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Combustion Trials of Coal-Water Mixture Fuel in Two Small Utility Boilers in Eastern Canada

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COMBUSTION TRIALS OF COAL-WATER MIXTURE FUEL IN TWO SMALL UTILITY BOILERS IN EASTERN CANADA

by

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ABSTRACT

Interest in coal-liquid mixtures as potential oil replacement fuels has been continuing in Canada since the early seventies. The initial motives for this interest were the rapidly rising cost of oil coupled with an insecurity of supply. The possibility of the recurrence of extreme energy price and supply fluctuations is the reason for continued efforts in the development of coal-liquid mixtures and in particular coal-water mixtures for utility boiler applications. A brief description is given of an earlier program undertaken at Chatham, New Brunswick, in which coal-oil mixtures were used in a small utility boiler. This program showed that burner and equipment wear was a significant impediment to coal-oil mixture utilization and led to the inclusion of coal cleaning, in the preparation process, as a means of reducing the sulphur and abrasive ash content of the coal.

Under a cooperative agreement between Energy, Mines and Resources Canada, the New Brunswick Electric Power Commission and the Cape Breton Development Corporation, a 7 t/h preparation facility has been built to produce a coal-water mixture fuel for testing in two small utility boilers located at Chatham, N.B. An update is given of the status of this program as well as plans for the future program in Eastern Canada.

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ESSAIS DE COMBUSTION DE MÉLANGES CHARBON-EAU DANS DEUX PETITES CHAURIDERS DE CENTRALE ÉLECTRIQUE DANS L'EST DU CANADA

par

H. Whaley*, D.M. Rankin** et P.J. Read*

RÉSUMÉ

L'intérêt manifesté au Canada depuis le début des années 70 envers les possibilités offertes par les mélanges charbon-liquide pour remplacer le pétrole se maintient. A l'origine, les motifs en étaient le coût croissant du pétrole et l'insécurité des approvisionnements. La possibilité de nouvelles poussées des prix et de fluctuations extrêmes des approvisionnements d'énergie justifient maintenant les efforts déployés pour mettre au point des mélanges charbon-liquide et notamment des mélanges charbon-eau destinés aux chaudières de centrales électriques. Le programme antérieur mené à Chatham (Nouveau-Brunswick) et compartant l'utilisation de mélanges charbon-eau dans une petite chaudière de centrale électrique est décrit brièvement. Il avait permis de constater que l'usure du brûleur et du matériel constituait un empêchement de taille à l'utilisation des mélanges charbon-eau et a entraîné l'inclusion d'une étape d'épuration du charbon dans le procéd de preéparation du charbon, en tant que moyen de réduire les teneurs en soufre et en cendres abrasives.

Dans le cadre d'une entente de coopération entre Énergie, Mines et Ressources Canada, la Commission d'énergie électrique du Nouveau-Brunswick et la Société de développement du Cap-Breton, on a construit une installation d'une capacité de 7 tonnes/heure pour préparer le mélange charbon-eau qui sera utilisé comme carburant lors d'essais dans deux petites chaudières de centrale électrique situées à Chatham (N.-B.). Le rapport décrit l'état d'avancement du programme et expose des plans pour le programme des travaux à entreprendre dans l'est du Canada.

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Coal-water mixture (CWM) technology offers a means of replacing oil by coal, where direct substitution of a solid fuel is impossible or uneconomic. There is a potential for this replacement in many stationary combustors and in some mobile uses, provided the fuel can be burned reliably, cleanly, safely and economically. This paper reports the progress in the development of CWM technology.

In Eastern Canada, major quantities of electricity are generated from oil because natural gas has not been generally available and local coals are both expensive and high in sulphur content. This situation leads to the potential for replacement of oil by CWM being highest in New Brunswick and the other Atlantic provinces. CWM technology may ultimately be used in Western Canada or for export but the decision was taken to investigate its potential in Eastern Canada because of the region's more urgent need and possible environmental benefits. Also, the region's smaller utility boilers are more suitable for demonstration purposes.

Utilities and other industries which might use CWM generally are not in a position to convert or even to assess the economics of converting, until there is proof that the fuel can be burned reliably and safely. Therefore, the present program's objective is to demonstrate the efficient combustion of CWM in two small coal-capable utility boilers. it is then planned to proceed to demonstrations in a small oil-designed unit and ultimately in oil-designed utility-scale units. Once these demonstrations have been completed it is expected that normal commercial practice will take advantage of the technology, whenever it is economically feasible.

BACKGROUND

In 1972 the Canadian Combustion Research Laboratory (CCRL) conducted an in-house program to study the combustion and heat transfer characteristics of several coal-oil mixtures (COM) in a pilot-scale research tunnel furnace. The results of this work were presented at a joint industry/government seminar in 1972 to stimulate interest in this technology(1). Subsequent evaluations of the data were presented at the International Flame Research Foundation, IFRF, 4th Members Conference(2) and the ASME winter annual meeting(3) both in 1976. This early research into COM combustion was discontinued because the availability of cheap fuel oil did not make COM attractive to industry. However, following the rapid escalation of oil prices in the late seventies, there was renewed interest in COM technology and EMR Canada as part of its program to reduce reliance on foreign oil supplies, encouraged this interest by financial and technological support through demonstration projects and R&D.

The first demonstration project was undertaken from 1977 to 1980, in three phases, to study the potential for utilization of COM in a small utility boiler at Chatham, N.B.

The Chatham Thermal Generating Station, Unit No. 1 of 10 MW(e) capacity, was selected for this project because of its small size, coal design, and the fact that it is rarely required to supply electricity to the grid. Thus the unit had the operational flexibility required for the COM study. The boiler, manufactured by Foster Wheeler and rated at 17.6 t/h steam flow, is a dual-fired boiler capable of independently firing coal or oil and simultaneously burning coal and oil, using separate burners.

