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CANMET

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

ENERGY RESEARCH LABORATORIES

ANNUAL REPORT 1985/1986

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MAY 1986

ENERGY RESEARCH PROGRAM

ENERGY RESEARCH LABORATORIES

DIVISION REPORT ERP/ERL 86-29(TR)

FOREWORD

A principal objective of CANMET's Energy Research Program is the development of the technologies required to conserve and to increase the supply of liquid fossil fuels in Canada to bridge the gap that exists between domestic supply and demand (both internal demand and export opportunities). The Energy Research Laboratories (ERL) responds to this R&D objective on matters related to the upgrading of oil sands, heavy oil and synthetic crude production; coal combustion; coal gasification and liquefaction; and improved oil and gas domestic heating furnaces. Important input and guidance on project selection and implementation is provided by industry advisory committees and user groups. Shared-cost projects with industry are underway in-house, and major elements are undertaken in the private sector through shared-cost contract R&D programs.

This report summarizes the activities of ERL during fiscal year 1985/86 and is intended as a report to CANMET management and staff and as a working document for preparing the CANMET Review and other branch publications.

For operational purposes the division is made up of three laboratories: the Combustion and Carbonization Research Laboratory, the Synthetic Fuels Research Laboratory, and the Hydrocarbon Processing Research Laboratory.

The attached organization chart indicates the major functions and the principal scientists and engineers in charge of operations. The resources assigned to the laboratories in 1985/86 were as follows:

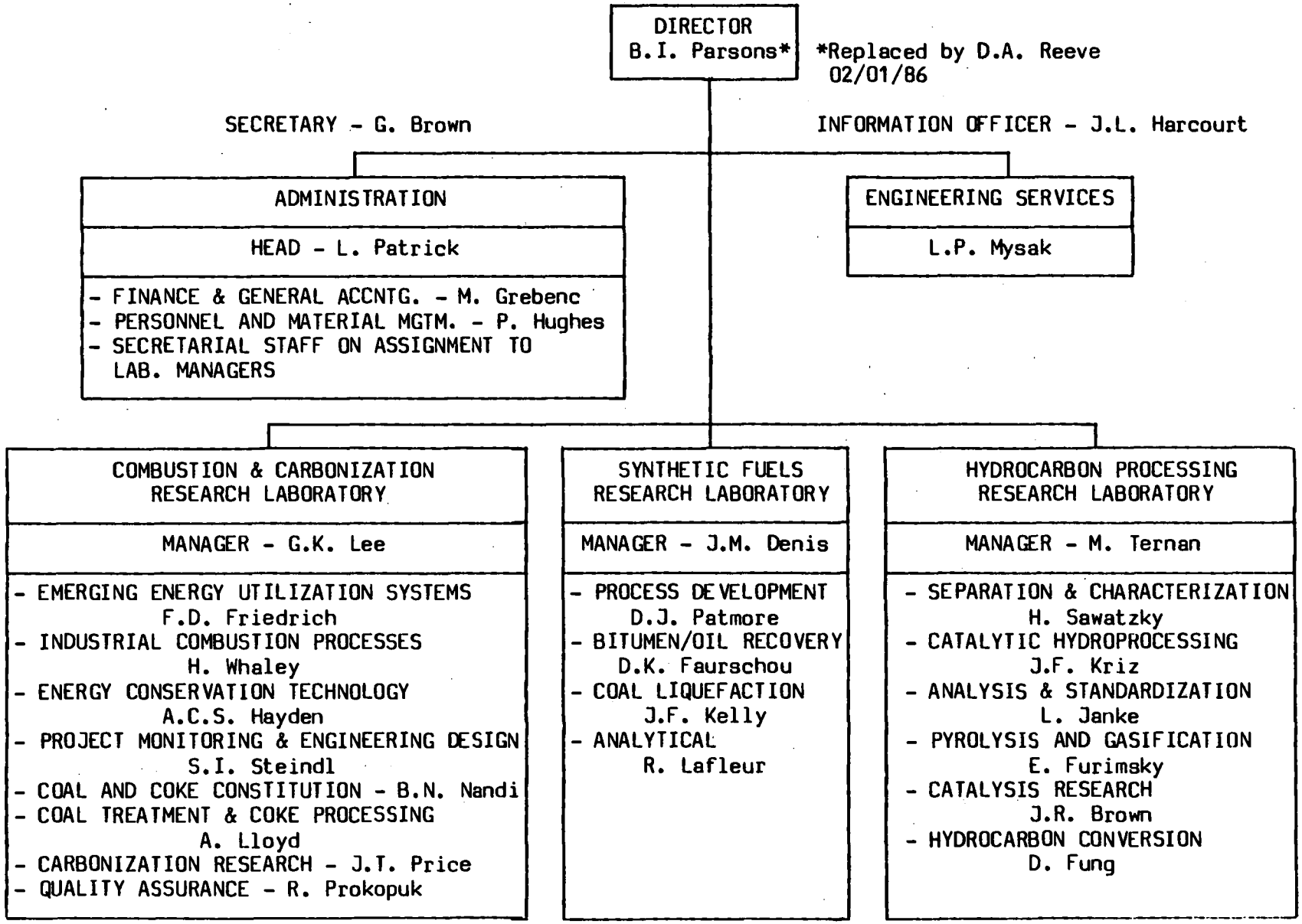
Laboratory	Person Years	Salaries $K	Operating $K	Capital $K	Contracts $K
Combustion & Carbonization Research Laboratory	57	2238	1031	905	2347
Synthetic Fuels Research Laboratory	51	2003	755	966	4176
Hydrocarbon Processing Research Laboratory	37	1453	705	975	2566
Administration	22	864	900	75	
TOTALS	167	6558	3391	2921	9089

