Energy, Mines and Resources Canada
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CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

ANNUAL REPORT OF THE ACTIVITIES OF THE CANADIAN COMBUSTION RESEARCH LABORATORY

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HIGHLIGHTS

A number of on-going projects at the Canadian Combustion Research Laboratory were modified or extended during 1980 in response to changing Departmental priorities and private sector needs. Energy conservation efforts, with resource assistance from the Conservation and Renewable Energy Branch, were broadened considerably and the work on coal utilization in industrial and electricity processes, much of which was cost-shared with industry, was given added impetus.

Under residential space heating, facilities were set-up to evaluate ultra-high efficiency gas furnaces, the sooting propensity of aromatic fuel oils derived from synthetic crude and the use of alcohol as an alternative to No. 2 oil. In addition, the replacement of oil by low-grade coal and biomass in large-scale equipment continued, with emphasis on elucidating the combustion characteristics of new thermal coals for export and on minimizing the technical risks for commercial fluidized-bed combustion systems. Environmental studies, an integral component of all combustion R & D, were addressed through a modest in-house project on the fate of trace elements and the abatement of acid rain precursors during combustion and through specific international collaborative agreements with the International Energy Agency and the International Flame Research Foundation on NO_x formations in flames.

As in previous years, CCRL scientists served as scientific authorities on a number of CANMET contracts designed to stimulate the research capability of private sector laboratories or to improve the competitiveness of Canadian industry. These contracts - valued at over $2 million - involved mostly technology development and demonstrations including $920 K for detailed designs for the fluidized-bed heating plant at CFB Summerside, $335 K for coal-oil mixture combustion and $50 K for automotive fuel economy trials under winter conditions.

Scientific input was also provided on a wide range of topics to the Natural Sciences and Engineering Research Council, the Canadian Electrical Association, The ENFOR program, and the federal-provincial agreements on Renewable Energy.

At year end the staff at CCRL numbered 24 including two new positions assigned to the Conservation sub-activity. Scientific, industrial and public interst in on-going projects resulted in 17 published papers, 20 lectures and seminars, 35 press and TV interviews and 23 internal reports.

CONSERVATION TECHNOLOGY (332000)

Transportation (332100)

Automobile and Truck Fuel Efficiency

Automobile Fuel Economy

Since 1973, CCRL has had a program to study the effects of Canadian climate on automobile fuel consumption. Results have indicated that engines with conventional technology, fuel economy degrades rapidly with decreases in ambient temperature. Engines having advanced combustion design, such as high speed diesels, lean burn or stratified charge, degrade far less, with the added benefit of lower emissions. Results have been reported to the Society of Automotive Engineers and have resulted in a major manufacturer (Chrysler) submitting an unsolicited proposal to improve automobile engine technology specifically to perform to Canadian winter conditions and designed to Canadian emissions standards. Modifications include a significant increase in compression ratio, improved fuel evaporation and preheat, optimized spark timings over the whole temperature range, and other devices to improve cold temperature performance, while using energy efficient leaded gasoline. Modifications to the engines are being carried out by Chrysler using company funds, with testing being jointly sponsored by CANMET and Transport Canada.

Lead Trap Trials

Since 1978 CCRL has conducted road tests to determine the effectiveness of lead traps mounted on automobiles to collect solid particulates in the exhaust gases from leaded-gasoline fueled automobiles. These trials have involved eight vehicles from the Department of National Defence (DND), with four of the vehicles unequipped to act as controls. The results, reported to the Air Pollution Control Association were as follows:

1. Automotive exhaust lead traps can replace standard mufflers and portions of the exhaust system and reduce automotive lead emissions by 80%.

2. There is no discernible deterioration of trapping efficiency with mileage accumulation.

3. Automotive exhaust lead traps are equally effective over the wide

range of ambient temperatures encountered during the extremes of winter and summer driving conditions in Canada.

4. Purging of previously collected lead traps which occurs with standard exhaust systems does not take place with well designed lead traps.

5. The use of lead traps will not affect fuel consumption, vehicle driveability and exhaust muffling. Automotive exhaust lead traps are relatively simple, have no moving parts, require no maintenance and can be designed to last the life of the car.

6. If the use of leaded gasoline is increased in Canada to obtain better refinery efficiency and lower vehicle fuel consumption, automotive lead traps offer a viable means to control lead emissions into the environment, if such control is considered necessary.

This paper presents the results of a two year experimental road test program to determine the performance of automotive exhaust lead traps under a range of Canadian climate conditions from -25°C to +24°C. The test fleet consisted of 8 identically equipped automobiles using leaded gasoline. Results show that exhaust lead traps could replace standard mufflers and reduce atmospheric lead emissions from automobiles by 80%, with no discernable deterioration in trapping efficiency over more than 50,000 km of driving. With effective use of lead traps, energy savings associated with the use of lead in gasoline can be realized, even if tailpipe emissions of lead are regulated in future.

Oil and Gas Combustion (332300)

Residential Space Heating

Oil-Fired Heating Systems

For the past 10 years, CCRL has had a major program to improve the performance of oil fired domestic heating systems. To do this, CCRL conducted extensive laboratory studies of a wide range of heating equipment for the Oil Heating Association of Canada, as well as for individual oil companies, manufacturers and users. As well, over several winters detailed studies were carried out in a large number of oil-heated houses in the Ottawa area, measuring such things as fuel consumption, number of cycles, and hours of operation for different technologies. The results were correlated with such parameters as outside temperature and weather conditions, thermostat settings and house insulation. An "Efficiency Manual" on residential oil heating has been written to detail how results from CCRL laboratory and field work on residential oil heating systems can be translated into significant fuel savings.

This book is a manual for servicemen, designers and builders on how existing oil heating systems function and various system and hardware modifications which can be applied to improve their seasonal efficiency by as much as 25%. In particular, proper sizing of the heating system is stressed, with decreasing firing rate and in the use of chimney dampers improving off-load performance. Major efficiency gains can be realized by retrofitting a conventional burner with a retention head, increasing steady state efficiency by 10-15%. Detailed retrofit techniques are presented. Other improvements, such as reduction in sooting with a delayed action solenoid valve, improved heat distribution by duct insulation and ensuring an adequate supply of combustion air are also stressed.

This manual has been widely acclaimed by officials in the oil industry, provincial and federal agencies and in the building industry as the first book which clearly defines the areas where efficiency is lost and presents easily applied techniques developed from CCRL R & D to reduce these losses significantly. Similar comments have been received from the US industry and state and federal agencies. During 1980, 1000 French copies and 7000 English copies of this manual were distributed to industries within Canada.

It is used by all provinces as a training manual for all personnel taking courses to be a licenced servicemen, and as the basis for upgrading efficiency courses being presented by all provinces to existing licenced servicemen

Gas-Fired Heating Systems

A conventional new gas furnace with a pilot light and naturally aspirating burner has a seasonal efficiency of 55 to 60% as compared to 65-70% for an oil furnace with retention head burner. On the gas furnace, a continuously burning pilot light wastes about 5 to 7% of the total consumption over a year. Another 12% is lost in the steam which forms on combustion of the gas, and escapes up the chimney. The draft hood, constantly open, allows a significant loss of heated air up the chimney, both when the furnace is on and when it is off.

Recently, gas furnace technology has undergone rapid development to improve efficiency. At least two types of new generation furnaces similar in concept to models already available in the United States, are in the certification process through the Canadian Gas Association and provincial authorities.

One more efficient type now available has electric ignition and a built-in vent damper, the latter preventing heated air from the house from being drawn up the chimney during the furnace off-cycle. This unit is likely 10-15% more efficient than a conventional furnace. Savings will be much less if a gas-fired water heater is also installed, since the latter reduces the effect of the damper.

A new high efficiency non-condensing unit offers fuel savings of 15-25% over the conventional model. It is equipped with electrical ignition instead of the pilot and a built-in induced draft fan, with the draft hood eliminated. This dramatically reduces the air requirement of the furnace in operation and reduces the warm air outflow, both while the furnace is on and when it is off.

The new condensing furnaces have additional heat exchange surface to reduce the flue gas temperature below the dew point and regain the latent heat it contained. There will be no need for a chimney. Combustion products are merely vented through an outside wall and condensate drained off through a plastic tube. These furnaces promise to be 25-40% more efficient than a conventional furnace.