The Phase I COM program at Chatham began in 1977/78 and employed simple mechanical mixing of coal (pulverized and collected in a cyclone and baghouse) with No. 6 fuel oil in a blender. The COM was then pumped to the four existing steam-atomized oil burners, using a screw-type oil pump. Neither the pumps nor the burners were specifically chosen for COM application, consequently significant wear problems, which could be attributed to the abrasive coal ash, were encountered. The results of Phase I operation, in which a 10 wt % coal - No. 6 fuel oil mixture was burned, were previously reported in detail(4).

Modifications were made to the COM preparation system during the 1978/79 Phase II program to accommodate the National Research Council (NRC) oil agglomeration system(5). The purpose of the agglomeration process is to beneficiate the coal by partial ash and sulphur removal, with a corresponding reduction in materials erosion and stack fly ash and SO_2 emissions. A wet scrubbing system was used to replace the former cyclone-baghouse combination to facilitate collecting the pulverized coal in water for secondary grinding, using a wet mill.

Two types of burner tips were tested in Phase II, a Y-jet type and a similar burner with replaceable inserts. The burner tip erosion encountered during Phase I still remained a major problem and the performance of the agglomeration system was not as good as had been demonstrated in the laboratory(6). The Phase III program, which ended in April 1980, was undertaken to improve the effectiveness of the oil agglomeration process and to test two new burners for long-term performance on COM. Neither of these objectives was met, primarily due to the equipment wear problems, associated with the highly abrasive coal used to make the COM(7,8).

After more than 1500 h of operation on COM ranging from 10 wt % to 40 wt % coal, it was concluded that:

(1) the erosion of burner tips was the main obstacle preventing the successful utilization of COM technology in the small utility boiler at Chatham, N.B.;

(2) the erosion, which resulted in progressive flame deterioration, could be attributed to the use of highly abrasive coal in the COM;

(3) incorporating an in-line coal cleaning process to reduce the ash and pyrites content of the coal did not solve the erosion problem;

(4) significant wear-related damage to pumps, valves and secondary grinding equipment could be eliminated by appropriate materials and equipment design considerations;

(5) pipework was relatively unaffected by wear, essentially due to the low prevailing fluid velocities.

It was deduced that the major problem of burner tip erosion could be solved by choosing a less abrasive coal, improving coal cleaning by ash and pyrites rejection, further reductions in coal particle size, materials selection, or the use of externally atomized burners with low COM efflux velocities and a simple configuration. These findings have been subsequently reinforced by a CANMET study of atomizer wear undertaken at the Onatario Research Foundation(9).

ECONOMIC AND PHYSICAL REQUIREMENTS

The price range which coal-water mixtures (CWM) can command is determined by competing fuels. In large industries and electric utilities these fuels are usually residual oil, Bunker 'C' oil or coal. Smaller energy consumers use No. 2 or 4 fuel oil or natural gas which, in Canada, may also be used in larger industries and utilities. For most of these users, the prices per unit of energy for the competing fluid fuels are approximately two thirds of crude oil. To attract customers by pricing significantly below that of the competition, CWM must sell for less than 50% of crude oil prices on a heat value basis. On this basis the most expensive Canadian thermal coal sells for somewhat less than 50% of the crude oil price, so where direct use of coal is possible it is the most attractive fossil fuel. However, where solid fuel cannot be used, even if the starting material for COM is one of the more expensive Canadian coals, there is nearly a 50% margin above its regular price available to cover additional costs of preparation by the supplier and of operation by the user, as well as a reasonable return on investment.

Feedstock costs all but preclude the use of COM, since at the upper physical limit (about 50%) of coal concentration, the cost of coal, oil and preparation exceeds the price of competing fuels. There may be an exception to this generalization for proprietary fuels containing about 25% oil, 15% water and 60% coal, particularly for modest-scale heating plants and marine use, but overall the Canadian program has veered away from its earlier interest in COM, on economic grounds.

Canada has the objective of decreasing its atmospheric emissions of sulphur oxides by 50% from 1980 to 1990 and the substitution of low-sulphur coal for residual oil can materially assist in reaching this objective. The multi-stage cleaning process, associated with CWM, can reduce medium-sulphur coal to this desirable state. However, even where such mixtures might be chosen as an oil substitute preferable to coal on environmental grounds alone, (such as in a furnace originally designed to burn coal but later switched to oil to minimize particulate as well as sulphur emissions), the competitveness of clean-burning natural gas sets an upper limit to the price.

Removal of mineral matter from coal is important for boiler performance, economy of distribution, ash disposal, and environmental protection. Conventional coal beneficiation removes much of the adventitious mineral matter, but cannot extract minerals that are very finely interspersed or are part of the molecular structure of the coal.

For sulphur, the occurrence may be in pyritic, sulphatic or organic form. Very finely divided pyritic sulphur is often reported as organic because it is so difficult to remove by physical means. In Canada most beneficiation is currently applied to coarser coking coals, however, when coals are burned as a slurry and fine grinding is essential, advantage can be taken of this grinding to liberate sulphur compounds and other minerals. Therefore, in the preparation of CWM, conventional washing is followed by milling and froth flotation which separates coal from mineral matter on the basis of surface characteristics. Coal from the Sydney coalfield in Nova Scotia is particularly amenable to this treatment and shows promise of good yields with mineral matter in the 1.5 to 3% range and with about two thirds of the original sulphur removed.

In utilizing CWM in utility boilers, particularly those designed for oil firing, there are many problems to be overcome. Usually an oil-designed boiler is smaller, the steam-rising tube banks are configured differently and the gas velocities in the banks are much higher than for an equivalent capacity coal-fired unit. In addition, coal-based fuels may contain ash which poses problems of tube erosion and slagging and/or fouling. The ignition, flame and heat transfer characteristics of CWM are quite different from those of heavy oil, therefore the heat release pattern from the flame may not be suitable for an oil-designed unit. The combination of all these factors means that an oil-designed unit may be derated i.e., it may not be able to attain the maximum generating capacity for which it was designed, when firing oil. Studies have indicated that such derating may be very significant, but this remains to be shown in practice(10,11). In addition to depending on the design of the boiler and its operating characteristics, the extent of this loss of electrical output will also depend on the coal, its rank and reactivity (volatile matter, inert macerals content, degree of oxidation) as well as its ash content and composition, and the slagging/fouling propensity of the ash.

