evaluations are due to begin in June 1983 in unit No. 1 and September 1983 in unit No. 2, and progress to date is on time.

In addition, all engineering support services are on schedule. These are fuel transportation, pumping, storage and compressed air for atomization.

LONG RANGE STRATEGY

If the projects at Chatham and Sydney are successful, it is quite clear that there are significant implications both for the CWM supplier and for the maritime utilities. To put the former into perspective, there are about 10 GW of potentially convertible oil-fired generating capacity in New England and about 5 GW in eastern Canada, including Ontario and Quebec. All of the Canadian capacity is accessible by water without the need for expensive conventional coal docks as are over 75% of the U.S. stations. Taking utilization factors into account, this translates into a potential market for about six million tonnes of CWM fuel available by water routes and about one million tonnes requiring rail access. In addition, a preliminary view of the west European market has indicated sales potential for a further three million tonnes there. Since CWM fuel made at Sydney will be based on expensive coal from under the sea, it will only be able to compete with other coal-water fuels in markets where it can be delivered for the least expense. Thus transportation costs become extremely important and these will need to be investigated carefully.

The primary objective of the burner tests at Chatham is to develop burners that will provide satisfactory flame and combustion properties and withstand the abrasive action of CWM for a reasonable period of time. From the utility viewpoint, this period of time is considered to be about 2000 hours.