CCRL has a contract with Clare Brothers to produce a retrofit condensing flue heat exchanger for existing gas-fired furnaces. This unit uses a secondary finned-tube stainless steel heat exchanger located in the cold air return to condense the combustion products, gaining most of the potential savings of the new condensing furnace.

Industrial Heating and Processing

Low-Calorific Gas Burner Development (CGRI)

Under Phase III of a contract with the Canadian Gas Research Institute a 300 kw burner for low energy gas was designed and developed. In field trials at an operating wood gasifier, the burner was successfully fired at partial and full load on hot, dirty gases with heating values from 3-6 MJ/m^3. One major problem was incomplete combustion of tarry liquids which were ejected from the flame at about 10 L/h. This problem will be studied and hopefully resolved during 1981 under Phase IV of this contract by incorporating a secondary burn-out cell at the burner exit.

Effect of Oil Atomization Parameters on Heat Transfer (FERA)

This project was commissioned by the Combustion Sub-Committee of the Ferrous Energy Research Association (FERA) Technical Committee. The work was performed in the CCRL research tunnel furnace, using the same dual-fuel, barrel-mix, burner, provided by FERA for Phase I. The objective of the Phase II project was to evaluate the effect of varying steam/oil ratio and fuel oil temperatures on the heating efficiency of the steam-atomized oil flame while maintaining a constant burner emulsion pressure. Burner emulsion pressures were maintained at approximately 50 or 70 psig by changing the burner tip size for each change in the steam-oil ratio. At the request of the FERA Combustion Sub-Committee only raw data was to be acquired and reported; accordingly no interpretation of the experimental results was provided.

Coal Technology (334000)

Combustion (334600)

Conventional Coal Combustion

Coal Utilization

Current conventional combustion activities at the Canadian Combustion Research Laboratory (CCRL) reflect the increasingly important contribution that coal is expected to make in meeting our future energy requirements and reducing our dependence on foreign oil. Canadian thermal coal production, which increased from about 10 million tonnes in 1974 to about 20 million tonnes in 1980, will likely reach 50 to 60 million tonnes by 1990. This escalating demand for coal will, however, be heavily dependent on the ability of conventional and emerging combustion systems to cope with disruptive conflicts caused by variations in fuel quality, on requirements for better equipment availability and on the implementation of progressively more stringent environmental constraints.

The objectives of the CCRL conventional coal combustion research group are as follows:

1. To develop new or improved techniques for efficiently utilizing pulverized coal and renewable fuels as a substitute for oil in industrial processes.

2. To define and optimize the combustion performance of low-grade coals from new mines or waste materials in pulverized-fired combustion systems.

3. To promote the development, and where feasible, the implementation of coal-liquid mixtures (CLM) as a substitute for oil in existing oil-fired equipment and as an alternative to direct coal firing in other combustion equipment.

4. To conserve the use of fuel oil through operational and design modifications to industrial combustion systems.

5. To keep abreast of domestic and foreign combustion R & D and where appropriate, to participate in joint R & D and D projects relevant to Canadian needs.

With the above objectives in mind, the following projects were undertaken in the 1980 FY.

Sage Creek Coal

Under a cost-shared agreement with Techman Ltd and Rio Algoma, a three-phase project was initiated to study the combustion properties of different blends of coal from Sage Creek. In phase 1, which is now complete, a blend of No. 4 Upper and No. 4 Lower seams was burned in the pilot-scale research boiler. This oxidized coal ignited and burned with a stable flame but burn-out was marginal and slagging of refractory surfaces around the burner was severe. The marginal burn-out was due largely to the high percentage of oxidized vitrinite. At 5% oxygen in the flue gas, the severity of slagging was reduced and the burn-out improved slightly. It was concluded that a blend containing less than 45% total inert macerals would probably be a satisfactory boiler fuel.

Onakawana Lignite

At the request of Onakawana Development Ltd, the feasibility of using Onakawana lignite in utility boilers and industrial furnaces was evaluated in a two-phase program. Phase 1 involved suspension burning in the pilot-scale boiler and Phase 2 involved a study of combustion parameters in a small-scale fluidized-bed combustor.

The Phase 1 evaluation demonstrated that the lignite has excellent combustion characteristics, moderate sulphur and nitrogen oxide emissions, low fouling potential and fairly coarse fly ash particles. Ash resistivity was in the optimal range of 10^8-10^{10} ohm-cm at 150°C indicating that precipitator performance should be good to very good. The company is considering the investigation of limestone dosage to control sulphur oxide emissions. The lignite ash produced a highly viscous slag and was rated as having a moderate slagging potential. However, its slagging potential can be minimized by careful attention to furnace heat release rates and by maximizing the moisture content of the "as fired" lignite to reduce flame temperatures. These strategies can also reduce NO_x emissions.

Bienfait Lignite

This project was a continuation of that begun in 1979 in collaboration with Ontario Hydro. The objectives of the combustion trials were to assess the slagging propensity of Bienfait Lignite (Saskatchewan) and to determine whether the slagging could be controlled by intermittent addition of calcium carbonate. Three coals were supplied for evaluation; two coals with 6% and 9% nominal Na_2O in the coal ash contained less than 1% sulphur whereas the third coal which had 7 1/2% Na_2O in coal ash contained 3% sulphur. A blend of the two low sulphur coals to give a 7 1/2 Na_2O coal for comparison with the high sulphur coal, was also evaluated. Three levels of intermittent $CaCO_3$ addition corresponding to 0.16%, 0.08% and 0.04% of the fuel feed rate were tried in various addition modes, but none were successful in controlling ash slagging.

Blackfoot Coals

A collaborative test program in the CCRL pilot-scale boiler has been undertaken with Crowsnest Resources Ltd. to evaluate the combustion performance and the slagging tendency of three coals from the Blackfoot mine. Two of the coals, Poor Eagle and Eastern Block were ranked as sub-bituminous "B" and the Central Block was lignite "B". The coals were not expected to slag but some slagging did occur. Considerable bottom ash was deposited, despite the short duration of the test burner (~4h). It was determined that this slagging and excessive bottom ash deposition was due to the abnormally high clay content of the coal samples. The company is now considering washing the coals prior to combustion in order to eliminate some of this contaminant.

Tent Mountain-Vicary Creek Coal Rejects

An experimental combustion study to establish the flame and heat characteristics of the beneficiated Tent Mountain-Vicary Creek coal rejects was undertaken in a refractory lined calorimetric furnace. These results were compared with those obtained using a commercially available No. 6 fuel oil. The pulverized coal flames iginited and burned readily with combustion efficiences comparable to No. 6 fuel oil, using burner swirl numbers of 0 and 1 and at excess air levels corresponding to 3% and 5% oxygen in the flue gas. The sulphur oxide (SO_x) and nitrogen oxide (NO_x) concentrations in the flue gas were well below current North American emission guidelines for coal-fired boilers. This study has now been completed and a report is currently being prepared.

Blended Thermal Coals

This project which was conducted in collaboration with Ontario Hydro was to assess the combustion performance of various blends of three coals typically supplied to Nanticoke Generating Station. The project began in 1979 and continued into 1980. The three coals were a US bituminous blend from Pennsylvania and Byron Creek and Coal Valley from western Canada. During 1980, baseline data was obtained on the two Canadian coals as part of the CANMET in-house research program. The investigation is continuing on a number of blends to maximize the use of Canadian coal in those boilers which were originally designed for a Pennsylvania high-volatile bituminous coal.

Control of Combustion Products

SO_2 Emissions from Suncor Coke

In a collaborative project with Suncor Inc., a series of combustion trials were conducted to evaluate the effectiveness of co-firing limestone with petroleum coke to reduce SO_2 emissions. Over 50% of the input sulphur was converted to $CaSO_4$ at Ca/S mol ratios of 3.2 and as expected the degree of superheater fouling decreased as the limestone dosage rate increased. However, the limestone additions tended to promote slagging of refractory surfaces and did not decrease NO_x emissions. Steam flow was reduced by about 25% at a Ca/S mol ratio of 3.2, due to the deposition of dusty, light-coloured ash on the furnace walls. In a commercial operation this effect could be readily avoided by normal soot-blowing.