Several estimates have indicated that deposition of slag on the boiler tubes, conservatively designed for oil firing, would contribute very substantially to boiler derating which could be more than 50% when coal is used as fuel(10,11). The site chosen for preliminary tests was again the generating station at Chatham, N.B., since it has two coal-burning boilers which were adapted to burn oil; one is front-wall fired at 10 MW(e) and the other is tangentially fired at 22 ME(e). The results obtained at Chatham, where CWM burners have replaced the oil nozzles, are yielding virtually all the data required to assess burners and fuel, without the risk of damaging a bigger unit or seriously interrupting electricity supply.

OBJECTIVES OF PRESENT PROGRAM

The development of the Canadian coal-liquid mixture program through its early stages and the rationale behind the Canadian approach have already been described(12). The ultimate objective of the program is to derive enough data on the fuels and how to burn them so that potential users will be able to make decisions to replace oil, based on economics and without abnormal technical risk. An essential component of the program is the establishment of a quality-cost-price relationship. Obviously it costs more to prepare a high-quality, i.e. low-sulphur, low-ash mixture than a low-quality one. For CWM, conventional cleaning applied to the highest quality coal can reduce mineral matter to 3% and sulphur to 1.2%. Grinding and multi-stage flotation can reduce these levels to 1.5% and 0.8% respectively. If lower quality, less expensive coals are used, the same process is expected to attain about 3% ash and 1.5% sulphur.

The program includes preparation and assessment of the combustion characteristics of a range of fuels from the cleanest CWM that can be manufactured to those containing more ash and sulphur. These tests will help to determine the extent and cost of physical cleaning needed to achieve satisfactory boiler operations.

Use of CWM by utilities requires a delivery and storage system, including agitation and pumps that can deal with fluctuations in diurnal and seasonal demand. The program is demonstrating methods of transportation, which would be applicable to industrial users and one of the combustion tests was carried out during freezing temperatures, so that problems caused by low temperature operations have been identified and solved.

The performance of utility boilers, designed for oil, is expected to be significantly different when using CWM. The unit derating problem has already been mentioned and each unit to be converted will need a detailed individual assessment to ascertain its loss in electrical generating capacity, when firing CWM. One objective of the current program is to provide data for determining the inter-relationship between properties and quantity of mineral matter in in the coal-water fuel, the flame, and unit derating. It must be noted that a significant requirement of the CWM program is that the burners be compatible with the retention of fuel oil capability, to attain full generating capacity during peak power demand periods.

After the demonstrations at Chatham, the next step is to design systems for burning CWM in oil-designed and larger utility units. In Eastern Canada there are several oil-designed front-wall and tangentially-fired units. The current program embraces the design of coal-water systems for both configurations. The next immediate step in the program is to conduct tests in an oil-designed boiler similar to the larger Chatham boiler.

DETAILS OF PRESENT PROGRAM

The present program comprises several elements, now virtually complete, which combine to achieve the objectives set out above. These are the costruction of a 7 t/h pilot plant at Sydney, Nova Scotia, for preparation of a CWM containing over 70% coal; the design of burners suitable for reliable combustion of this fuel; the demonstration of the use of the fuel and burners at Chatham in both units.

The pilot plant treats clean coal (minus 3 mm) from an adjacent conventional dense-medium coal preparation plant which reduces the mineral matter from about 8% to 3%. The pilot plant, which is schematically illustrated in Fig. 1, comprises two stages of grinding, particle size control, two stages of froth flotation (further reducing the mineral matter to about 1.5%), and the mixer to add a stabilizer, followed by holding tanks. The flow sheet is based on the proprietary CARBOGEL process. The target solids content is 75% with viscosity in the 800-1500 centipoise ($mN.S/m^2$) range at low shear rates. It is also required that the fuel is not dilatant. The prepared fuel is then held in days storage tanks for regular delivery by rail tanker to Chatham (about 750 km). A 250-m^3 storage tank, already in existence at Chatham, forms the buffer to match demand with production capacity.

Fuel production costs are recovered by the producer through the price charged to the electric utility. After a credit for the value of the electrical energy produced, the remaining cost of the demonstration, including combustion of the fuel, is borne by the federal government. Construction of the pilot plant began in November 1982 and was completed in July 1983.

Concurrently with the construction of the pilot plant, a program to develop CWM burners for the 10 MW(e) front-wall fired and 22 MW(e) tangentially fired units at Chatham, N.B. was undertaken. The two phases are:

<u>Phase I: Design, testing and evaluation of a burner rated at approximately 30 GJ/h thermal input, of a type suitable for a coal-water slurry fuel combustion in the 10 MW(e) front-wall fired Chatham Unit No. 1</u> - A testing and evaluation program for the burner together with boiler performance assessment will be developed for the performance trials in Chatham Unit No. 1, to be undertaken during Phase II. A similar program for tangentially fired units was also undertaken, leading to performance trials in Chatham Unit No. 2 of 22 MW(e) capacity. Burners for both units were designed and tested prior to installation at Chatham.