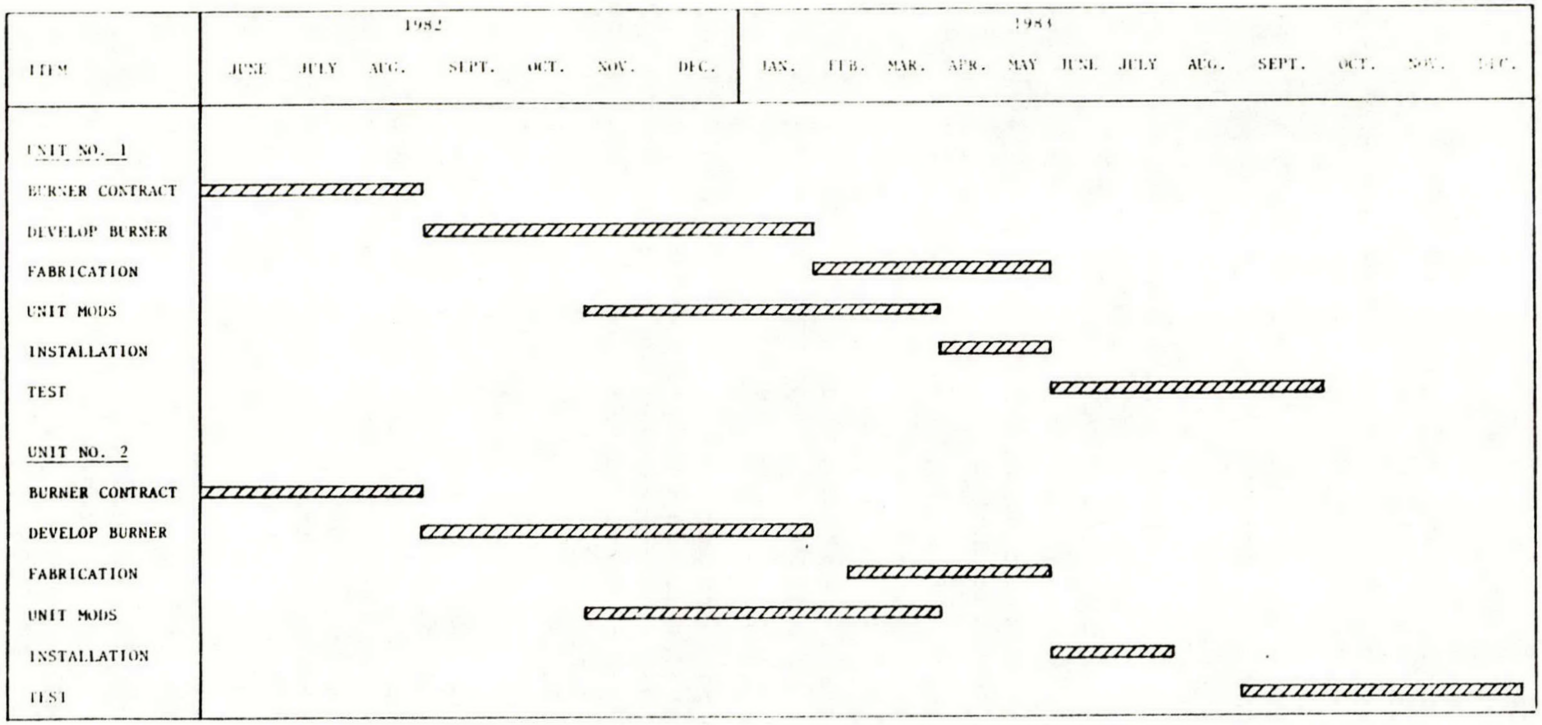


Figure 5 - Schedule for Burner Development and Testing: Chatham CWM Project

Other pertinent information required from the Chatham Project will be to establish operating data on the physical properties of CWM's, particularly in relation to long distance transportation, storage, pumping and recirculation, and atomization.

As both steam generators at Chatham are small and since both were originally designed to burn coal, financial inducements to the utilities will only occur in the Maritime provinces if expensive imported oil is displaced in larger furnaces now burning residual oil.

In the provinces of Newfoundland, New Brunswick and Nova Scotia, there are eight oil-designed steam generators in the range of 100 MW(e) to 150 MW(e), which may be suitable for conversion to CWM.

For such a conversion, a number of alternatives are open, namely:

1. Convert to CWM and derate the unit output as imposed by the characteristics of the CWM.
2. Convert to CWM and, consider boiler design changes that will enable full rating to be maintained.
3. Convert to CWM, but retain the capability for oil-firing. Hence full load may be achieved when firing oil and a derated output when firing CWM.
4. Convert to CWM, but retain capability to burn oil or CWM by boiler design changes, to achieve full load operation by either mode of firing.

The preferred alternative may vary for each utility, since the best engineering and economic choice may depend upon a number of "site specific" factors. There are many common engineering considerations of conversion, the major ones being fuel handling, ash disposal, furnace gas and air pass configuration.

FUEL HANDLING

Apart from establishing that CWM's do not destablize during the transportation, storage, pumping and recirculation processes, because of the severe winters in the Maritime provinces, CWM fuels must be protected from freezing. This may call for special fuel heating arrangements which will add to the conversion costs. Also, it must be ensured that existing oil tanks and transfer pipework and pumps are suitable for storing and transporting CWM with agitation, heating and heat tracing if necessary.

ASH DISPOSAL

Even with a beneficiated CWM, containing about 2% ash, a 150 MW(e), steam generator, will, at full load produce about a tonne of ash per hour. This quantity, especially in a furnace designed to burn residual oil, poses a number of problems, such as:

(a) Reduction of gas velocities to maintain tube erosion within acceptable limits. Average gas velocities usually in the range of 25-30 m/s when firing oil may be limited to 12-15 m/s when firing CWM.

(b) The gas temperature entering the close pitched first pass should be less than the initial deformation temperature of the ash, which may be below 1100^{o}C with some eastern Canadian coals. Also, if slagging of the first pass heating surface is to be avoided, the ash fusion characteristics of all potential CWM coals should be known.

(c) A complete reassessment of water wall, superheater, reheater, economizer and air heater sootblowing requirements may be necessary.

(d) Installation of a new, or modifications to the existing, bottom ash removal system. Either option could involve excavating below grade level. Due to the steeper ash hopper slope required for coal firing, modifications may have to be made to the furnace bottom which would affect furnace heat release rates.

(e) Installation of new, or upgrading of existing, dust collection equipment to ensure that particulate emission rates comply with regulatory requirements. In units where there is a little room between the air heater gas outlet and the stack breaching, retrofitting of dust collecting equipment could prove expensive, if not impossible.

(f) The acquisition of suitable ash disposal areas including the most economic method of transportation if no other means of disposal is available.