Important achievements and highlights of the year's work are summarized at the beginning of each laboratory report.

D.A. Reeve

D.A. Reeve
Director
Energy Research Laboratories

ENERGY RESEARCH LABORATORIES



AVANT-PROPOS

Un objectif principal du programme de CANMET sur la recherche énergétique est le développement de technologies pour la conservation et l'accroissement de l'approvisionnement du Canada en combustibles fossiles liquides et ainsi réduire l'écart entre l'offre et la demande en tenant compte et du marché national et des possibilites d'exportation. Les Laboratoires de recherche sur l'énergie (LRE) se chargent des responsabilités en R&D sous cet objectif en matière de valorisation des sables bitumineux, des pétroles lourds et de la production de pétroles synthétiques; de combustion, gaséification et liquéfaction du charbon; et d'amélioration des chaudières de chauffage domestique alimentées au gaz ou au mazout. Des comités consultatifs formés de représentants de l'industrie et de clients des laboratoires aident à orienter le choix et le déroulement des projets. Des projets à frais partagés avec l'industrie sont en cours dans les laboratoires, et des parties importantes se déroulent dans le secteur industriel sous des programmes de contrats à frais partagés pour la R&D.

Le présent rapport est un résumé des activités des Laboratoires de recherche sur l'énergie pour l'année financière 1985/1986. Il s'adresse à la direction et au personnel de CANMET et il s'agit d'un document de travail devant permettre la préparation de la Revue de CANMET et d'autres publications de la Direction.

La Division comprend trois laboratoires: le Laboratoire de recherche sur la combustion et la carbonisation, le Laboratoire de recherche sur les combustibles synthétiques, et le Laboratoire de recherche sur la traitement des hydrocarbures.

L'organigramme ci-joint indique les activités principales et les scientifiques et ingénieurs responsables de ces activités. Les ressources dont disposaient les laboratoires en 1985/1986 ont été utilisées de la manière suivante:

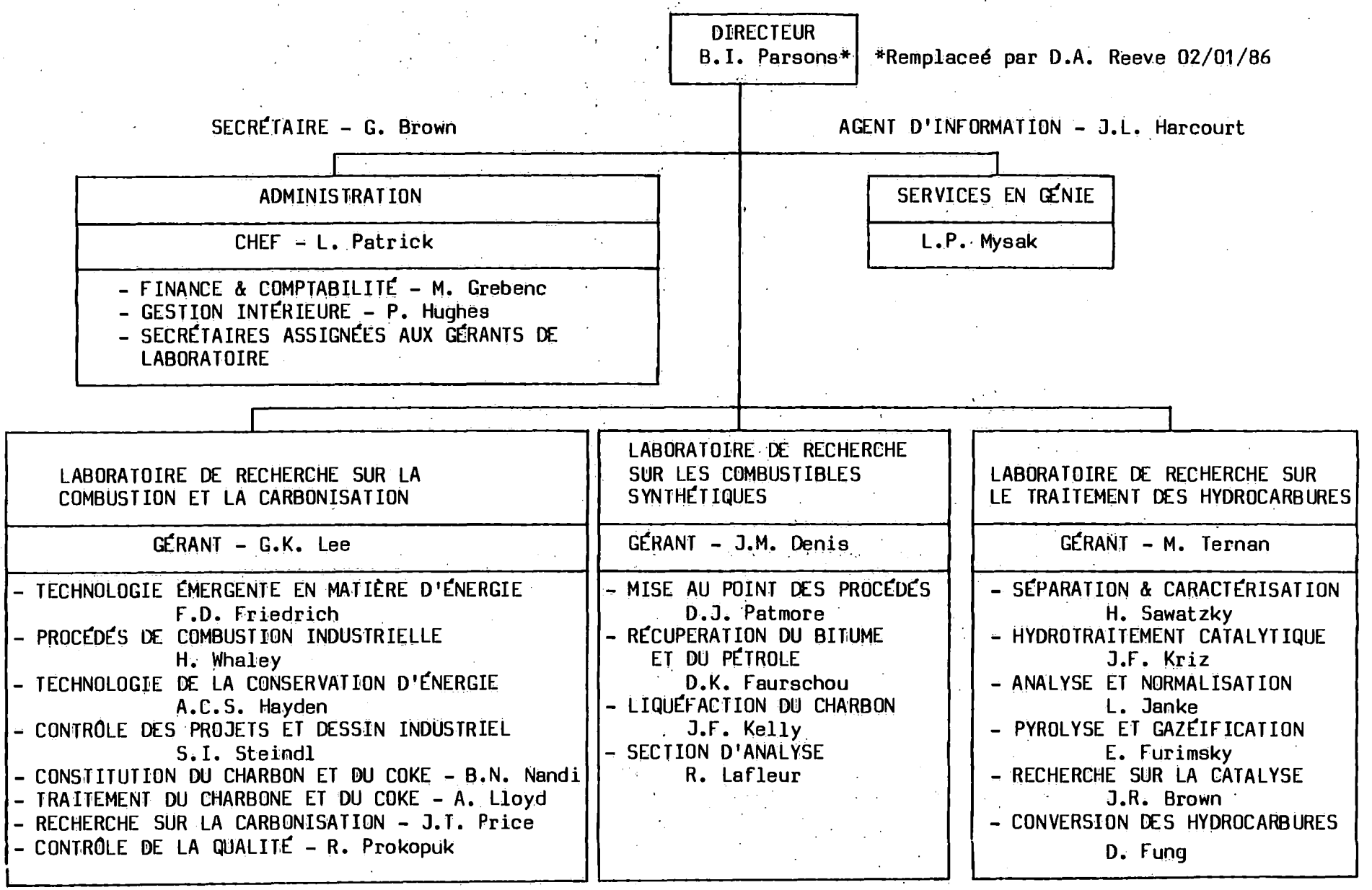
Laboratoire	Année-Personne	Salaires $K	Exploitation $K	Immobilisation $K	Contrats $K
Laboratoire de recherche sur la combustion et la carbonisation	57	2238	1031	905	2347
Laboratoire de recherche sur les combustibles synthétiques	51	2003	755	966	4176
Laboratoire de recherche sur le traitement des hydrocarbures	37	1453	705	975	2566
Administration	22	864	900	75	
TOTAUX	167	6558	3391	2921	9089

Les réalisations importantes et les faits saillants des travaux de l'année son résumés au début de chaque rapport des laboratoires.

D.A. Reeve

D.A. Reeve
Directeur
Laboratoires de recherche sur l'énergie

LABORATOIRES DE RECHERCHE SUR L'ÉNERGIE



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PART I

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

HIGHLIGHTS

During the past year increased emphasis was placed on performing shared-cost research and development for external agencies and industry and on expanding longer-term, basic science elements of projects in collaboration with universities. Demonstration activities sponsored by EMR and the private sector continued to require considerable scientific direction and support.