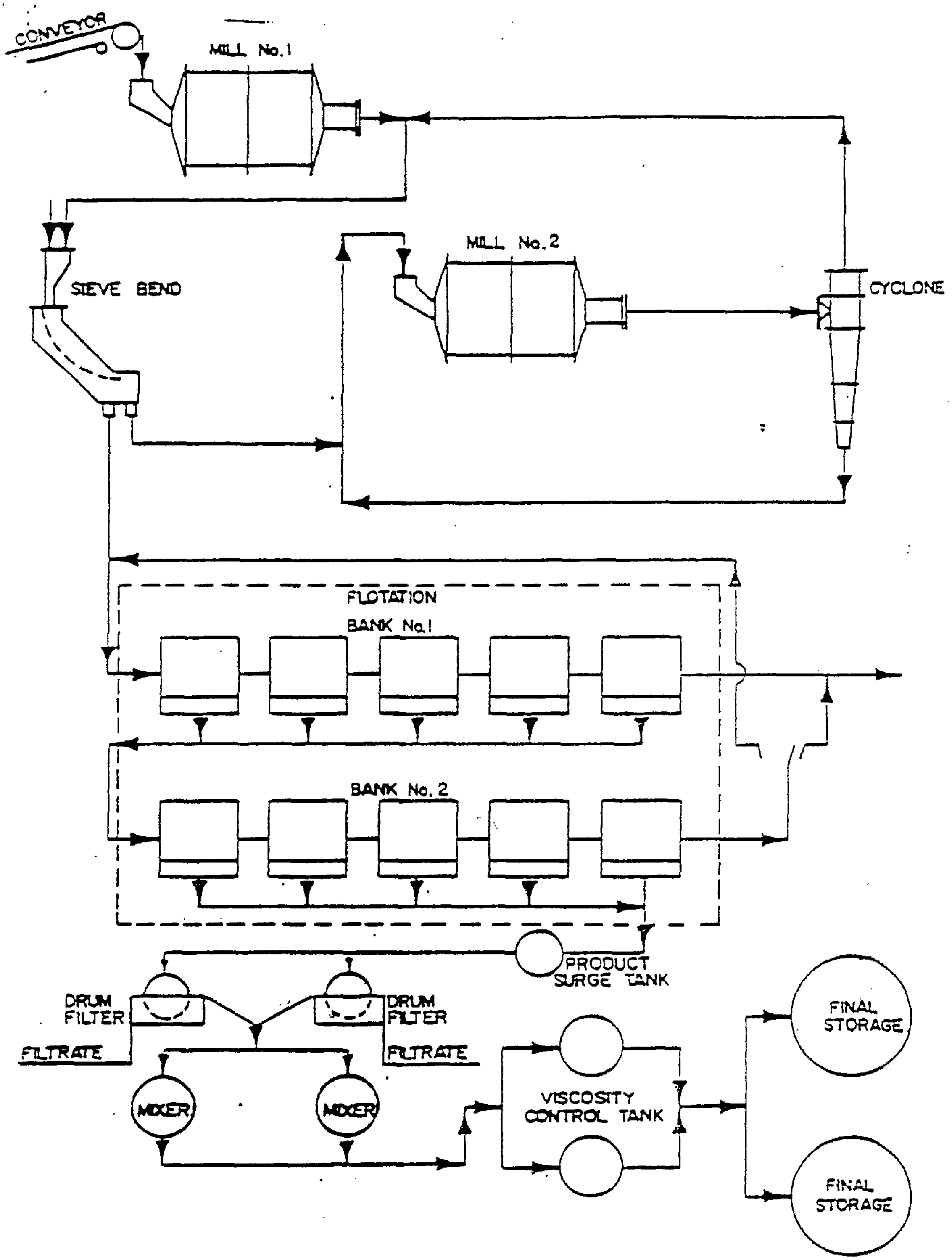


Fig. 1 - Coal-water mixture pilot-plant flow diagram

Phase II: Assessment of burner and boiler performance when firing coal-water mixtures in front-wall and tangentially fired boilers, with special emphasis on reliability of equipment - At the time of writing it is anticipated that 6000 t of fuel will be required for the performance trials. The fuel contains about 1.6% ash and is similar to that used in Phase I for burner development. The Phase II performance trials began in late summer of 1983 and should be completed by Spring 1984. It is expected that these two phases should lead to the testing of burners for demonstration of CWM technology in oil-designed utility boilers from 50 to 150 MW(e) capacity and of both basic configurations typical of Eastern Canada.

CURRENT PROGRESS

At the time of writing, the Cape Breton Development Corporation (CBDC), the New Brunswick Electric Power Commission (NBEPC) and Energy, Mines and Resources (EMR) have signed formal contracts to conduct the program. The CBDC has entered a licensing agreement with A.B. Carbogel to use their patented process and the plant is now designed and built and supplying fuel to Chatham on an as needed basis. The original plant schedule specified July, 1983 for completion of equipment installation and start-up and the first fuel was produced in late July.

The NBEPC has issued burner development and boiler modification contracts to Foster-Wheeler Ltd. (FW) and Combustion Engineering Ltd. (CE) for their respective boilers at Chatham. The current schedule for burner testing and development for the two units is shown in Fig. 2. This schedule shows that, at the time of writing, burners have been developed for Unit No. 1 by Forney Engineering, the burner manufacturing subsidiary of Foster-Wheeler. These were installed on the unit during July and a preliminary evaluation was conducted in late July 1983.