Low NO_x Coal Burner Studies

Three low-NO_x burner studies, all under contract, are in various stages of completion. The first is a study of the role of fuel nitrogen in NO formation. It is being carried out in California under an IEA agreement with the USA, Denmark, Sweden and Canada as participants. Seven Canadian coals have been evaluated in a technical-scale rig and Canadian participation in larger-scale burner on 3 of the 7 coals submitted is being considered.

The second study is a collaborative EMR project with the Canadian Electrical Association. In this contract, Ontario Hydro is evaluating the costs and the effectiveness of retrofitting a new design of low-NO_x burner to a 500 MW boiler at the Nanticoke Generating Station. Installation of one row of burners is complete and field trials are scheduled for early 1981.

The third study is another retrofit installation at CFB Gagetown using an International Flame Research Foundation, staged-combustion burner. Objectives of the project, supported by EMR, DND and Environment Canada, are to determine the influence of both the burner designs and dry limestone injection on sulphur and nitrogen oxide emissions from Maritime coal. The feasibility of retrofitting this boiler has been confirmed and baseline combustion and emissions have been measured. A contract for the boiler modification is under negotiation.

Trace Element Emissions

Trace element emmisions from coal-fired power stations are becoming a major environmental concern. Unfortunately quantitative and qualitative data is very scarce, in-situ measurement techniques are not well-defined and in-depth analytical experience is not widely available. To help resolve this knowledge gap, in-house samples of coal and fireside residues are being analyzed for elements including actinides for a number of Canadian coals of different rank that have been evaluated in the CCRL pilot-scale boiler.

In another study, the Canadian Electrical Association with EMR and Environment Canada participation is negotiating a contract with Battelle Northwest to study the flow of trace element emissions from four Canadian thermal generating stations to their eventual receptors. The study is expected to start in early 1981 and finish in late 1982.

Plume Dispersion

In 1980, consolidation of the plume rise data generated during six years of research in the CANMET/industry plume dispersion program, resulted in a paper to the 73rd annual Air Pollution Control Association meeting (June, 1980) in Montreal.

The plume rise data were compared to two forms of the relationship derived by Briggs which is a standard predictive relationship in the literature. In all, ten sources in stable and unstable conditions, five geographic regions and three seasons were represented by the data.

It has been shown that the data can be represented by the Briggs form of equation, particularly for stable conditions. In neutral conditions the data suggest a proportionality constant of 0.87 and a leveling-off at 15 stack heights rather than a 1.6 constant and a levelling-off at 10 stack heights as suggested by Briggs. In stable conditions the Briggs levelling-off value of 2.9 for the dimensionless plume rise is in good agreement with the findings in this paper, but this occurs at a dimensionless downwind distance of 18.4 rather than 2.4. A slight variation in the maximum plume rise with the bulk Richardson number over the dispersion zone has been noted for stable conditions. A paper, based on the dispersion studies at sour gas plants in the Rocky Mountain Foothills, was published in the journal of the Air Pollution Control Association in 1980.

Coal Oil Mixtures

New Brunswick Electric Power Commission

The 10 MW(e) utility boiler demonstration project at Chatham, N.B. has been underway since 1977.

The Phase III boiler trials which ended in April 1980 were undertaken with two major objectives, to improve the effectiveness of the oil agglomeration coal-cleaning process and to test two burners for long-term performance on COM. Efforts toward achieving these objectives were curtailed due to the equipment wear problems associated with the highly abrasive New Brunswick coal used to make the COM. Nevertheless, much useful information on COM technology was generated during the Phase III operation, despite this continuing problem.

Two types of internally steam atomized burners were assessed for combustion performance and abrasive wear, a replaceable nozzle insert type during Phases II and III and a "Y" jet type during Phase III.

It must be mentioned that whilst minimizing the wear of COM equipment components was an important overall objective of the project, it was not possible to maintain the necessary control of input parameters required for a more definitive study of wear. The objectives of the trials were to improve the performance of the agglomeration system and to gradually increase the coal content of the COM up to about 40 wt %. Quite often, therefore, it becomes difficult to compare the wear of nozzle components because of variation in fuel flow rates and ash coal content; all important contributors to the wear phenomenon. The wear of other components such as the wet grinding mill, and the various pumps and connecting pipe work could only be examined in general terms, since these components were used during the entire Phase II and Phase III programs, where COM coal contents varied from 10 wt % to 40 wt %, ash input from 2 wt % to 7 wt % and the power generated by the unit from 2 MW(e) to 10 MW(e).

The solution of the burner wear problem at Chatham requires consideration of many factors such as:

1. Burner design, by avoiding abrupt COM directional changes and high velocities and the use of externally-atomized burners utilizing low COM efflux velocities.

2. Materials selection, choice of abrasion resistant materials that can be readily machined or fabricated into burner tips. The use of harder materials such as tungsten carbide significantly reduces the burner tip erosion. There appears to be an inverse variation between material hardness and wear rate, although it is difficult to establish a precise mathematical relationship due to the inadequate control of

critical operating parameters.

3. COM characteristics, use of finer particles in the COM and less abrasive coals that have been beneficiated, if necessary, to remove high levels of ash.

Other COM handling equipment such as pumps, valves and secondary grinding equipment also suffered from significant wear related damage which resulted in deteriorating performance. It is felt that this problem can be eliminated by appropriate materials and equipment design considerations. COM transfer lines were relatively unaffected by wear; essentially due to the low prevailing fluid velocities.

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

The work at Chatham had been expected to lead to a 100 MW(e) demonstration project at Dalhousie, New Brunswick, but the present economic analysis indicates that it is more reasonable to convert all units above 100 MW(e) in the province to full coal firing. During 1980 two papers on the Chatham work were presented; one to the 6th IFRF members conference in Holland and the other to the 73rd APCA annual meeting in Montreal.

Ontario Research Foundation (ORF)

This project, the combustion of coal-oil mixtures and coal-oil emulsions, was jointly sponsored by the Ontario Ministry of Energy, Ontario Hydro, the Steel Company of Canada, Gulf Oil Canada and CANMET. It began in 1978 and was concluded in 1980.

The project included the following elements: coal beneficiation, COM preparation, combustion evaluation, slagging, fouling and emissions assessments. The three coals selected for COM evaluation were a western Canadian low-sulphur bituminous, an eastern Canadian high-ash, high-sulphur bituminous and a Pennsylvania bituminous coal.

In the coal beneficiation work, samples of each coal were evaluated in both laboratory and pilot-scale cleaning equipment prior to COM preparation and combustion. Both conventional and spherical agglomeration coal cleaning techniques were used. In the COM combustion trials the two Canadian coals were cleaned and the US coal was simply crushed and pulverized. The COM preparation had originally included the use of a vortex mixing device so that the coal could be mixed with oil or an oil emulsion to form the COM, which would then be passed to the burner without contacting a pump. This arrangement would eliminate potential pump erosion problems such as those experienced at Chatham during Phase I.

Preliminary work at ORF, using the vortex mixer, indicated that the mass throughput was too low to effectively form a COM which could be fed directly to the burner. Since the main objective of the program was the combustion evaluation, work on this aspect of COM preparation was deferred and a simple shear-mixing tank was installed to provide the COM. However, the vortex mixing device was used to produce an emulsion which was used to form a COM containing micro-dispersed water, and this was tested and compared with COM.

In the combustion evaluation of COM, the three coals were mixed to form a 30 wt % COM and also a 30% COM containing 20% water. Tests were conducted at two firing rates, 7 GJ/h and 3.25 to 4 GJ/h and using two different types of burner; a high intensity burner developed at ORF with Gulf Oil and known as the Vortometric burner, and a standard Peabody burner. Both burners performed well in the tunnel furnace arrangement of the test facility despite the fact that the Vortometric produces a highly rotating flame resulting in some wall flame impingement. A continuation program involving further work on COM preparation and combustion is currently being considered for funding.

