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Energy Mines and Resources Canada

October 1982

For presentation at the American Flame Research Committee International Symposium on Conversion to Solid Fuels, Newport Beach, California, October 26-28, 1982.

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
DIVISIONAL REPORT ERP/ERL 82-42 (OP)

EVOLUTION OF CANADA'S COAL-LIQUID MIXTURE PROGRAM

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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 motives for this interest have been the rapidly rising cost of oil coupled with an insecurity of supply. These factors have caused the western industrialized nations to seek feasible alternatives to petroleum-based fuels.

A description is given of the three phases of an early program undertaken at Chatham, New Brunswick in which coal-oil mixtures were used in a small utility boiler. Phase I of this program showed that burner and equipment wear was a significant impediment to coil-oil mixture utilization. This led to the inclusion of an oil agglomeration coal beneficiation process being incorporated into the fuel preparation process as a means of reducing the sulphur and abrasive ash content of the coal.

The evolution of this early program into the present program of coal-water slurry technology development for utility applications is described in detail, together with other support programs which may enable coal-liquid mixtures to penetrate the industrial and transportation sectors.

1. Introduction

Coal-liquid mixtures could replace oil in many stationary combustors and in some mobile uses provided that they can be burned reliably, cleanly, safely and economically. This paper deals with Canada's approach to development of coal-liquid-mixture technology to meet these requirements. Canada is a net importer of some ten percent of its oil consumption and will become 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 domestic fuels, particularly natural gas and coal. Coal-liquid mixtures offer a means of replacing oil by coal where direct substitution of a solid fuel is impossible or uneconomic.

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 sulphur. The need for oil replacement is thus most urgent where it is most difficult to find an economic substitute. Coal-liquid mixtures may ultimately find use in the West or for export but the decision was taken to investigate their potential in eastern Canada because of the most urgent need, because of the possibility of environmental benefits, and because there are more smaller units of a suitable size for demonstration in the East.

Economics dictate that coal-liquid mixtures, because they inherently cost more per unit of energy than coal, must be tailored for a fuel market in which they can command a higher price than coal. To command this higher price, the coal-liquid-mixture fuel must have desirable qualities that its coal feedstock lacks. The primary qualities required, besides combustibility, are behaviour as a liquid with appropriate viscosity for pumping, transportation and storage, minimization of ash-handling and collection requirements, and, a vital selling point in some cases, a decrease in sulphur content.

Utilities and other industries which might use coal-liquid mixtures are generally not in a position to switch to such a fuel or even to assess the economics of switching while there is no proof that it can be burned reliably and safely. The program will therefore demonstrate the combustion of coal-liquid mixtures at small commercial scale, make available trial quantities of coal-liquid mixtures manufactured from Canadian coal, and ensure that all ancillary equipment is available for conversion of larger units. Once these goals have been achieved it is expected that normal commercial practice will take advantage of the technology wherever it is economic to do so.

2. 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 in a pilot-scale research tunnel furnace. The results of this work were presented at a joint industry/government seminar in 1972(1) in order to stimulate interest in coal-oil mixture technology. 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 coal-oil mixture combustion was discontinued because the availability of cheap fuel oil did not make coal-oil mixtures attractive to industry. However, following the rapid escalation of oil prices in the late seventies there was renewed interest in coal-oil mixture technology and Energy, Mines and Resources, 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 and D.

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

The Chatham Thermal Generating Station, Unit No. 1 of 10 MW(e) generating capacity was selected for this project, due to 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 coal-oil mixture study. The boiler, manufactured by Foster Wheeler, is rated at 17.6 kg/s steam flow and is a dual-fired boiler, having the capability for independently firing coal or oil and of simultaneously burning coal and oil using separate burners.

The Phase I coal-oil mixture program at Chatham was begun 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 coal-oil mixture 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 the coal-oil mixture application and as a consequence 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, have previously been reported in detail[4].

Modifications were made to the coal-oil mixture preparation system during the 1978/79 Phase II program to accommodate the NRC oil agglomeration system. 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.

The oil agglomeration process[5] has become a key part of the Canadian coal-liquid mixture program where Eastern coals of high ash content are to be used.

