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H. Whaley

Canadian Combustion Research Laboratory

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Horace Thaley
Canadian Combustion Research Laboratory

ABSTRACT

In 1972, the Canadian Combustion Research Laboratory (CCRL) of the Department of Energy, Mines and Resources conducted a limited evaluation of the combustion characteristics of a coal- No. 2 fuel oil suspension in a pilot-scale research tunnel furnace. The results of this work were presented at an industry/government seminar in May 1972 in order to stimulate interest in coal-oil mixture (COM) technology. At that time there was little interest in Canada in the subject and the program was subsequently discontinued. Recently there has been renewed interest in COM's as a means of substituting coal for oil which was prompted by rapidly escalating oil prices and projected shortages.

In order to encourage the use of coal in place of premium fuels, the Department of Energy, Mines and Resources Coal Conversion Program has invited R and D projects for funding which meet this objective. The program, which was initiated in 1976 has one project involving coal-oil mixtures currently in progress in Phase II 1977-78 and three more will commence during Phase III 1978-79 which began on April 1, 1978. A brief description of each project is given.

INTRODUCTION

In Canada, the federal department of Energy, Mines and Resources (EMR) is the principal agency responsible for the development, utilization and conservation of the mineral and energy resources of the country. Within the department are a number of groups engaged in a co-ordinated research program which is directed towards the development of specific mineral and energy technologies for national use. These groups fall under the research organization of EMR the Canada Centre for Mineral and Energy Technology (CANMET), which is directly responsible for administering the Mineral and Energy Research Programs. In addition, to the in-house program of energy and mineral research, some of which is jointly funded with industry, there is a government sponsored program of contract research. Research projects in specific energy and mineral related areas are invited for consideration and may either be fully funded (100% Government Funding) or jointly funded (50% Government - 50% Project Proposer).

In order to encourage the use of coal in place of premium fuels, the department initiated the coal conversion program in 1976 to meet this objective. In Phase II of the program which covered the period April 1, 1977 to March 31, 1978 a jointly funded program with the New Brunswick Electric Power Commission was initiated to study the feasibility of burning coal-oil mixtures in a small generating facility. Phase III of the program covering the period April 1, 1978 to March 31, 1979 includes a continuation of the New Brunswick Power project and the initiation of three others dealing with various aspects of coal-oil mixture research.

BACKGROUND

In 1972, the Canadian Combustion Research Laboratory (CCRL), which is a constituent laboratory of CANMET, conducted a limited in-house program to study the combustion characteristics of No. 2 fuel oil - coal slurries in a pilot-scale research tunnel furnace. The results of this work were presented at a joint industry/government seminar in 1972 in order to stimulate interest in coal-oil mixture technology.[1] Subsequent evaluations of the data were presented at the 1976 ASME Winter Annual Meeting and the International Flame Research Foundation (IFRF) 4th Members Conference held in May 1976 in Holland.[2, 3] At the time the research program was being conducted and subsequent to the coal-in-oil seminar there appeared to be little interest in Canada in coal-in-oil mixture combustion and the in-house program was discontinued in favour of other higher priority combustion research projects.

Recently, renewed interest in coal due largely to rapidly increasing oil prices has focused attention on the potential of coal-in-oil mixtures as a means of using coal without the costly burner and equipment modifications usually associated with conventional coal combustion. At the present moment CCRL has scheduled an in-house coal-in-oil mixture combustion program utilizing No. 6 fuel oil and selected Canadian coals. The flame and heat transfer characteristics of COM flames will be examined in the pilot-scale research tunnel furnace. The program which will begin in the fall of 1978 is essentially a continuation of that which was discontinued in 1972. However, the major effort of the Department of Energy, Mines and Resources in COM R and D lies in the private sector through the coal conversion program research funding.

COAL CONVERSION PROGRAM COM PROJECTS

New Brunswick Electric Power Commission

The New Brunswick Electric Power Commission COM project is essentially a feasibility study being conducted in a small power station boiler. The initial phase of the project which began in October 1977 has been described by Jeffries etal.(4) The plant selected for the project is located at Chatham, New Brunswick and comprises two small units of 12.5 MW and 21 MW with the former being used for the COM project. Due to the age of the plant and its relatively small size, it is ideal for research purposes since it is not normally operated because of power generation economies. This stand-by situation allows ample time for the modifications and test operation without being constrained to supply power to the grid. The unit selected is a Foster Wheeler three drum type supplied in 1945. It is designed to generate 140,000 lb/hr of steam at 605 psig and 835°F from feedwater at 350°F. The combustion chamber is reverse fired in which the hot flame gases recirculate back along the side walls before entering the boiler tube banks. The boiler is designed for either coal or oil firing, consequently boiler modifications to permit COM firing will be minimized. The modifications to the fuel supply system have been made so that the COM supply system is in parallel with the existing heavy fuel oil supply to allow for rapid change over in case of an emergency or standby power demand.