General Comminution Incorporated

Traditionally coal oil mixtures have been prepared by grinding coal in a dry or semi-dry state and then dispersing the finely ground coal in oil to form a slurry. Significant advantages, such as the elimination of surface oxidation of the coal, the elimination of the need for dust control equipment and the enhanced dispersion of the coal in the oil, can be envisaged when the coal is ground in an oil suspension. General Comminution Incorporated have developed a laboratory size "SZEGO" mill with a maximum throughput capacity of 0.5 tons of coal per hour for grinding coal oil mixtures. Preliminary experiments in this mill indicate that a coal/water (60/40) slurry containing -3/4 inch coal feed can be ground to 85%-200 mesh size in a single pass, at a coal feed rate of 400 kg/h. A particle mean size of 12 to 20 microns can be obtained in 2 to 4 passes through the mill. Since this mill is not in sustained commercial operation, information on wear, maintenance and related operational details are minimal. Accordingly, CANMET, with CCRL direction agreed to co-sponsor a program to design and construct a prototype "SZEGO" mill capable of grinding 1 to 3 t/h of coal. This unit will then be used to obtain sufficient performance and scale-up data to prepare a functional design of a commercial size "SZEGO" mill, capable of producing 10-30 t/h of coal as a slurry. This program is progressing satisfactorily, although slightly delayed and is scheduled for completion in October, 1981.

Emerging Energy Technology

It has become apparent that the emerging technology of fluidized bed combusiton (FBC) could be of great benefit to the Canadian energy scene because it offers the following benefits:

1. The ability to burn high-sulphur coal with convenient control of SO_2 emissions through use of limestone beds. This is important for eastern Canadian coals.

2. The ability to burn coals having combinations of high moisture content, high ash content and low reactivity. This is important for some western Canadian coals, and coke by-products of oil sands extraction.

3. A solid fuel-burning technology which is economic in small as well as large sizes, and thus might provide a means for utilizing coal or wood waste to replace oil and natural gas in the commercial and industrial markets.

4. In the case of pressurized FBC, a means to more efficient coal-to-electricity cycles.

However, while FBC technology is available on a normal commercial basis for incineration of waste materials such as sewage sludge and wood waste, its application to coal-fired steam generation is still under development, with only a few commercial-scale demonstrations in the western world. The CANMET energy program has accordingly given a high priority to encouraging the rapid applicaton of FBC technology to Canadian needs, both through pilot-scale research and development, and the support of full-scale demonstration projects. A more complete background to these activities is given in last year's annual report; the following contitutes a summary of activities in the 1980/81 FY.

Summerside Fluidized-Bed

This project was launched in 1977 when EMR and Defence Canada (DND) agreed to co-sponsor the demonstration of an atmospheric FBC boiler in the heating plant at CFB Summerside. DND defined its needs as a new heating plant containing two steam boilers, each having a capacity of 18,000 kg/h. It was further agreed that the design coal would be Prince coal from Cape Breton, having a sulphur content of about 5%, that SO_2 emissions would be controlled by means of a limestone bed, and that the boilers would be designed for supplementary firing of wood chips, up to 30% heat input of any load.

Since, in 1977, no Canadian boiler manufacturers were in a position to offer fluidized bed boilers it was found necessary to transfer foreign technology to Canadian suppliers. This was done through a series of contracts, carried out during 1978 and 1979, under which conceptual boiler designs and conceptual plant designs were developed by two separate engineering and manufacturing teams working in competition.

The technology transfer process was completed in FY 1980 as Phase 3; Detailed Design and Firm Price Proposal. In it Foster Wheeler Ltd. and Dominion Bridge-Sulzer Ltd, were given contracts to generate, in competition, detailed designs for a two-boiler heating plant, complete with all boiler auxiliaries and materials handling and storage facilities. The contracts were in the amount of $425,000 and $495,000 respectively.

The duties of Scientific Authority for the Phase 3 contracts were carried by a member of CCRL. The contracts were issued in February 1980 and were completed on January 5, 1981, the tender submission date. During that time the Technical Committee met approximately every six weeks with each contractor to monitor progress of the work, to ensure that the designs would meet the operating requirements of the plant, and to ensure that both bids were being prepared to the same performance specification, so that direct comparison would be possible. During the same period a supplementary contract, awarded to Foster-Wheeler Ltd, for pilot-scale test work, was completed. This covered about 200 hr of tests in a 20 in square combustor with the design coal, the design limestone, wood chips and another eastern Canadian coal containing about 8% sulphur.

On January 5, 1981 both contractors submitted their detailed designs and firm price proposals for the supply of a turnkey heating plant containing two 18,000 kg/h boilers, one boiler to be installed during the initial construction phase, the second to be installed after the first had been thoroughly proven. Foster-Wheeler's price, based on American technology, was approximately $14 million, whereas Dominion Bridge-Sulzer's price, based on British technology, was approximately $21 million. This accomplished the technology transfer objective of the project in that two Canadian suppliers are now capable of offering fluidized bed boilers for heating plant applications.

The Technical Committee spent approximately five weeks conducting a detailed review of the two proposals. This included meetings with both contractors, and scoring of both proposals against a set of selection criteria which had been prepared previously. Although the Dominion Bridge-Sulzer proposal was given a higher score by the Techcical Committee, the Foster-Wheeler proposal was evaluated as technically acceptable. Accordingly the Technical Committee recommended to the project Steering Committee that the lower tender be accepted.

In subsequent negotiations with Foster-Wheeler Ltd, conducted by Defence Construction Ltd with the support of the Technical Committee, the price was reduced to approximately $13.1 million. This was accomplished by modifications to the scope of work and by agreeing to have both boilers installed at the same time, thus avoiding escalation in the cost of the second boiler. The major change to the scope of the work was in reducing the wood chip handling system from a continuous to a part-time capability. By means of a minor change to the coal-handling system, it will be posible to use it to feed wood chips to the wood-chip day bins when coal bunkering is not required, and thus eliminate several hundred thousand dollars worth of dedicated wood handling equipment. The coal bunkers need only be filled every four days at full plant capacity; in this intervening period the coal handling system can be used to convey wood chips for demonstration combustion tests.

Final Treasury Board approval for the project has been obtained, and Defence Construction Ltd has awarded the construction contract to Foster-Wheeler Ltd. Site work is expected to start in May 1981, and the boilers should be ready for commissioning in December 1982.

The Summerside project, as the first application of fluidized-bed boilers in Canada, has aroused considerable interest both in Canada and internationally. A CCRL staff member presented a paper on the two conceptual boiler designs to an international conference held in November 1980 in London, England. The Communications Branch of EMR has commissioned a film to publicize the project, and detailed information is being made available as a Canadian contribution to the 8-nation IEA Information Exchange agreement on Atmospheric Fluidized-Bed Combustion.

Industrial Fluidized-Bed Boiler Demonstration

As detailed in last year's annual report, in March 1980 CANMET invited expressions of interest via the DSS Research Bulletin in a joint industry-government project to demonstrate an industrial-scale FBC boiler, approximately 100 tph of steam capacity, to burn coal, preferably with up to 50% co-firing of wood waste. Seven responses were recieved and review of these by CCRL staff showed that four could meet the guidelines of combining design capability, fabricating capability in Canada, and indentification of a Canadian end user willing to provide part of the capital cost. Discussions concerning timing and cost-sharing were held with one manufacturer and his potential client, but the project, which is being managed by Energy Policy Sector - Coal, is being held in abeyance until a funding route has been established. That done, CCRL staff will continue in a technical advisory capacity.

Utility Fluidized-Bed Boiler Demonstration

The site review study, cofunded by EMR and Nova Scotia Power Corporation (NSPC) and described in the last annual report, has been completed and reviewed by CCRL staff on behalf of Energy Policy Sector - Coal.
Of the various possibilities, most promising to both EMR and NSPC is the Point Tupper generating station, where a 150 MWe AFBC boiler could replace an

existing oil-fired boiler, utilizing the existing turbogenerator equipment. Steam conditions at 540°C superheat and 540°C reheat would be typical of utility practice and the capacity of 150 MWe (approx. 455 tph of steam) is large enough to be a significant demonstration of the application of AFBC to utility practice. However, NSPC are not yet prepared to rule out the Trenton generating station, where an AFBC boiler generating approx. 300 tph of steam at 540°C superheat could supply some older turbogenerators through a de-superheating station. This scheme would not involve reheat and therefore is less typical of modern utility practice.

The firm of Coal Processing Consultants (CPC) have been contracted to carry out a more detailed review of both the Point Tupper and the Trenton sites, and, when a final selection has been made, to prepare detailed specifications for an appropriate AFBC boiler, including a risk analysis. In connection with the latter task, CPC arranged a series of meetings with the American boiler manufacturers and their Canadian counterparts who had recently submitted detailed designs and price quotations to the Tennessee Valley Authority for a 200 MWe AFBC utility boiler. Thus the present state of the art was established, and corrosion of in-bed heat exchange surface was identified as the area of major risk. CCRL staff represented Energy Policy Sector - Coal at these meetings.