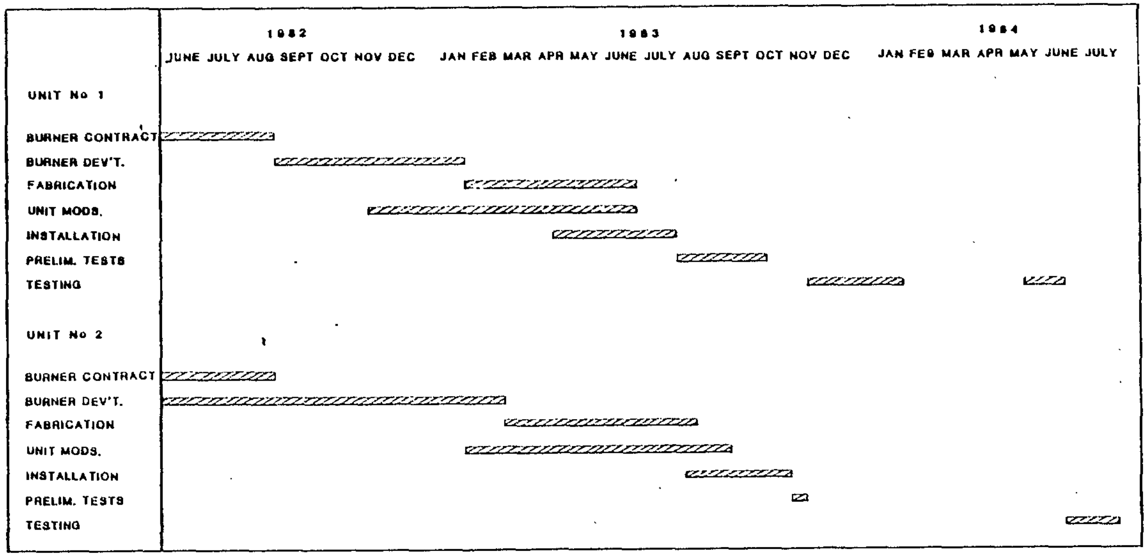


Fig. 2 - Schedule for burner development and testing at Chatham

UNIT NO 1. BOILER DESCRIPTION AND TEST PROGRAM

The Chatham Unit 1 boiler was originally installed in the late 1940's and was designed to fire pulverized coal. The boiler is a balanced draft, type SA unit with the following nameplate data:

Manufacturer:	Foster Wheeler
Steam flow at super heat:	63,600 kg/h
Operating pressure:	4170 kPa
Steam temperature:	450°C
Feedwater inlet temperature:	177°C
Number of burners:	4 (2x2) Front Fired

Steam from the boiler is used to drive a turbine generator with an output of approximately 12.5 MW(e). The boiler was converted to heavy oil and was used for the coal-oil mixture program mentioned earlier. A schematic side view of the boiler is shown in Fig. 3.

The burner and windbox shown in Fig. 4 is specifically designed to burn CWM fuel. It consists of two combustion air passages and a specially designed atomizer. A primary air zone is created along the burner centreline at the exist of the primary throat. Low velocity air passes through this zone to generate strong recirculation and long fuel residence times. Secondary air passes through an outer rotating air register for further stabilization and mixing. The atomizer is of a conical internal-mix design for low pressure operation. Each burner is rated at approximately 40 GJ/h.

Ignition and support energy are provided by a single high energy spark igniter and two light-oil pilots rated at 6 GJ/h each. Experience at Chatham has, however, shown that for light-off and low load support only one light-oil pilot is necessary.