Intramural research was highlighted by the completion of the construction phase of a laser system for flame probing, the certification of a CANMET-developed, retrofit module for significantly increasing conventional residential gas furnace efficiencies, and a carbonization study which indicated that the cold strength of blast furnace coke may not generally correlate well with its hot strength. In addition, the results of CCRL round-robin research on biomass combustion were incorporated into proposed standards by the Canadian Standards Association and the American Society for Testing and Materials for wood burning appliances, and a novel burner for coal/water fuels incorporating a National Research Council (NRC) design of ceramic atomizer was developed.

The successful extrapolation of completed research to operationally reliable systems was demonstrated through a number of major projects. Three of the accomplishments in this difficult and exacting field included the acceptance of the Summerside fluidized bed heating plant and its subsequent operation on high-sulphur coals with over 90% in-bed capture of the sulphur; the generation of baseline combustion and emissions data from three different industrial stoker-fired systems for energy recovery from wood refuse; and the operational performance of a coal/water fuel in a cement kiln.

Contract research, an important component of both the in-house and the demonstration projects centred around the design of an automated petrography system for Western Canadian coals, the potential steam derating due to conversion of boilers from residual oil to coal/water fuels, the fragmentation of coal during bubbling fluidized-bed combustion and a series of studies to improve fuel utilization in six energy-intensive industrial processes.

Laboratory scientists were also actively involved in six research agreements sponsored by the International Energy Agency. These agreements covered:

a) atmospheric fluidized bed combustion;
b) coal-liquid mixtures;
c) low NO_x coal combustion;
d) basic coal combustion science;
e) district heating; and
f) heat pumps.

CCRL's budget for 1985/86 was allocated as follows:

	$K
Salaries	2238
Capital	905
Operating	1031
Contracts	2347
TOTAL	6521

The staff prepared 34 research reports, published 44 papers and made 47 presentations.

ENERGY CONSERVATION TECHNOLOGY

SPACE HEATING - OIL AND GAS

The objective of this program is to reduce consumption of fuels for space and service water heating through improved combustion technology and the optimization of operational conditions, while ensuring safe operating conditions and minimal impingement on the environment.

The major emphasis is directed to the evolution of technology and strategies to replace oil with natural gas as the primary space and water heating fuel. By developing retrofit devices and new designs of combustion systems to improve burner/furnace efficiency and reduce potential unsafe operating conditions with present systems and to encourage more energy efficient housing, efficiency improvements from 20 to 40% are possible on gas. By using substitute and degraded liquid fuels, additional oil may be available for the transportation sector.

In-house laboratory R&D on new technologies for space and water heating is ongoing, with additional projects in the field, mainly by contract. Development of specific advanced technologies is also carried out by contract to industry. Seasonal performance experimental procedures are being developed and new designs produced, with the results transmitted to standards writing agencies, testing laboratories, manufacturers and government agencies through standards committees, published papers, seminars, associations, e.g., Canadian Standards Association, Canadian Gas Association, Canadian Wood Energy Institute, Ontario Petroleum Association and Canadian Home Builders Association, and through close cooperation with individual manufacturers and utilities. Liaison is also maintained with US developments, particularly relating to environmental concerns and alternative technologies.

The retrofit condensing furnace, developed with CCRL and Clare Brothers, which can augment the efficiency of existing residential gas furnaces by 20-30%, has now been placed on the market in both Canada and the US by Clare. Additional technical support by CCRL is being given to Clare to demonstrate to these authorities that the unit is not only more efficient, but also considerably safer than the existing unmodified gas furnaces. The field trial of this equipment has been extended to the end

of this heating season, with both power burner and no-draft hood configurations added.

The final phase study on plastic heat exchangers with Consumers' Gas-Spider Engineering is complete, having examined alternative plastics and material assembly/bonding techniques. A polyethylene/polypropylene co-polymer, similar to that used in the first prototype, is the most suitable material for the range of temperatures and corrosive media to be encountered. Two new prototypes, constructed from the new material with actual manufacturing-type bonding techniques are undergoing long-term cyclic testing at CCRL.

Increased use of Canadian distillate fuel oils processed from synthetic crudes has caused concern for deteriorated performance. In cooperation with the oil industry, a series of experiments has been carried out to examine the effect of fuel quality degradation. Combustion characteristics such as burner ignition behaviour, emissions of incomplete combustion products, furnace temperatures, efficiencies and excess air levels are obtained from controlled laboratory experiments, simulating a real-life home environment. The test protocol requires a 1-h steady state run from cold start, followed by five 10-min on, 10-min off cycles.