When CPC have completed their present contract, which is expected to take the remainder of 1981, a decision on how to proceed further will have to be made. One possibility is to contract the major Canadian boiler manufacturers to develop detailed designs and cost proposals on a competitive basis. Allowing two years for this phase, an order might be placed in 1984.

NSPC is serving as the lead agency in this project, with funding being provided under the federal-provincial Oil Substitution Agreement. CCRL's role is to provide technical and scientific input on behalf of Energy Policy Sector - Coal.

Fluidized-Bed Combustion of Syncrude Coke

Coke is a major by product of the Syncrude Oil Sands recovery plant, being produced at the rate of about 2000 tons per day. In terms of energy content it is a high grade fuel, having a calorific value of about 30 MJ/kg but its high sulphur content (8 to 9%) and its low volatile matter content make it unsuitable for conventional combustion technology. Therefore it is presently being dumped, while the steam and power requirements of the Syncrude plant are generated with natural gas.

A variation on conventional FBC technology which seems particularly suited to low-reactivity fuels is the recirculating fluidized-bed. It employs high fluidizing velocities, coupled with refractory-lined cyclones at the furnace exit which trap the mixture of elutriated fly ash and unburned carbon and return it, without significant loss of temperature, to the furnace for further opportunity of combustion. Effective residence time for combustion is thus prolonged. The system has been most fully developed in Finland, where it has been successfully applied to heating an industrial boiler at up to 90,000 kg/h of steam, cofiring with coal and peat.

CCRL therefore took the initiative in arranging a contract under which combustion tests with Syncrude Coke will be carried out in a pilot-scale recirculating FBC by the firm of A. Ahlstrom Ltd. in Karhula, Finland. A work statement has been drafted and agreed upon, and the aid of AOSTRA was enlisted in shipping a 20 ton sample of fresh coke from Fort McMurray to Finland. The combustion tests will likely be carried out in May 1981, at a cost about $50,000. If reasonable combustion performance can be achieved, a significant first step toward utilizing Syncrude coke will have been made.

The consortium of Petro-Canada Nova has also expressed interest in these tests. The consortium is designing another tar sands extraction plant, and demonstration of successful coke combustion system would have significant impact on their process design. They have requested permission to witness the combustion tests along with the CCRL staff member who is scientific authority for the contract.

Coal Feeder for Pressurized Applications

A significant problem area in the operation of pressurized fluidized-bed combustors and coal conversion processes operating at elevated pressures, such certain gasifiers, is feeding of coal into a reactor at several atmospheres pressure while maintaining an adequate gas seal. Devices presently in use are expensive, cumbersome, energy intensive, or all three.

CCRL has become aware of a potentially attractive alternative in the form of a proprietary feeder developed in Canada to feed hardwood chips into a steam cooker operating at about 2400 kPa. This device has been thoroughly proven in the commercial fodder-processing application for which it was designed, but it has never been tested with coal. Early in 1980 CANMET attempted to negotiate an R & D contract for testing the feeder with coal, but at that time the supplier could not make a proto type available.

Discussions with the supplier led to the conclusion that much useful information could be generated on a bench scale, and that bench-scale tests would be a desirable first step in any case. Accordingly a work statement was drafted and proposals were invited, resulting, early in 1981, in a contract to Warnock Hersey Professional Services Ltd in the amount of $10,800. The work consists of compressing coal to pressures ranging from 350 kPa to 14,000 kPa and then measuring the permeability of the compressed coal to gases with pressures up to 1400 kPa. Two sizes of coal are to be used, each at three different levels of moisture. The actual test work has been sub-contracted to the Geotechnical Research Centre at McGill University.

At the time of writing, approximately half the test program has been completed and the results are very encouraging. The contract will be completed early in the new fiscal year and a decision will then be made on whether to proceed further.

Fluid Bed Coal Dryer

The Western Canadian coal industry has extensive coal upgrading facilities which reduce the ash content of the as mined coal to a level acceptable to their coking and thermal coal markets. Washery rejects, the by-product of this upgrading activity, are produced at the rate of about seven million tons per year, and thus constitute a significant untapped energy source, even though they typically contain 50% ash and 20% moisture.

In 1976 CANMET initiated a contract for pilot-scale R & D which demonstrated that the rejects can be burned in an uncooled AFBC. In 1980, CANMET responded to an unsolicited proposal from Luscar Ltd to further investigate means for utilizing this waste material. This took the form of a co-funded study to; a) produce a conceptual design for an AFB combustor to supply hot gases for Luscar's full-scale dryer at Coal Valley, Alberta, b) produce a cost estimate for the combustor and its auxiliaries, and c) determine the economics of the AFBC system compared to the existing system. CANMET's contribution is $35,000 and a CCRL staff member serves as Scientific Authority for the contract.

Dorr-Oliver Canada Ltd, who have considerable experience as suppliers of FBC systems for work materials, were sub-contracted to prepare a design for the waste combustor, subsequent hot-gas clean-up, and an oil-cooled heat exchanger which would supply space heating for the coal preparation plant. Dorr-Oliver also carried out pilot-scale tests at their laboratory in Stanford, Conneticut. These tests established that the coal rejects can be burned with high efficiency at temperatures between 650 and 950°C, but an elaborate gas clean-up system is required if the specified criteria for ash carry-over and system turn-down are to be met.

Dorr-Oliver's cost estimate for a full-scale system with a heat input of 70 MW is about $10 million, exclusive of erection costs. Luscar's additional costs for erection and balance-of-plant; including building, materials handling and heat distribution, appear to be of the same magnitude. A final report is nearly complete and its submission will complete work under the present contract.

Savings in clean coal for dryer fuel and propane for plant heating are not expected to justify a capital investment of $20 million under normal industrial investment criteria. However, Luscar have already initiated studies to determine whether plant operational requirements can tolerate a reduced turndown capability and an increased dust loading in the gases to the dryer. Dorr-Oliver, for their part, are preparing a second cost estimate based upon less stringent performance criteria. Luscar Ltd have also invited two other suppliers of fluidized bed combustors to prepare cost estimates for the required process equipment. Consequently, a more favourable economic scenario may emerge in a few months. A decision to proceed with a full-scale demonstration may then be made, possibly with some federal assistance.

Pilot Scale Fluidized-Bed

The full-scale application of FBC technology has a continuing requirement for detailed information which can often be obtained from pilot-scale equipment. Performance characteristics of specific fuels, neutralization characteristics of specific limestones, metallurgical aspects of erosion and corrosion, effects of bed depth, fluidizing velocity and bed temperature on combustion, sulphur neutralization and heat transfer are all areas where pilot-scale research can contribute essential knowledge. CANMET supports pilot-scale research, both in-house at CCRL, and via contract at Queens University.

Design Parameters

Beginning in 1975 CCRL developed a pilot-scale, partially-cooled combustor having an inside diameter of approximately 20 cm. It has been used since 1978 to generate data on a variety of Canadian coals and other solid fuels, examples being Hat Creek coal waste, Suncor coke, Alberta sub-bituminous coal and New Brunswick bituminous coal.

During the past year all the previous test work was brought to the draft report stage or better. The most extensive study, a detailed comparison of Highvale (Alberta sub-bituminous) and Minto (New Brunswick bituminous) coals with respect to sulphur neutralization by ash constituents, formed the basis of an M.Sc. research thesis by a CCRL staff member. It will be defended at the Univerty of Western Ontario in June, 1981. A paper derived from this work has been offered to the 1981 ASME Winter Annual Meeting. Another paper describing the FBC tests with Suncor coke has been accepted for presentation at the 64th Chemical Conference to be held in Halifax, May 31-June 3, 1981.

Work was completed on a combustion evaluation program on an oxidized coal from the Line Creek area of British Columbia, under a cost-shared project with Crowsnest Resources Ltd. The final report is now at the word processor stage, and a paper describing the results will be presented in May, at Carleton University, at a conference sponsored by the Canadian Section of the Combustion Institute.