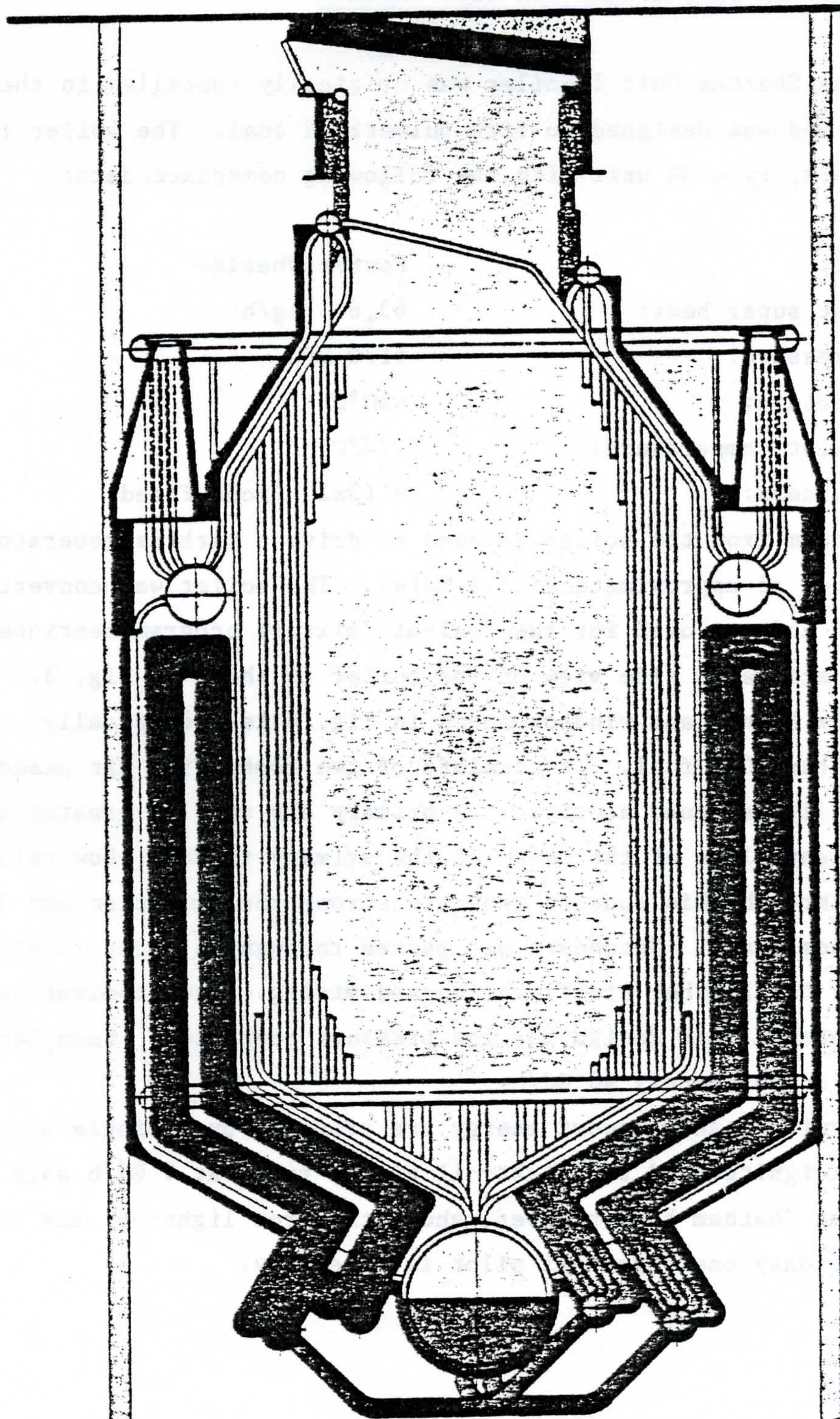
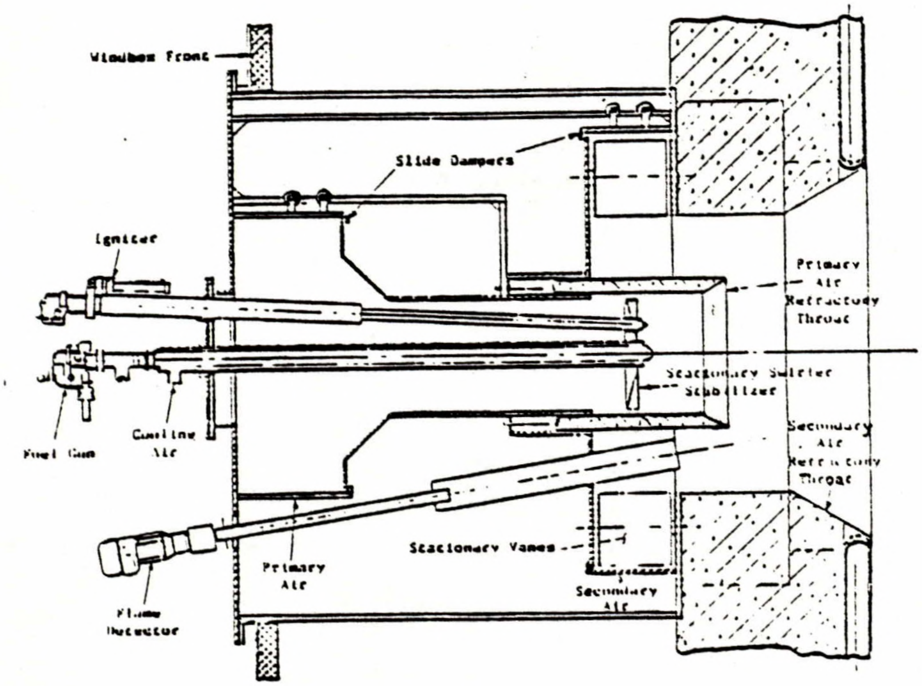
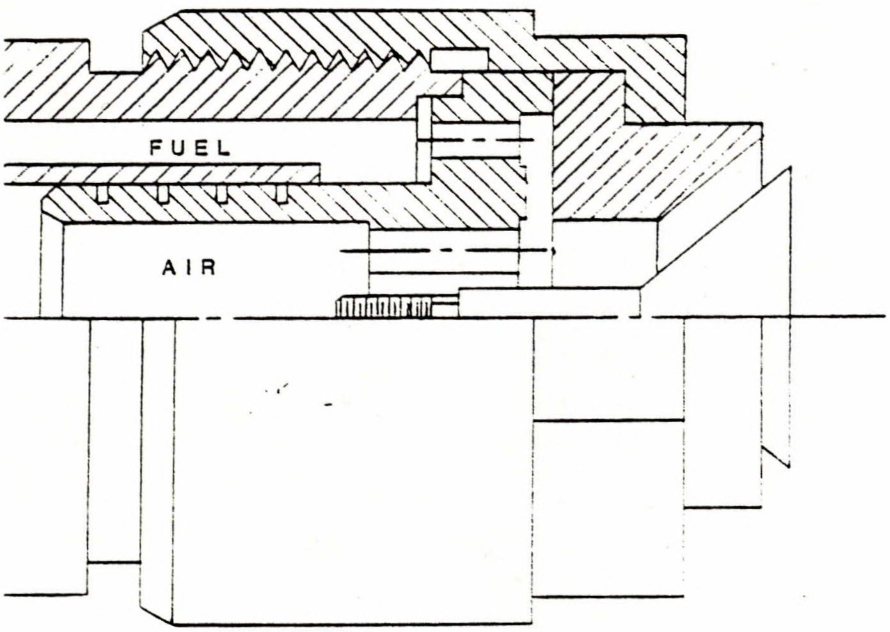


Fig. 3 - Illustration of Chatham Unit No. 1, front-wall fired boiler



a) Burner Assembly



b) Atomizer

Fig. 4 - Schematic of burner and atomizers
for Chatham Unit No. 1

The burners were supplied as four independent burner/windbox assemblies. To accommodate the new burners, modifications were required to both the boiler front wall and combustion air ducting adjacent to the burners. A total of five wall tubes were replaced to accommodate the larger burner throats. Brickwork and refractory around the throats were modified accordingly. The combustion air ducts were also modified to fit the deeper CWM burner windboxes. Balancing dampers were removed from the duct and incorporated as sleeve type dampers over the outer burner registers.

Each burner is designed to allow a wide range of adjustments, some of which are not normally present on commercial burners. These adjustments allow the precise positioning necessary to optimize burner performance. Some of the adjustable features include:

- Inner throat position
- Swirler position
- Atomizer position
- Igniter and HESI positions

The burner is easily adapted to heavy oil firing by changing the fuel gun tip and the position of the primary air damper. No other modifications are necessary.

A test program was developed to evaluate both burner and boiler performance on CWM and oil. The basic objectives of the program were:

(1) to investigate the wear characteristics of various burner nozzle materials;

(2) to evaluate burner performance with respect to carbon burnout, excess air, NO_x, SO_x and CO_2 emissions;

(3) to evaluate boiler performance, efficiency and changes in heat transfer characteristics.

All baseline oil tests and 100 h of the wear evaluation have been completed. The full test program is expected to be completed by early spring. The unit has been fired at full load on CWM without support energy. Light-off has proved to be routined as was transfer back to fuel oil. A 20% load was achieved without support fuel. Mechanically, few problems have been experienced with either burners or fuel handling equipment. The firing systems have generally performed well with some minor problems caused by foreign material contamination.