The principle of the method is that fine particles in suspension can readily be agglomerated by the addition under agitation of a bridging liquid which preferentially wets the solid particles and is immiscible with the suspending liquid. In the cleaning of coals by grinding in water to release impurities, the carbonaceous constituents can be agglomerated and recovered with many different oils as a collector liquid, while the inorganic constituents remain in the aqueous suspension and are rejected. Conventional gravity methods for the cleaning of coals are not practical for particles finer than about 150 micrometres and methods such as froth flotation which depend upon differences in surface chemistry of coal and mineral matter are used for the finer sizes. Flotation, however, becomes less effective where extremely fine sizes of coal must be processed or if the clay content is high. The oil agglomeration process provides an attractive method for the cleaning and recovery of these fine coal particles in the form of compact, oil-bonded aggregates.

The ability to utilize fine coal particles is particularly useful for coals which contain finely-disseminated impurities as in the case of the New Brunswick coal used at Chatham. These coals can be ground in water to a size sufficiently fine to liberate the required amount of impurities and reconstituted as oil-bonded agglomerates free of the liberated mineral matter. Alternatively, fines contained in waste slurries from conventional cleaning operations can be recovered by oil agglomeration as a low-cost source of clean fine coal. This latter aspect is particularly important where friable coals are being mined.

Two types of burner tips were tried 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 with two major objectives, to improve the effectiveness of the agglomeration process and to test two new burners for long-term performance on coal-oil mixture. Neither of these objectives were met primarily due to the equipment wear problems associated with the highly abrasive coal used to make the coal-oil mixture[7,8].

After three phases amounting to more than 1500 hours of operation on coal-oil mixture ranging from 10 wt % to 40 wt % coal, it was concluded that:

The abrasive wear of burner tips has been the main obstacle preventing the successful utilization of coal-oil mixture technology in a small utility boiler in Chatham N.B. The abrasive wear which results in progressive flame deterioration can be attributed to the use of a highly abrasive coal in the coal-oil mixture. The problem still persists even when incorporating an in-line coal cleaning process to reduce the ash and pyrites content of the coal.

Pumps, valves and secondary grinding equipment also suffered from significant wear-related damage which resulted in deterioration of performance. It is felt that this problem can be eliminated by appropriate materials and equipment design considerations. Pipework was relatively unaffected by wear, essentially due to the low prevailing fluid velocities.

The major problem of burner tip erosion may be solved by choice of a less abrasive coal, improved coal cleaning by ash and pyrites rejection, further reductions in coal particle size, materials selection or the use of externally atomized burners with low coal-oil mixture efflux velocities and a simple configuration.

In 1980 and 1981 a pilot plant for production of coal-oil-water mixtures was constructed in Dartmouth, Nova Scotia, with assistance from the governments of Canada and Nova Scotia through their Oil Substitution and Conservation Agreement. This pilot plant is designed to produce about 5 tonnes per hour of coal-oil-water mixture containing about 60 percent coal, 25 percent oil and 15 percent water. Special proprietary features of the preparation process include a specially designed grinding mill, ultrasonic stabilization of the mixture, and spherical agglomeration to reduce mineral matter. Production and small-scale combustion of fuel (known by the proprietary name of Scotia Liquicoal) from this plant have progressed well, apart from the severe wear on burner tips which paralleled early experience at Chatham. The relative advantages of a coal-oil-water mixture over coal-water are its better ignitability and reactivity and less susceptibility to freezing: the relative disadvantages are that it requires a substantial proportion of oil and that its viscosity varies widely with temperature.

In developing a marketing strategy for their product Scotia Liquicoal conducted field trials in small commercial installations to demonstrate the feasibility of burning their fuel . During these boiler evaluations, burner tip erosion remained the major problem which the company was then compelled to address as a matter of some urgency. Using the experience gained at Chatham and in consultation with experts at the National Research Council (NRC) and the Canada Centre for Mineral and Energy Technology (CANMET), a ceramic burner tip was selected and spray tested for 200 h on coal-oil-water mixture under a simulated operating conditions. When this nozzle was compared to a conventional Y-jet tip the abrasive wear was less than one percent compared to 40 percent for the Y-jet (measured as the percentage increase in flow due to flow channel wear under standard test conditions[9]). The ceramic nozzle has now been rigorously tested under intermittent and steady conditions without failure despite some extreme thermal shock procedures. The company now plans to test the nozzle in a 1000 h demonstration in an industrial boiler or kiln.