Under a cost-shared contract with Onakawana Developments Ltd, still another combustion evaluation project was carried out with the 20 cm FB combustor. The fuel in this case was Onakawana lignite from the James Bay area of Ontario. A report has been drafted but is not yet in final form. Upon completion of these tests, the combustor was dismantled to make way for a new, more versatile combustor described in the following section.

CCRL Mark 2 combustor

Perhaps the most important information gained from the 20 cm FB combustor was clarification of the design requirements of a pilot-scale combustor which would more fully meet the varied needs of the CCRL R & D program. These are:

1. Variable in-bed heat transfer surface.
2. Capability for measuring heat transfer rates.

3. Robust, maintenance-free construction.
4. Provision for both overbed and inbed feeding of wet, sized coal.
5. Provision for fly ash recycle.
6. Provision for limestone injection.
7. Good access for sampling probes and measurements.
8. Means for visible inspection of the bed.

Design of a new combustor to meet these requirements was begun in 1979. A 0.38 m square bed section was selected as a compromise between economy of construction and operation, and reliable representation of full scale. The combustor shaft was designed as several sections one above the other, each consisting of a hard refractory brick liner backed by insulating brick and encased in a steel shell. A water header assembly at bed level permits bed cooling to be varied from an adiabatic condition to a high level of heat removal with up to 48 cooling tubes passing through the bed. Measurement of water flow and temperature rise through the cooling tubes permits determination of heat transfer rates. The fuel feed arrangement incorporates a hopper and variable-speed screw feeder mounted on an electronic weigh scale discharging via a flexible connection into a second, water-cooled screw feeder which delivers the coal into the combustor, either above the bed or into the bed below the heat exchanger tubes. Another variable-speed feeder can be used to feed limestone into the flexible connection between the coal feeders. Numerous access ports and a sapphire window provide means for fly ash reinjection, probing, and observing the bed surface.

Fabrication of the combustor sections by a local welding shop was completed in June 1980. The refractory lining was installed, the combustor was assembled, and the refractory was cured during the course of the summer. Concurrently a finned-tube air cooled heat exchanger for cooling the combustion gases was designed at CCRL, and fabricated by a local shop.

Installation of the varous new components, adaptation of components used on the previous combustor, and instrumentation comprised a substantial task which occupied the remainder of the year and is not yet complete. To provide access to the upper levels of the rig a catwalk had to be designed, but this was complicated by the need to be able to remove large components such as the flue-gas-to-air heat exchanger from time to time. A sectional catwalk, bolted together, solved this problem, and a contract for its fabricaton and installation was completed in March 1981. Also, an additional water line to service the bed cooling tubes was installed by Public Works Canada.

In its final form the pilot-scale facility will comprise the combustor with in-bed and freeboard heat exchange surface, a cyclone dust collector with a reinjection system, the flue-gas-to-air heat exchanger, a bag filter for final particulate removal, and an induced draft system. Most of these components are now on site but installation is not yet complete. At present the combustor and cyclone have been temporarily connected to the existing laboratory flue gas exhaust system, bypassing the flue-gas-to-air heat exchanger and the bag filter. This has permitted commissioning to proceed to adiabatic operation on coal at low firing rates in order to develop light-up procedures, check out instrumentation, and establish the operating characteristics of the combustor.

Much of the next year will be required to bring the pilot-scale facility to its final form. For example, to efficiently utilize manpower it is important to provide a mode of automatic operation so that the combustor can be kept hot overnight. Otherwise much of the working day is lost in reaching thermal equilibrium. However, the facility is serviceable in its present form and during the coming year it is intended to alternate R & D programs with further construction.

Early in 1980 a report describing the CCRL program in fluidized bed combustion was prepared. It outlines national needs, current objectives, current projects both in demonstrations and R & D, and an estimate of the resources required over the next five years. It was submitted as a Canadian contribution to the recently-formed eight-nation IEA Information Exchange Agreement on Atmospheric Fluidized Bed Combustion. A member of CCRL staff has been appointed as Canada's technical delegate.

Fluidized Bed Mechanisms

In 1979 CANMET signed a two-year contract with the Chemical Engineering Department at Queen's University for the development and operation of a pilot-scale fluidized bed combustor. It is intended to extend this support over several years, and thus have Queen's supplement the work of CCRL in two areas; characterization of Canadian limestone and dolomites as sulphur sorbents, and the enhancement of sorbent efficiency by means of additives. A

CCRL staff member serves as Scientific Authority for the contract.

It was agreed that Queen's would obtain a combustor indentical to the CCRL Mark 2 facility already described and during FY 1979 approximately $78,000 was spent on instruments, feeders and supplies. During the past fiscal year approximately $200,000 was spent on procurement and erection of the pilot-scale facility. Mechanical construction is now nearly complete, installation of the light-up burner is scheduled for late March, and curing of the refractory lining of the combustor will then begin. Thus, the facility should be ready for service in May.

Queen's University has drafted a proposal for an R & D program to cover the next two years. It includes cold-model testing of fluidization parameters and bench-scale research on limestone characteristics as well as a program of coal combustion tests with the pilot-scale facility. Assessment of the proposal is under way at CCRL.

Technology for Renewables (337000)

Combustion and Conversion (337700)

Residential Space Heating

Combustion of Synthetic Fireplace Logs

At the request of Burnco Industries Ltd, and the Department of Industry Trade and Commerce, a series of combustion trials were conducted to measure the combustion performance and emissions of synthetic fireplace logs in a fireplace environment. This information was required by the British Clean Air Inspectorate prior to approving the use of these logs as a fireplace fuel for space heating. Dry, hardwood maple logs, the standard reference fuel for wood burning performance, was used to provide a baseline against which the synthetic logs were compared.

The synthetic fireplace logs contained about 90% paraffin, 2.6% moisture and about 7% sawdust. The maple wood had been air-dried for about 2 years and had about 15% moisture on a wet basis. On a weight basis, the synthetic logs at 37,276 KJ/kg had nearly twice the calorific value of the maple wood at 19,306 KJ/kg.

Regardless of whether the fireplace doors were open or closed or whether the chimney draft was high or low, each fireplace log burned for about 3 hours, but their heat release rate was less than 25% of that produced by the dry maple.

It was concluded that non-airtight fireplaces or stoves are capable of burning single synthetic logs of the type used without risk of overheating or of producing excessive pollution relative to wood.

Wood-Fired Space Heating

The use of wood for domestic heating is becoming common in many parts of the United States and Canada. Projected continued price increases and supply difficulties for conventional domestic heating fuels (oil and natural gas), as well as the perceived attractiveness of using a potentially renewable energy source, indicate the trend to wood heating is likely to continue.

At the same time, there is increasing concern over the emissions from domestic wood-fired appliances. Incompletely burned gases and condensed liquids cause environmental concern downstream from the source, as well as posing safety hazards from the occupants of the dwelling itself, in the form of toxic carbon monoxide from combustible "creosote". These incomplete products of combustion also represent an efficiency loss, so that reducing these emissions can contribute to more efficient use of wood energy.

CCRL has developed a continuous heat loss test procedure to measure solid fuel-fired appliance performance and has carried out an R & D program to determine the effects of design on performance, considering both efficiency and emissions. Papers have been presented to the Air Pollution Control Association, The Canadian Wood Energy Institute and the American Wood Heating Alliance detailing results to date. A summary is as follows:

1. For controlled combustion wood space heaters, efficiency appears to be maximized within a small range for any specific appliance model.
2. Emissions tend to decrease with increased firing rate.
3. Well-designed sidedraft units appear more efficient than other designs.
4. Emission levels of incomplete combustion products are related to design, particularly when expressed as a function of heat output. Emission factors of a sidedraft type are less than half those of an updraft, while the horizontal baffle puts out only 70% of the updraft emissions.
5. Freestanding fireplaces are very inefficient. At the same time, they

have high emission rates when expressed as a function of heat output.

6. The largest variation in efficiency occured not between appliance types, but rather between different models of the updraft design.
7. The performance of various heaters within a given type will vary depending on how the particular design utilizes the potential performance advantages offered by its type.
8. Reduction in the emissions of incomplete combustion products likely mean reduced creosote formation in flue pipes and chimneys. If this reduction allows higher flue gas temperatures for a given efficiency and heat output, creosote formation will be further reduced.