UNIT NO. 2 BOILER DESCRIPTION AND TEST PROGRAM

Chatham Unit 2 boiler is of the same vintage as unit 1 and was designed to fire pulverized coal. The boiler is a balanced draft, type VU unit with the following nameplate data:

Manufacturer:	Combustion Engineering
Steam plan:	95,500 kg/h
Operating pressure:	6040 kPa
Steam temperature:	480°C
Feedwater inlet temperature:	180°C
Number of burners:	4 corner-fired

A schematic of the boiler is shown in Fig. 5 and the burner windbox and fuel atomizer system is shown in Fig. 6.

The initial nozzle development program specified a four-step approach. The first step consisted of bench-scale characterization of the CWM in parallel with the basic development of the different atomizer alternatives. Next, the developed burner tips were tested to establish atomization quality. The most promising alternative was selected and this tip was then full-scale combustion tested at 70 GJ/h (Fig. 6) at the CE test facilities in Windsor, CT., U.S.A.

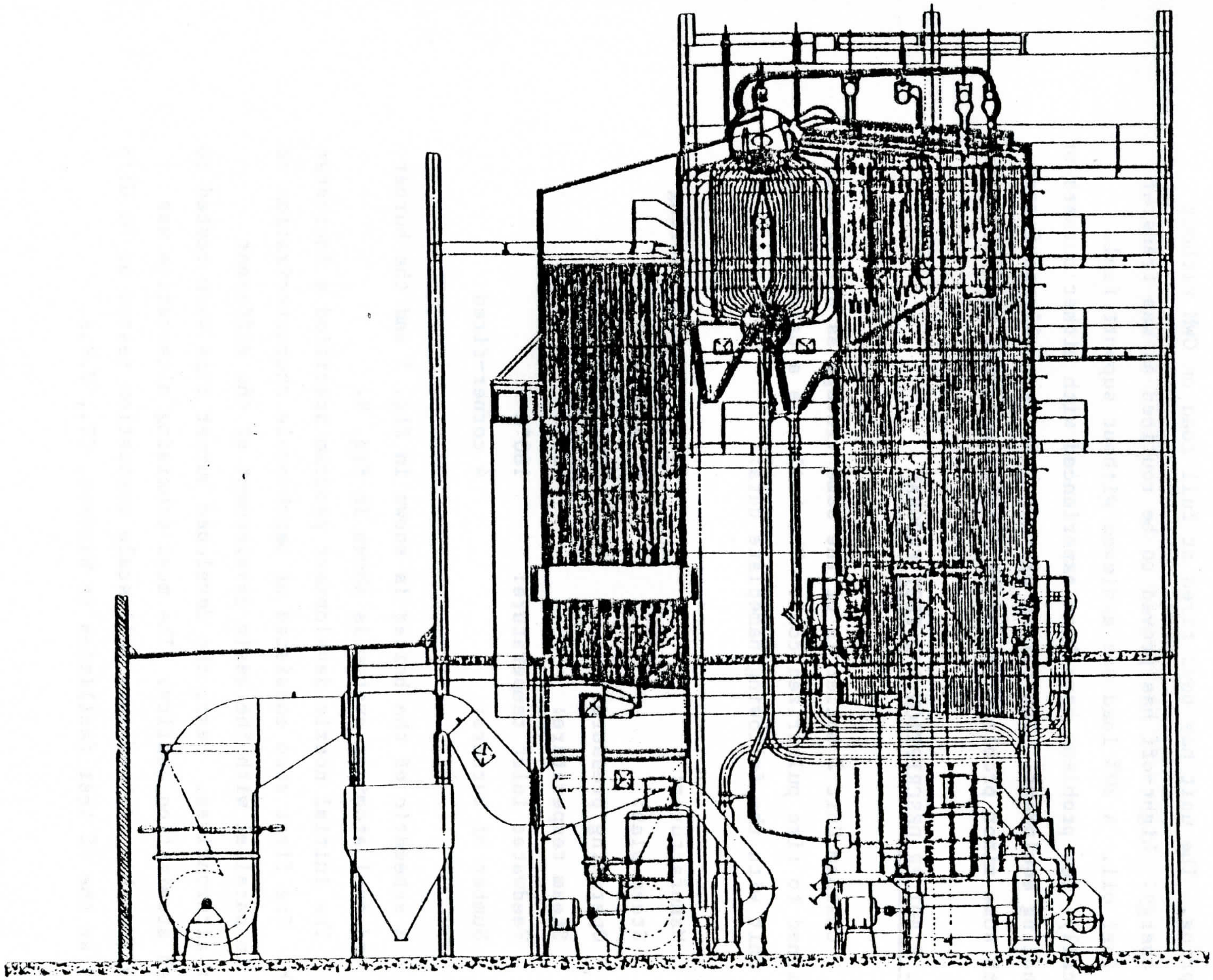
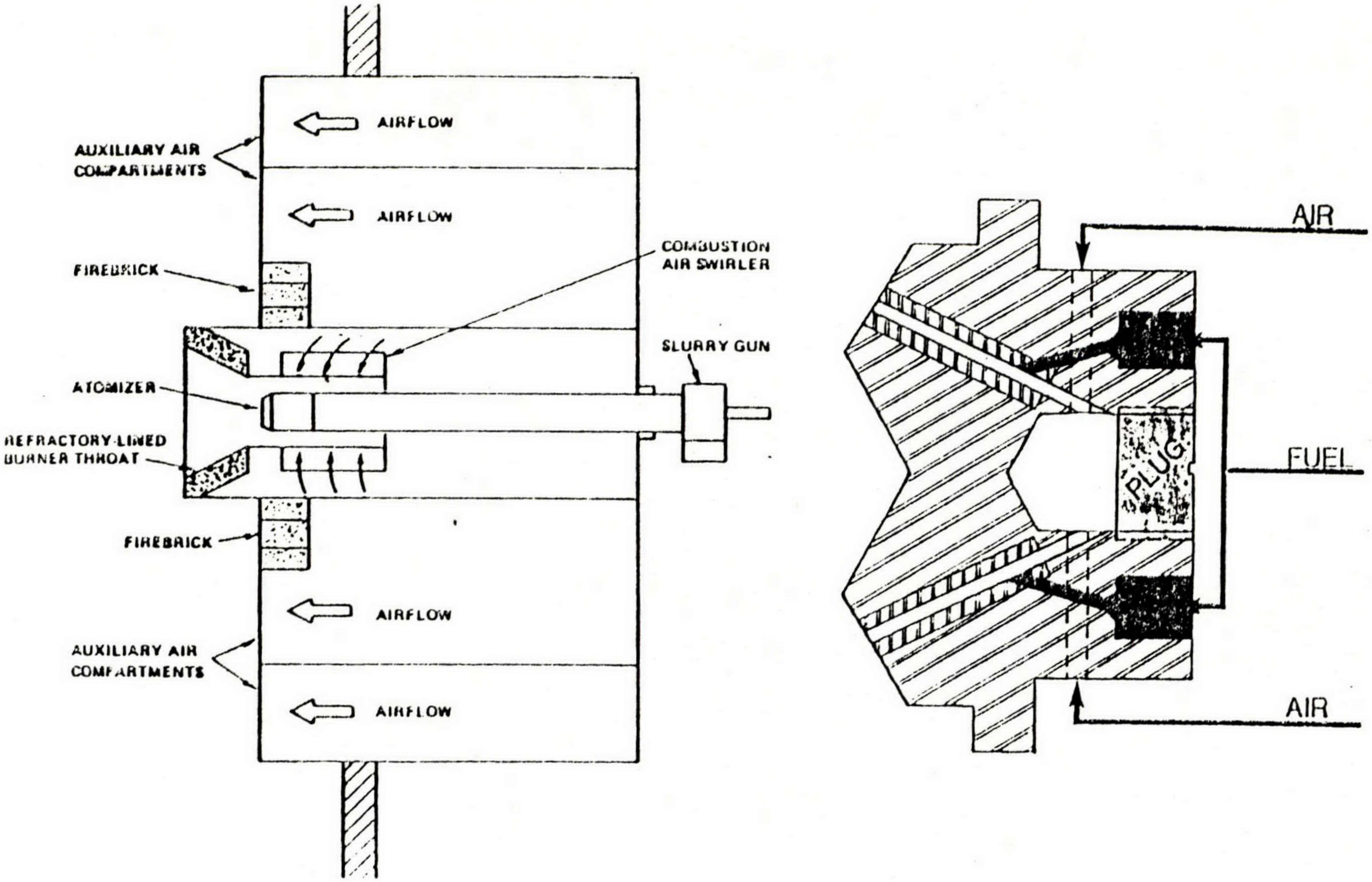