3. Current problems and opportunities

The price range which coal-liquid mixtures can command is determined by competing fuels. In large industries and electric utilities these fuels are usually residual oil, Bunker 'C' or coal. Smaller energy consumers use No. 2 or No. 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 that of crude oil. In order to attract customers by pricing significantly below that of the competition, coal-liquid mixtures must therefore sell for less than 60 percent of crude oil prices on a heat value basis. The most expensive Canadian coal sells for about 40 percent 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 a coal-liquid mixture is one of the more expensive Canadian coals, there is about a 50 percent margin above its regular price available to cover additional preparation costs and return on investment.

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

Canada has the objective of decreasing its atmospheric emissions of sulphur oxides by 50 percent between 1980 and 1990 and the substitution of low sulphur coal for residual oil can materially assist in reaching this objective. The multistage cleaning process associated with coal-liquid mixtures 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 competitiveness of clean-burning natural gas sets an upper limit to the price.

In utilizing coal-oil mixtures in utility boilers, particularly those designed for oil-firing, many problems arise which must be overcome. Usually an oil-designed boiler is smaller, the steam-raising tube banks are configured differently and the gas velocities in the banks much higher than for an equivalent capacity coal-fired unit. In addition to this, coal slurry fuels contain ash which poses problems of tube erosion and slagging and/or fouling. The ignition, flame and heat transfer characteristics of coal-oil mixtures may be quite different from those of heavy fuel oil and therefore the heat release pattern from the flame may not be suitable for the oil-designed unit. The combination of all these factors usually means that the oil-designed unit will be derated; that is it will not be able to attain the maximum generating capacity for which it was designed when firing oil. The extent of this loss of electrical output will depend on the coal, its rank and reactivity, (volatile matter, inert macerals content, degree of oxidation) as well as the ash content and composition and the slagging/fouling propensity of the ash.

A coal-liquid mixture which burns well is not necessarily ideal for transportation or storage. The mixture should ideally have a low viscosity which does not vary with temperature and should be readily pumpable after long periods of storage. It should not freeze in anticipated weather conditions. It should contain a minimum of inert components to minimize transportation and storage costs. At the present stage of the program, transportation of coal-liquid mixtures will be by road, rail or barge, therefore the ultimate requirement for very low viscosity, which is needed for pipeline transportation, can be waived but the need for maximum concentration of combustibles remains.

Removal of mineral matter from coal is important for boiler performance, for economy of distribution, for ash disposal, and for 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. In the case of 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, where coals will be 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 coal-liquid mixtures, conventional washing is followed by milling and separation on the basis of surface characteristics: froth flotation for coal-water mixtures and oil agglomeration for coal-oil-water mixtures. Coal from the Sydney coalfield in Nova Scotia is particularly amenable to this combination of processes and shows promise of good yields with mineral matter in the 1.5 to 3 percent range and with about two-thirds of the original sulphur removed.

Several estimates have indicated that deposition of slag on the tubes of boilers tightly designed for oil firing would contribute very substantially to boiler derating which could be as much as 50 percent when coal is used as fuel. The site chosen for preliminary tests was again the generating station at Chatham, New Brunswick since it has two boilers originally designed to burn coal but recently adapted to burn oil, one front-wall fired and one tangentially fired, and of 12 and 23 MW(e) capacity respectively. The results obtained at Chatham, where coal-liquid-mixture burners will replace oil nozzles, will yield, at a small utility scale, virtually all the data required to assess burners and fuel without risk of damaging a bigger furnace or of seriously interrupting electricity supply.

4. Objectives of Present Program

The ultimate objective of the coal-liquid-mixture program is to derive enough data concerning the fuels and how to burn them that potential users will be able to make decisions to replace oil, based on economics and without technical risk. An essential sub-objective 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. Research into the application of oil agglomeration to coal-oil-water mixtures has indicated the costs in terms of light oil addition for various levels of rejection of mineral matter including sulphur. Depending on the fineness of grind and mineral content needed, light oil requirements may vary from 1 to 5 percent of coal weight. For coal-water mixtures, conventional cleaning applied to the highest quality coal can reduce mineral matter to 3 percent and sulphur to 1.2 percent: grinding and multistage flotation can reduce these levels to 1.5 percent and 0.8 percent respectively: if lower quality (less expensive) coals are used, the same process is expected to attain about 3 percent minerals and 1.5 percent sulphur, the cost difference being in the starting feedstock rather than in the process.

The program will include preparation and combustion of the cleanest coal-water mixtures that can be manufactured as well as fuels containing more ash and sulphur. This range of fuels will enable an economic assessment to relate cost of production to saleability and price which is one of the major objectives.