In the COM preparation system, the coal is fed from the bunker into the mill where it is pulverized to PF fineness, 80% through 200 mesh. A cyclone separator then separates the coal and primary air, the latter being passed through a baghouse to collect the coal fines, which may then be returned to the COM blender. From the cyclone separator the coal is gravity fed via a rotary screw feeder into the COM blender. Initial mixing of the COM is achieved by direct contact of the incoming supply of heavy fuel oil and coal from the coal feeder. Some preliminary coal wetting is avhieved by an oil spray located above the incoming coal feed. The slurry for firing at the boiler is extracted from the blender via a recirculation line which is necessary to prevent the settling out of coal at low flow rates or when the boiler is shut down. Provision is made for steam purging of all COM lines supplying the burners and the return line to the blender.

The four burners on the boiler are Raskin steam atomized burners with large flow apertures. Operation with 10% coal slurry has shown considerable wear on these burner tips and new materials and burner designs will be investigated for the next phase of the work. The bulk of the COM preparation system was purchased from General Motors, Warren, Michigan, USA at the termination of tests at the Saginaw plant.

Operation of the boiler during the initial phase has been with both coal and oil separately as well as with a 10% coal-in-oil mixture. The coal used was Minto New Brunswick coal usually supplied to the power commission, which has 20-25% ash and about 8% sulphur. It will be interesting to compare the boiler and emission performance of COMs with the separate fuels particularly with coal alone to see if there are any changes in superheater fouling or slagging tendencies or other operational difficulties.

The objectives of Phase I of the program:

1. To demonstrate a coal/oil slurry comprising Minto NB coal and a typical heavy fuel or No. 6 fuel oil can be effectively burned.

2. To investigate environmental emissions and fly ash distributions

3. To ascertain whether simple mechanical mixing of coal-in-oil gives a COM which is suitable for power plant operation.

4. To investigate the heat transfer characteristics of the furnace when firing coal/oil slurry and coal and oil separately.

Phase II of the project which began on April 1, 1978 will extend the range of coal contents studied up to 40% by weight. In addition, the COM preparation system will be changed to include the National Research Council of Canada (NRCC) coal beneficiation process which has the capability of substantially reducing the ash content and halving the sulphur content of the Minto NB coal.(5) It is hoped that the reblending of the agglomerates can be achieved in the existing blender without substantial modification. During Phase II, twelve weeks of operation on various ranges of COM are planned and the boiler performance and emission characteristics will be monitored.

Saskatchewan Research Council

The Saskatchewan Research Council project is entitled "Proposal to Determine Rheological Properties of Coal-Oil Slurries". The major objective of the project which was scheduled to begin on April 1, 1978 is to obtain sufficient experimental rheological data on selected coal-oil mixtures to be able to undertake the design of transfer pipelines for potential coal gasification plant and COM combustion equipment likely to be utilized in Canada. The project will be comprised of our stages, three experimental and one of correlation which will take until the end of December 1978. Briefly these stages are:

(i) Selection of appropriate coals and oil; this will be undertaken by the Saskatchewan Research Council in collaboration with personnel from EMR and the provincial energy agencies of British Columbia, Alberta and Saskatchewan. A range of coals suitable for gasification and combustion will be selected mainly from coal fields in the western provinces. In addition, samples of bitumen and pitch from oil-sands processing plant will be made available and slurries with oil will be examined. The oil base will likely be No. 2 fuel oil and heavy fuel oil refined from western Canadian feedstock although it is possible that some pipeline crude could be used as the oil base of a COM.

(ii) The coals and oils selected will be evaluated separately; the relevant chemical compositions and physical properties will be determined for the samples of each obtained.

(iii) Rheological measurements of the COM's; the viscosities of each COM will be determined using a Brookfield coaxial viscometer. The coal or pitch/bitumen proportion in each COM will vary from 20% to 60% by weight. Slurry temperatures up to 200°C will be investigated. Various particle size distributions of the coal component of the COM will be selected to correspond to the different requirements for gasification and combustion.

(iv) After the rheological data on the COM's is obtained these will be correlated into functional relationships which can be used for design purposes. Empirical or theoretical equations will be developed from which piping requirements, pressure gradient and deposition velocities can be calculated for practical slurry handling equipment.