As well as being tested in the laboratory, stoves, furnaces and fireplace inserts are being tested in instrumented homes in the Ottawa area. Results have shown that a well-designed sidedraft or horizontal baffle stove, properly located, can be an effective complement to a conventional central heating system, and may even operate at a higher efficiency than that central system.

Industrial Technology

This activity consists of providing a technical advisory service to agencies such as CREB concerning the utilization of waste materials and biomass for the production of energy. The major effort during the past year was the review, on behalf of CREB, of proposals submitted under the EMR - Province of British Columbia federal-provincial agreement for demonstration of biomass fuels. The first proposal recommended a feasibility study and conceptual design for a fluidized-bed boiler burning wood waste or prepared garbage to generate steam in a commercial district heating system in downtown Vancouver. CCRL staff pointed out that sufficient data already exist to identify wood waste as the best fuel choice and to establish the economics as accurately as can be expected. Furthermore FBC technology is already commercially available with this fuel. Thus the feasibility study could be dispensed with, and the project could move directly into a design and tendering phase. Subsequently a second proposal based on the CCRL recommendation was reviewed, and advice was rendered on how to organize the project in terms of engineering design, tendering of equipment, evaluation of bids and supervision of construction.

Conventional Burning of Renewables

Manitoba Wood Wastes

Under a cost-shared agreement with Manitoba Forestry Resources Ltd (MANFOR), the Canadian Combustion Research Laboratory (CCRL) carried out a pilot-scale evaluation of the combustion and heat transfer characteristics of milled planer shavings. The shavings, which are a by-product of the MANFOR operations, are being considered as a substitute for fuel oil in a company lime calcining kiln at the The Pas, Manitoba.

The evaluation involved a series of trials in a refractory-lined tunnel furnace under conditons typical of those found in industrial calcining kilns.

The objectives of the combustion trials and related analytical work were:

1. To dermine the minimum degree of wood fineness required to produce an acceptable flame.
2. To evaluate the heat transfer characteristics of three size ranges of milled plane shavings supplied by MANFOR and a sawdust obtained locally using No. 6 and No. 2 fuel oils as a basis for comparison.
3. to characterize the particulate and gaseous products generated during combustion.

The wood fuel, which contained between 5% and 16% moisture, and had a calorific value of about 8700 Btu/lb, was milled to three particle size ranges. These were designated coarse, medium and fine and corresponded to mass mean diameters of 840 µm and 145 µm respectively.

The fine and medium material produced acceptable luminous flames and were considered comparable to oil flames; in fact the fine material transferred about 14% and 8% more heat than did No. 2 fuel oil and No. 6 fuel oil respectively.

The coarse material and locally-produced sawdust having a mass mean diameter of 1600 mm and a moisture content of 33% produced unstable flames, even when the combustion air was highly swirled.

Milled plane shavings would appear to be a feasible substitute for fuel oil in a kiln, if the wood is milled fine enough to produce a stable flame. The necessary degree of milling will be dependent on the scale of the equipment. In the CCRL pilot-plant facility mass median diameters of wood below 500 µm produced acceptable flames.

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Staff Changes

Appointments

E. Palmer	Technician	CCRL
D. Barker	Technician	CCRL

LABORATORY REPORTS

ERP/ERL REPORTS

1.	80-4		Pilot-Scale Combustion Evaluation of a Lignite-Bituminous Coal Blend	R. Prokopuk G.K. Lee R.G. Fouhse
2.	80-6	(CF)	THE FERA/CANMET PROJECT PART I: Experimental Data on the Effect of Atomization Variables on Heat Transfer from Oil Flames Using a Barrel-Mix Emulsion Burner	G.N. Banks R. Prokopuk H. Whaley G.K. Lee
3.	80-7	(CF)	THE FERA/CANMET PROJECT PART II: An Investigation of the Heat Transfer and Emission Characteristics of a Barrel-Mix Emulsion Burner	H. Whaley R. Prokopuk G.N. Banks G.K. Lee
4.	80-10	(CF)	Pilot-Scale Combustion Evaluation of Beneficiated Tent Mountain-Vicary Creek Coal Rejects	R. Prokopuk H. Whaley G.K. Lee
5.	80-11	(J)	The Canadian Coal-Oil Mixture Program	H. Whaley
6.	80-12	(OP)	Utilization of Beneficiated Coal-Oil Mixture in a Small Utility Boiler	H. Whaley P.J. Whalen F.W. Davies
7.	80-13	(OP,J)	Studied of Plume Rise During Neutral and Stable Conditions in Canada	H. Whaley G.K. Lee
8.	80-24	(O)	An Assessment of the Environmental Emissions from a Utility Boiler Firing Beneficiated Coal-Oil Mixtures	H. Whaley L.K. Lee C.C. Doiron

9.	80-25	(OP)	Coal Combustion Activities of the Canadian Combustion Research Laboratory	G.K. Lee F.D. Friedrich H. Whaley I.C.G. Ogle
10.	80-34	(TR)	Performance of Synthetic Fireplace Logs in a Non-Airtight, Fireplace-Type, Wood Stove	A.C.S. Hayden T.G. Sellers G.K. Lee
11.	80-42	(OP)	The CFB Summerside Project - An AFBC Boiler for High Sulphur Coal and Wood Chips	F.D. Friedrich
12.	80-30		1979 Annual Report of The Activities of the Canadian Combustion Research Laboratory	G.K. Lee et al (CCRL Staff)
13.	80-36	(CF)	Pilot-Scale Combustion Evaluation of Thermal Line Creek Coal from Fernie, British Columbia	R. Prokopuk H. Whaley G.N. Banks G.K. Lee
14.	80-39	(OP)	R, D & D In Fluidized-Bed Combustion The Coal Program for FY 1980-81 and Beyond	F.D. Friedrich
15.	80-46	(OP)	Effect of Wood Stove Design on Performance	A.C.S. Hayden R.W. Braaten
16.	80-46	(F)	L'Influence du type de poele a bois sur le Rendement	A.C.S. Hayden R.W. Braaten
17.	80-49	(OP)	Canadian Road Test of Automotive Exhaust Lead Traps	R.W. Braaten A.C.S. Hayden P. Reilly-Roe W.G. Kunz, Jr.

18.	80-61		Pilot-Scale Combustion Trials with Onakawana Lignite. Phase I. Pulverized-Fired Research Boiler	R. Prokopuk G.N. Banks G.K. Lee H. Whaley
19.	80-69		Performance of Domestic Wood-Fired Appliances	A.C.S. Hayden R.W. Braaten
20.	80-75	(TR)	The Summerside Project-An AFCB Boiler for High Sulphur Coal and Wood Chips	F.D. Friedrich
21.	80-83	(OP)	Coal-Oil Mixture Research and Development in Canada	H. Whaley C.E. Capes I.C.G. Ogle D.A. Reeve
22.	80-85	(OP)	Burner Nozzle Wear During Coal-Oil Mixture (COM) Combustion Trials in a Small Utility Boiler	H. Whaley P.J. Whalen
23.	CANMET REPORT 79-39		Fluid Bed Combustion - An Emerging Energy Technology	F.D. Friedrich

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Hayden, A.C.S., Braaten, R.W., "Canadian Road Test of Automotive Lead Traps", Presented at the 73rd Air Pollution Control Association Annual Meeting, Montreal, Canada, June, 1980.

Hayden, A.C.S., Braaten, R.W., "Efficient Wood Stove Design and Performance", Proceedings of Second Biomass R & D Seminar, March, 1980.

Hayden, A.C.S., "Reduction in Quality of Distillate Fuel Oil", Presented to the Fifth Annual Joint EPA/ASME/APCA Meeting on Stationary Source Combustion, Raleigh, U.S.A., December, 1980.

Hayden, A.C.S., "Potential and Problems with the Use of Canadian Coal in Domestic Solid Fuel-Fired Space Heaters", Presented at Wood Heating Seminar VII, Denver, U.S.A., August, 1980.

Miscellaneous, Publications, Conference and Seminar Presentations

Hayden, A.C.S., Braaten, R.W., "Efficient Residential Oil-Heating Systems", Manual for Servicemen, Designers and Builders, January, 1980.

Hayden, A.C.S., "Systemes Efficaces de Chauffage Residential a l'Huile", March, 1980.

Hayden, A.C.S., "Wood Stoves: Efficient Design and Performance", Information EMR, October, 1980.