Use of coal-liquid mixtures by utilities requires a delivery and storage system, including stirring vessels where necessary, and pumps which can deal with fluctuations in diurnal and seasonal demand. The program will demonstrate methods of transportation which would be applicable to industrial users and at least one of the combustion tests will be scheduled in freezing weather so that any problems due to low temperature operations can appear and be solved. Addition of antifreeze may be necessary, this will add to the cost but may improve combustion characteristics or cause corrosion problems.

The performance of utility boilers designed for oil will be significantly different when using coal-water mixtures. The problem of unit derating 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 a typical coal-water mixture. Again, the derating will depend strongly on the fuel and the boiler design. One of the objectives of the current program is to provide data for the determination of the inter relationship between quality and quantity of mineral matter in the coal-water fuel, the flame and unit derating. The utility company will then determine the net loss in its system generating capacity if several units are to be converted to coal-water fuel. It must be noted that a significant requirement of the coal-water mixture program is that the slurry burners be also able to utilize fuel oil, thereby retaining the capability to attain full generating capacity during peak demand periods.

Assuming successful demonstrations at Chatham, the next step will be to design systems for burning coal-water fuel in larger utility units. In eastern Canada there is a 100 MW(e) front-wall fired unit which originally used coal but was converted to oil in 1969 to minimize particulate emissions; there is also a 50 MW(e) tangentially fired unit designed for oil-burning. The current program embraces the design of coal-water systems for these two units.

5. Details of Present Program

The present program comprises several elements which will combine to achieve the objectives set out above. These are construction of a 5 tonne per hour pilot plant at Sydney, Nova Scotia, for preparation of a coal-water mixture containing about 70 percent coal, the design of burners suitable for reliable combustion of this fuel, the demonstration of the use of fuel and burners at Chatham and the design of coal-water burner systems for larger units. The fuel preparation pilot plant will treat clean coal (- 3 mm) from an adjacent conventional dense medium coal preparation plant which reduces the mineral matter content from about 8 percent to 3 percent. The pilot plant will comprise two stages of grinding, particle size control, two stages of froth flotation (further reducing the mineral matter to about 1.5 percent) and the mixing to add a stabilizer. The process is based on the proprietary CARBOGEL process. The target solids content is 75 percent with viscosity in the 800-1000 centipoise range. Attempts will be made to use different coals with higher mineral matter and sulphur contents, and with poorer washability characteristics: use of high (coking) quality coal is planned for the first trials to minimize problems with ash handling but coal from a seam with lower quality could save $20 per tonne (of coal). The prepared fuel will be held in day-storage tanks for regular delivery by tank truck (three trucks per day for some 750 km) to Chatham: storage tanks of 500 m^3 capacity already in existence at Chatham will form the buffer to match demand with production capacity. Fuel production costs will be recovered by the producer through the price charged to the electric utility. The utility will pass on the differential between this price and normal coal-fired generating costs, as well as the cost of burner development, to the federal government. The schedule, which calls for construction of the pilot plant to begin in August 1982, should be completed by March 1983 with start-up tests in April and May and regular fuel production in June 1983.

Concurrently with the construction of the coal-water pilot-plant preparation facility, a program to develop slurry burners for the 10 MW(e) front-wall fired and 22 MW(e) tangentially fired units at Chatham NB will be undertaken. The two phases of the coal-water program are as follows:

Phase I:

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 10 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 performance trials in Chatham Unit No. 1 to be undertaken during Phase III. A similar program for tangentially fired units will be undertaken leading to performance trials in Chatham Unit No. 2 of 22 MW(e) capacity.

Key elements of Phase I will be a review of the state of the art of coal-liquid mixture burner technology and recommendation of the most promising burner concepts for coal-water mixture firing for each boiler configuration. Full scale burners will then be designed and tested prior to installation in the units at Chatham NB.

Phase II:

This phase will be to assess burner and boiler performance when firing coal-water mixtures in front-wall and tangentially fired boilers, with special emphasis on reliability of equipment. It is anticipated that 6000 tonnes of fuel will be prepared for the performance trials, 2000 tonnes for Unit No. 1 and 4000 tonnes for Unit No. 2. The fuel will contain less than 2 percent ash and be similar to that used in Phase I for burner development. The Phase II performance trials are currently scheduled for the Spring of 1983. It is expected that these two phases should lead to the scale-up and testing of burners for demonstrations of coal-water mixture technology in oil-designed utility boilers in the 50 to 150 MW(e) capacity range and of both basic configurations typical of eastern Canada.