Ontario Research Foundation

This project is a study of the combustion and emission characteristics of coal-oil mixtures in a research tunnel furnace. The project has a scheduled starting date of April 1, 1978 and an estimated duration at the present time of 14 months. This project is the only one of the four described in which other co-sponsors provide funding besides the federal government. The co-sponsors are the Ontario Ministry of Energy, Gulf Oil Canada Limited, The Steel Company of Canada Limited and Ontario Hydro. Each co-sponsor will provide technical as well as financial input to the research program. In addition to investigating the combustion and emission

characteristics of COM's the Ontario Research Foundation (ORF) will examine potential fouling and slagging problems usually associated with the combustion of low grade coals. The project is aimed at the introduction of new and improved technology to COM combustion both to optimize fuel efficiency and to reduce levels of pollutant emissions. The following elements comprise important aspects of the studies:

(i) Use of the NRCC coal benefication process to provide spherical coal agglomerates with reduced ash and sulphur content which will then readily form a COM.

(ii) The Ontario Research Foundation hydroshear system which has successfully been used to supply emulsions of water and fuel oil will be adapted and used to blend the agglomerates into COMs.

(iii) Some of the COM combustion trials will be conducted using a high-intensity turbulent diffusion burner developed by Gulf and the Ontario Research Foundation. For comparative purposes tests will also be conducted on a conventional burner which will be selected by the co-sponsors of the project. Each burner will be fired on No. 6 fuel oil for reference purposes.

(iv) Water-in-oil emulsions have a demonstrated capability to reduce emissions and to change the characteristics of particulates. The role of water in COMs will be studied to see if the same benefits apply to their combustion.

The following stages will be carried out leading to the COM combustion trials which are scheduled to begin in July 1978.

(i) Coal Selection and Preparation:

The selection of suitable coal will be made by the project co-sponsors. Coal samples will then be obtained for analysis, grinding, benefication and agglomerate production and COM stabilization.

(ii) Coal-in-Oil Mixture Preparation:

The NRCC process produces agglomerates, these will be blended into a stable COM by the hydroshear process. Relevant physical properties of the COM will be determined.

(iii) Burner and Furnace Modifications and Combustion Performance Evaluation:

The test facility at the Ontario Research Foundation can handle burners of up to 20×10^6 Btu/hr capacity. It is currently equipped with the high-intensity burner which has been selected for part of the COM combustion trials. The co-sponsors will select a conventional burner that is widely used in Canada for comparative purposes. During the performance tests and exploratory trials, detailed an ysis of flue gas emissions, CO, CO_2, NO_x, SO_2, O_2 and particulates will be made using conventional monitoring techniques. The combustion performance of each burner both on No. 6 fuel oil and a range of COMs containing from 0 - 50% by weight of coal will be investigated. Any slagging or fouling problems not usually associated with oil firing will be studied, particularly with COMs of high coal content or containing coal of high ash content.

The Steel Company of Canada Limited (Stelco)

The project which is entitled "Development of Coal-Oil Slurry Fuels for Blast Furnace Injection" was scheduled to begin on April 1, 1978. Oil injection into blast furnace tuyères is not a new idea, with improved yield, blast furnace fuel savings and a reduction in the use of metallurgical coke being the major benefits. The aim of this project is to develop a slurry injection system which will use coal, coke oven tar, oil bottoms and creosote. The coke oven tar is a novel feature of the project and is attractive because of its availability in a steel works. The main objectives of the project besides the design of the slurry injection system are to find out the ability of the COM to displace fuel oil and natural gas in blast-furnace

ironmaking, and to what extent it will reduce the requirement for metallurgical coke. In this area coal-tar slurry formulated from the above ingredients would have an extremely high C:H ratio. The coal which will be used in the first instance will be a low quality coke-making coal which is used by Stelco to make coke. It will be interesting to compare the performance of the raw coal in a COM with its performance in a blast furnace as metallurgical coke. Other coals which are non-coking may be tried later if time permits. The criteria which will be used to assess the effectiveness of COMs in slurry injection into blast furnaces will be:

(i) the ability to reduce overall blast furnace energy consumption.

(ii) the long term availability of fuels.

(iii) the ability to integrate with existing operation.

The main components of the research program are the determination of physical properties of the COM and its components, pumping experiments, fuel metering and composition, and the stability of the COM. A series of combustion trials are planned. These will use a single tuyère which essentially will be a "tunnel-type" furnace and the effect of COM combustion on cooling will be observed. The initial phase of the project is expected to lead to the engineering design of equipment for a three tuyère trial on a blast furnace.

CONCLUSIONS

Four projects involving COMs are being undertaken in Canada as part of the EMR coal conversion program. One, a feasibility study of COM combustion in a 12.5 MW utility boiler began in October 1977. Three other projects are funded from April 1, 1978. One is a study of the physical properties of COMs and two others are R & D projects involving COM combustion and equipment development.

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