(g) Increase in operating and maintenance costs in converting to CWM.

FURNACE GAS AND AIR PASSES

(a) The mass flow rate of combustion gases when firing coal in the form of CWM is typically 15%-20% greater than the equivalent oil-fired products of combustion at the same thermal input. Unless the oil-fired unit was designed for gas recirculation, gas velocities will increase through the various heat exchange surfaces. In addition to the impact on tube erosion as discussed earlier, this increase in mass flow rate will also affect heat absorption rates. This could affect superheater/reheater temperature control.

(b) Furnace Plan Heat-release rates (EPRS) for oil-designed furnaces are typically of the order 8.0 x 10^6 w/m^2. When firing coal this figure could be restricted to about 5.0 x 10^6 w/m^2. As a first approximation these figures are indicative of a reduced furnace height and, therefore, the reduced "residence" times of oil designed steam generators.

(c) Depending upon the extent of modifications to the boiler, a reassessment will have to be made of fan power requirements:

If the preferred choice is to modify the boiler gas and pressure components to meet full load requirements when burning CWM, it would be necessary to establish whether the existing fans can meet the increased pressure and volume requirements.

Conversely, if derating is the preferred route, the fans will probably meet the requirements but will probably be operating less efficiently. Either option will add to the cost of CWM conversion.

(d) Since CWM's contain approximately 30% water, there will be a modest increase in wet flue gas losses.

(e) If major modifications are proposed to the boiler gas and pressure components then boiler support steel, including foundations will have to be thoroughly re-examined.

Of the eight steam generators in the Maritimes capable of being converted, some will be more amenable than others. Apart from the engineering aspects discussed in this section of the paper, other aspects such as age of unit, projected load factor, fuel transportation costs and existing furnace dimensions, particularly furnace heights, will influence the final selection.

The paper has attempted to emphasize that conversions to CWM's are site specific, for in addition to the engineering aspects which influence the economic choice, plant layout drawings are required to ensure that proposed modifications are feasible.

Any utility contemplating conversion to CWM will need to cooperate closely with the boiler manufacturers in order to obtain the best technical and financial data necessary to complete an accurate economic evaluation.

As the work at Chatham proceeds, it is hoped to establish which of the boilers in the 100 MW(e) - 150 MW (e) range in the Maritime provinces is the preferred engineering and economic choice.

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APPENDIX

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION

CHATHAM STATION UNIT NO. 1

<u>No. 1 Boiler</u>

Manufacturer	-	Foster Wheeler
Steam Flow	-	63,500 kg/h
Operating Pressure	-	4170 kPa
Steam Temp	-	446°C
Reheat	-	None
Feed Water Temp	-	177°C
Type of Boiler	-	Balanced Draft
Fuel	-	Original design New Brunswick Coal
	-	Presently firing No. 6 Oil
Ignition	-	No. 2 Oil
Burners	-	4 Front-Fired

<u>No. 1 Turbine</u>

Manufacturer	-	Parsons
Output (Gross)	-	12,500 kw
Number of Cylinders	-	One
Generator Cooling	-	Air Cooler
Type of Turbine	-	Condensing

CHATHAM STATION UNIT NO. 2

<u>No. 2 Boiler</u>

Manufacturer	-	Combustion Engineering Superheater Ltd.
Steam Flow	-	95,500 kg/h
Operating Pressure	-	5930 kPa
Steam Temp	-	482°C
Reheat	-	None
Feedwater Temp	-	179°C
Type of Boiler	-	Balanced Draft
Fuel	-	Original Design New Brunswick Coal
	-	Presently firing No. 6 Oil
Ignition	-	No. 2 Oil
Burners	-	4 Corner Fired - Oil Guns
	-	8 Corner Fired - Coal Burners

APPENDIX (Cont'd)

CHATHAM STATION UNIT NO. 2

No. 2 Turbine

Manufacturer	-	Brown Boveri
Output (Gross)	-	22,000 kw
Number of Cylinders	-	One
Generator Cooling	-	Hydrogen Cooler at 3.5 kPa
Type of Turbine	-	Condensing