Friedrich, F.D., Energy Systems; R & D Needs", Presentation to a Closed Meeting of OERD and CANMET Energy Research Program Office, Ottawa, March, 1980.

Friedrich, F.D., "Welcome and Introduction to a Seminar on Municipal Waste Utilization", Interdepartmental Seminar, Invited Attendance, Ottawa, May, 1980.

Friedrich, F.D., "Welcome and Introduction to a Seminar on MHD", Interdepartmental Seminar, Ottawa, February, 1980.

Friedrich, F.D., Whaley, H., Hayden, A.C.S., "CCRL Facilities and Research Program", Invited tour of CCRL by Members of Parliament, June, 1980.

Whaley, H., "Canadian Coal-Oil Mixtures Program", Seminar held at University of Toronto, December, 1980.

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

British Flame Research Committee (member) .... G.K. Lee

International Flame Research Foundation

Aerodynamics Panel (member) .... H. Whaley

Flame Chemistry Panel (member) .... E.J. Anthony

Organization of Economic Cooperation and Development

Long Range Transport of Air Pollution (member) .... H. Whaley

Waste Heat Utilization .... F.D. Friedrich

International Organization for Standardization (ISO)

Domestic Oil Burners .... A.C.S. Hayden

Stationary Source Emissions .... H. Whaley

International Energy Agency (IEA)

Coal-Oil Mixture Implementing Agreement .... H. Whaley

Atmospheric Fluidized Bed Combustion Agreement .... F.D. Friedrich

NORTH AMERICA

US/CANADA Research Committee on the Long Transport of Air Pollutants: Co-chaired by the US EPA and AES Environment Canada (member) .... H. Whaley

American Society of Mechanical Engineers

Fuels Division Research Committee (member) .... G.K. Lee

Research committee on Corrosion and Deposits from combustion Gases (member) .... G.K. Lee

Task Force on Energy Conversion Research (member) .... G.K. Lee

Air Pollution Control Division (member) .... H. Whaley

United States Department of Energy

COM Standards and Practices Committee (member) .... H. Whaley

COM Combustion Sub-committee (chairman) .... H. Whaley

US/Canadian Interagency Wood Combustion
Research Group (member) .... A.C.S. Hayden

Air Pollution Control Association
Residential Heating .... A.C.S. Hayden

CANADA - FEDERAL

Canadian Government Specifications Board
Committee 51-GP, Middle Distillate Fuels (member) .... A.C.S. Hayden
Committee 51-GP, Stationary Combustion (chairman) .... A.C.S. Hayden

Interdepartmental
Automobile Emission Standards (memner) .... A.C.S. Hayden
Fuel Committee (member) .... F.D. Friedrich
Retrofit Devices and Additives (member) .... A.C.S. Hayden
Task Force on Stck Height Estimation (member) .... H. Whaley
Future Liquid Fuel Use .... A.C.S. Hayden

CANADA - MISCELLANEOUS

Canadian Gas Association
Standards Committee (member) .... G.K. Lee

Canadian Gas Research Institute (director) .... G.K. Lee
Canadian Institute of Energy (director) .... F.D. Friedrich
Ottawa Branch (treasurer) .... E.J. Anthony

Canadian Standards Association
Positive Chimney Dampers (member) .... A.C.S. Hayden
Air Pollution Control (member) .... H. Whaley
Incineration Performance (member) .... F.D. Friedrich
Retrofitting of Oil Burners (member) .... R.W. Braaten
Sampling Emissions and Measurements (chairman) .... H. Whaley

Solid Fuel Burning Appliances (member) .... A.C.S. Hayden

Solid Fuel Installation (member) .... R.W. Braaten

Installation of Oil Burning Equipment .... A.C.S. Hayden

HUDAC

Future Space Conditioning Requirements .... A.C.S. Hayden

ULC - CSA

Joint Committee on Wood Burning Appliances (member) .... A.C.S. Hayden

CONTRACTS AND RESEARCH AGREEMENTS

Title	Investigation	Scientific Authority	Status, March 31, 1981
Recirculating Fluid Bed Combustion of Syncrude Coke	A. Amlstrom Ltd,	D.L. Desai	In progress
Report on Ash Disposal at DND Base Summerside	Intercontinential	F.D. Friedrich	Completed
Coal-Oil Mixture Combustion Trials in a 10 MWe Utility Boiler (Phase III)	New Brunswick Electric Power Commission	H. Whaley	Completed - awaiting final report
Design and Construction of Retrofit Package for as-fired Furnace	Clare Brothers Ltd.	A.C.S. Hayden	In progress
Testing of Retrofit Kits in Existing Residential Furnaces	AERO Environmental Ltd.	A.C.S. Hayden	Completed
Pilot Plant Trials ABC of Maritime Coal	Foster Wheeler Ltd.	F.D. Friedrich	Completed
Fluidized-Bed Heating Plant Design (Phase III)	Foster Wheeler Ltd.	F.D. Friedrich	Completed
Fluidized-Bed Heating Plant Design (Phase III)	Dominion Bridge Co. Ltd.	F.D. Friedrich	Completed
Pilot Plant Studies on Fluidized-Bed Coal	Queen's University	E.J. Anthony	In progress

Combustion

Fluidized-Bed Combustion Coal Dryer	Luscar Ltd.	F.D. Friedrich	In progress
Behaviour of Coal Particles Under High Pressure	Warnock Hersey Services Ltd.	D.L. Desai	In progress
Coal Slurry Preparation and Testing	General Comminution Incorporated	G.N. Banks	In progress
Molten Salt Coal Gasification	Surveyer, Nenniger and Chenevert, Inc.	G.N. Banks	Completed
Coal-Oil Rheological Characteristics	Saskatchewan Research Council	G.N. Banks	Work completed awaiting final report
Low-Btu Burner Development	Canadian Gas Research Council	G.K. Lee	Phase 3 completed Phase 4 in progress
NO_x Formation During Pulverized Fuel Combustion	Environmental and Energy Research Laboratories Inc.	G.K. Lee	In progress
Low-NO_x Burner Retro-fit at Nanticoke Generating Station	Ontario Hydro	G.K. Lee (for CEA)	In progress

CONTACTS, MEETINGS AND FIELD TRIPS

Industry, government, universities, the media and the general public, as in previous years, continued to impose heavy demands on the CCRL research staff for scientific advice, consulting servicies and information exchanges. In all more than 1000 telephone calls, written enquiries, meetings, laboratory visits and media interviews were handled. Some of these are summarized below:

H. Whaley attended the 6th International Flame Research Foundation (IRRF) member's conference in Holland during May, 1980 and a joint meeting of the IFRF pulverized fuel and aerodynamics panels in West Germany during September, 1980.

H. Whaley attended the Institute of Energy annual meeting in London, England during May, 1980.

H. Whaley was interviewed for the CTV program "House on the Hill", concerning the evaluation of Canadian coals in joint industry/government research programs.

During December, 1980, H. Whaley gave a one day seminar on the Canadian Coal-Oil Mixture program to graduate and undergraduate students of the University of Toronto.

During 1980, F.D. Friedrich advised and briefed several consultants, government officials, private industries and visitors on subjects such as; fluidized-bed combustion, MHD technology for power generation, wood densification and combustion, slagging and corrosion in coal-fired boilers, reduction of NO_x in conventional combustion systems and district heating systems fueled by municipal garbage combustion. A brief list of some of the people or groups advised were; Governor-General Schreyer, Coal Processing Consultants (Great Britain), Nova Scotia Ministry of Mines and Energy, Middleton Associates (Toronto), Domtar (Cornwall), University of Calgary, Alberta Dept. of Economic Planning, New York STate Electricity and Gas Company, Consumer and Corporate Affairs (Canada), Petroleum Research Agency (China) and Toshiba Industries (Japan).

During the past year A.C.S. Hayden was engaged in interviews by the media (French and English) 30 times on subjects pertaining to oil-furnace retrofitting, wood furnace technology, chemical cleaners, alcohol fuels in transportation and automobile lead traps and fuel economy. In addition he was guest lecturer or luncheon speaker on at least 15 different occasions. He also conducted a 2 day seminar (in French) to set up training courses for Quebec and New Brunswick servicemen to retrofit oil burners and a 2 day seminar (in English) to transfer CCRL residential wood technology to aid as a component in the federal "Off-Oil" program.