Fig. 5 - Schematic of Chatham Unit No. 2, tangentially-fired boiler



a) Burner Assembly

b) Atomizer

Fig. 6 - Schematic of burner and atomizer for Chatham Unit No. 2

To fire the CWM in unit 2, windbox modifications were carried out. The top and bottom air registers were removed, along with the two adjacent coal buckets. The oil compartment was also removed and replaced with a refractory-lined bucket. Also, to supply combustion air to the centre compartment at a higher pressure, a booster fan and associated ductwork had to be added to the system as shown in Fig. 6. The total ignition system capacity was 6 GJ/h. This ignition energy is considered necessary to ignite and stabilize the CWM.

Initial tests at Chatham were undertaken in November 1983 and some modifications to the burner system were subsequently made. It is expected that the complete CWM performance test on unit 2 will be completed by spring 1984 as shown in Fig. 2.

FUTURE PROGRAM

The major objective of the current program is to assess whether CWM technology is feasible for use in utility boilers. Obviously many side benefits of the program will accrue in the industrial sector, particularly in the area of burner development. Because of the much wider variety of types of industrial boilers and process combustors, clearly the non-utility development of coal-liquid mixture technology will be much more difficult. Although much scale-up information will be generated as larger utility demonstrations proceed, the small Chatham units are typical of many industrial boilers which may directly utilize the operating experience gained there. Consequently, at the conclusion of the CWM program in Canada, some of the industrial sector, particularly large kilns and boilers, may convert to CWM as fuels. There will be a need for significantly more R&D support for the penetration of coal-liquid mixtures into the industrial, marine and diesel markets.

The next stage planned for the CWM utility demonstration program in Eastern Canada will be the selection and testing of burners in a 20 MW(e) oil-designed front-wall fired boiler located in Charlottetown, Prince Edward Island and operated by Maritime Electric Company Ltd. This will not only test burner technology as at Chatham, but will indicate boiler-side feasibility of the fuel in more compact oil-designed units. It is hoped the Charlottetown demonstration will be completed in early 1985.

Following the Chatham and Charlottetown demonstrations, scale-up is the next obvious step. Design of burners for front-wall or tangentially fired boilers in the 50 to 150 MW(e) range is planned as a third phase of the CWM program. A start has been made on a generalized derating study which uses modelling techniques to predict boiler performance when boilers designed for oil are fired with CWM(10,11). A priori reasoning cannot predict specific derating effects because there is insufficient experience connecting the formation of ash from coal-water flames burning finely ground coal in an atomized spray to slagging or erosive effects on boiler tube surfaces. Also, it appears that the emissivity and burning characteristics of CWM are unlike coal and this will significantly influence derating. When more information concerning ash properties, ash formation, and combustion characteristics is available from the current work, the program will proceed to include specific application studies to 100 and 150 MW(e) oil-fired boilers in Atlantic Canada. These studies will determine the minimum overall cost, by balancing the costs of boiler operation and derating against those of fuel preparation and beneficiation.

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