During the last five decades, coal has been considered as a possible fuel for diesel engines. This interest has usually been moderated by the fact that until fairly recently, the availability of relatively cheap diesel fuel together with its ease of use has made other fuels, unattractive. For the same reasons that coal-liquid mixtures are now receiving attention as industrial and utility fuels, a coal-based diesel fuel becomes more attractive. Chemically processed coal-derived fuels are very costly and some attention is now being given in Canada to mixtures of very clean coal and diesel fuel as a means of reducing the consumption of expensive refined petroleum products in diesel engines. Obviously high speed diesel engines are unsuitable for coal-liquid mixtures, but the low and medium speed diesels with longer combustion chamber residence times may be suitable for less reactive fuels such as coal-liquid mixtures. The major problem with the use of coal-liquid mixtures in diesel engines is likely to be the injector and the possibility of abrasive wear and premature failure. In order to address this problem CANMET and the NRC have been studying injector performance using a clean coal-diesel fuel mixture. The feed coal supplied was 3.3 percent ash Nova Scotia coal which was then cleaned by the oil agglomeration process to less than one percent ash. In the final mixture, the clean coal was mixed to 28 wt percent with diesel fuel and was 90 percent less than 10 micron. Some problems with stability were observed but it was concluded that with some modification and materials hardening the injector would withstand prolonged use. It is now planned to conduct stationary combustion tests in a medium-speed diesel locomotive engine.

In its role of technology support to the various coal-liquid mixture projects that are being undertaken, CANMET is involved in contract and in-house research to address the following key problem areas:

1) Burner development for coal-liquid mixtures including the study of abrasive wear of atomizer components.

2) Assessment of the potential loss of capacity (derating) when converting oil-designed boilers to coal-water mixtures.

3) Slagging and fouling assessments of coal-liquid mixtures in utility and industrial boilers and combustors.

4) Parameters for upgrading existing and designing new environmental control equipment for oil-fired boilers when converting to coal-liquid mixtures.

5) Combustion and heat transfer properties of coal-liquid mixtures in various combustion system configurations.

6) Upgrading coal quality by advanced cleaning techniques in order to minimize abrasive wear and to reduce environmental emissions of sulphur dioxide and flyash.

6. Current Progress

At the time of writing, formal contracts have been signed among the Cape Breton Development Corporation, the New Brunswick Electric Power Commission and the federal government to conduct the program, Cape Breton Development Corporation has entered a licensing agreement with Boliden - Scaniainventor to use their CARBOGEL process, the detailed design of the pilot plant has been finalized, requests for proposals have been issued and five bids have been received for design and development of burners for front-wall and tangentially fired boilers. Foundation work for the pilot plant has begun and two batches of coal-water mixture of 30 tonnes and 150 tonnes have been produced in Sweden using Nova Scotian coal. These batches have met the design objectives of less than two percent ash and more than 70 percent coal with a viscosity less than 1000 centipoises; the sulphur content was reduced from about 2.5 percent in the raw coal to below one percent; the weight yield of coal to fuel was over 80 percent and the heating value yield over 90 percent.

7. Future Program

The major emphasis of the current program is to assess whether coal-water mixtures are feasible for use in utility boilers. There will obviously be many side benefits of the program in the industrial sector, particularly in the area of burner development for coal-water mixtures. Because of the much wider variety of types of industrial boilers and process combustors it is clear that the non-utility development of coal-liquid mixture technology will be much more difficult. A start has been made in this direction with the development of the ceramic atomizer by Scotia Liquicoal, and it is anticipated that this burner will require industrial demonstration in boilers, kilns, both of which are drastically different in their burner, flame shape and heat transfer requirements. However, whilst 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 coal-water mixture program in eastern Canada, some of the industrial sector, particularly large kilns and boilers, may convert to coal-water mixtures as fuels. However, smaller units, which may not be large enough to accommodate this slower burning unreactive fuel, may be compelled to use coal-oil or coal-oil-water mixtures. There will be need for significantly more R and D support for the penetration of coal-liquid mixtures into the industrial, marine and diesel markets.

Following the Chatham 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 coal-water mixture 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 coal-water mixtures. 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. When more information concerning ash properties and ash formation is available from the current work, the program will go on to include specific application studies to 100 and 150 MW(e) oil-fired boilers in Nova Scotia which will predict the minimum overall cost, by balancing the costs of boiler derating against those of fuel beneficiation.

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