Fuels are analyzed for their paraffinic, olefinic, naphthenic and aromatic contents, as well as viscosity, density, carbon residue, elemental components, distillation range, etc. The experimental results show that while the combustion characteristics are influenced by interacting physical-chemical properties, fuel aromaticity and viscosity show a strong correlation with particulate and gaseous emissions.

The potential exists for significant reductions in energy consumption by improving the efficiency of residential oil-fired heating systems. Residential oil furnaces in Canada are compared only on the basis of their steady state efficiencies. Such a measurement neglects cyclic and off-cycle performance, as well as the effect of dilution air. On the other hand, a seasonal efficiency standard would take these factors into account. It is possible to have two furnaces with the same steady state efficiency, yet with 10-20% differences in their actual seasonal performance, due to differences in technology. A detailed paper, developed for the Canadian Standards Association, presented techniques to enable the Canadian Standards Association to formulate a seasonal efficiency standard for oil furnaces.

Clare Brothers are developing, under contract, a high efficiency, low-air-requirement oil furnace for northern applications. Potential fuel savings are 20-30%, relative to a conventional furnace, without the problems of condensing. Preliminary design work is underway, with a working prototype to be produced in the summer of 1986.

Since severe problems may occur with masonry and prefabricated metal chimneys, in both new and existing installations, operational characteristics of fossil fuel- and wood-fired appliances are being examined in relation to the chimneys they feed. Both steady state and cycling characteristics are important. Changes in fuel, the use of mixed

energy sources and improvements in efficiency have all affected the chimney environment. Existing chimneys experience many defects, some caused by poor construction, some caused by mismatching with appliances. Moisture damage, usually from the flue gas, is seen as a major cause of chimney failure. Modifications to the venting system, such as relining and repair, or the use of additional metal liners may improve the chimney performance.

With the increased interest in energy conservation, homes are being made tighter with more insulation and weatherstripping. At the same time, it is becoming increasingly difficult to ensure that combustion appliances receive adequate air to operate safely and properly. The various combustion systems found in Canadian homes have large differences in their air requirements, with implications for efficiency. Cold outside air must enter the house, be warmed up to room temperature and then immediately exhausted up the chimney. More importantly, it raises serious questions of the ability of tight housing to supply combustion air requirements, with implications for the health of the inhabitants.

ENERSOLVE (INDUSTRIAL ENERGY CONSERVATION)

The ENERSOLVE program is concerned with increasing the efficiency of utilization and reduction of consumption of oil and gas in industrial processes. Much of the present industrial equipment, particularly if more than 10 years old, may not be operating or even operable at maximum attainable efficiency of fuel use. Scope exists to technically upgrade most installations to attain greater fuel economy. The program is intended to support a limited number of specific studies on retrofit of combustion systems in a variety of industrial sectors and regions of Canada. By this means, a fully documented capability for energy conservation will be formulated by the performers, enabling them to subsequently and privately offer such services to industry in general, perhaps even with a guaranteed pay-back.

Six additional pre-engineering studies, including on-site testing, have now been carried out in the following industries over the past year: structural clay products; dairy processing; pipes foundry; brewery; steelmaking - Ontario; steelmaking - Saskatchewan.

During the course of the ENERSOLVE studies, it has been found that Canadian industry often uses rigid procedures developed for steam-raising boilers with specific fuels to determine performance without realizing the simplifications or complexities required for other industrial processes or for different fuels. It has become apparent that there is a significant lack of knowledge of the fundamentals of combustion system analysis and of the major potential benefits that may accrue from improvements to that system. It is important that the general principles, industrial results and the fact that there are now Canadian consultants who are developing the skills to provide such a service to industry should be made widely known.

A detailed technology transfer program is now being set up by the Industrial Energy Division (IED) of ECOS. CCRL is working closely with this group to ensure that the findings of ENERSOLVE reach effectively the

widest possible audience through a detailed combustion manual and audio-visual training package. In particular, to ensure technical reliability and compatibility with ENERSOLVE results, CCRL is writing the technical manual/module on combustion, one of a number of manuals being prepared for IED.

In addition, in cooperation with the Natural Gas Branch and Communications Branch, EMR, CCRL conducted combustion seminars with potential industrial users of natural gas in the Lac St. Jean area of Quebec. These detailed technical seminars provided a background of data and examples to demonstrate how combustion systems should be analyzed and how improvements might be implemented, using natural gas.

Two potential industrial sites for a retrofit flue gas condensing system on a gas-fired unit have been identified. Contracts have been let to carry out detailed analyses for application of this technology offering the major efficiency gains, which have now been realized in the residential sector. One site is a meat packing plant in British Columbia, the other is a pulp and paper boiler in Ontario.

BIOMASS COMBUSTION

Residential Wood Combustion

Wood stoves have been shown to be an efficient and often inexpensive way to heat a house. However, often significant amounts of incomplete combustion products can be produced, resulting in a potential fire hazard if deposited in the chimney in the form of creosote, or in a severe air pollution problem, in regions of poor fumigation. CCRL efforts have been directed towards changing the design of these appliances in order to improve combustion performance and by generating techniques by which the performance can be effectively measured.

In addition to carrying out further work to finalize these standards, CCRL is now carrying out an experimental program to extend the standard to cover central heating appliances. Other efforts are primarily geared to develop techniques or strategies to improve the performance of existing appliances in the field, particularly for areas such as Whitehorse, where severe air pollution problems can be traced directly to the use of wood burning appliances.

Round robin testing of the proposed CSA standard for efficiency and emissions of wood stoves has been completed successfully, with a similar procedure also being adopted by ASTM in the US. Work has been proceeding on techniques to improve the performance of existing appliances, and technical support is being given to a long term field study of appliance performance in homes, sponsored by the US Coalition of North East Governors.

Within the laboratory, construction has been completed on a wood conditioning room. This allows the preparation of fuel wood test charges having a uniform moisture content. As well, a dilution sampling system has been installed to allow direct sampling of particulate emissions from the wood burning appliances.

Over the year, six advanced design wood stoves and two furnaces have been evaluated in the laboratory. There has also been considerable test procedure development and refinement, both for CSA and for ASTM. Projects have included the evaluation of catalyst versus non-catalyst performance, the effects of fuel species, fuel charge configuration, and disabling automatic controls.

Central wood furnaces, because of their cyclic on-off "stew" operation in response to thermostat control, have the potential to be major emitters and creosote generators, while suffering efficiency penalties. Determination of their seasonal performance requires a combination of the cyclic procedure developed for gas furnaces with the fuel composition change developed for wood stoves. Techniques are being developed to enable furnace manufacturers to improve the design and operation of their appliances, and to regulators to determine feasible techniques to control the emissions from such units. Combining work in the laboratory and contract work to the Centre de recherche industrielle du Québec, techniques are being developed to measure the cyclic performance of central wood burning furnaces and boilers, and to give design changes to these extremely poor performing appliances.

Papers have been presented on the wood furnace work, on design effects to improve performance of existing stoves, on the interaction of wood burning fireplaces and stoves on the air requirements of tight housing and on the requirements of chimneys to safely serve these appliances.

The high emissions from residential wood burning stoves are due to incomplete combustion, resulting from design shortfalls in present appliances. Emissions increase significantly when the firing rate of an appliance is reduced below a certain level, the "critical burning rate". New combustion designs offer potential to reduce these emissions. While new designs are important, emissions from presently installed equipment can be reduced if the firing rate is kept above the "critical rate" of the typical overnight burn condition. One way is to reduce the effective heat transfer surface of the appliance by the use of double-walled flue pipe in place of single-walled pipe from the appliance to the chimney; this forces the stove to run in a hotter more efficient manner. There are two additional benefits: (i) efficiency will be increased; and (ii) the propensity to produce creosote will be decreased, making the appliances safer to operate.

Industrial Wood Combustion

Since 1980 CANMET has provided substantial scientific support to federal and private sector programs related to the combustion of biomass in industrial boilers and processes. This support has included the evaluation of proposals, advice on new initiatives, the formulation of project tasks and the management of contracts.

Two research contracts, one valued at $1300K over four years and one valued at $250K over one year, were completed in 1985/86, under a program jointly funded by ENFOR and the Bioenergy Development Program to evaluate the combustion, steam production and emission characteristics of

four different industrial wood-fired boilers. The results of these evaluations, which are reported in a 14-volume set, have been applied by the participating plants to reduce steam costs significantly and by the industry in general to optimize specifications for new equipment.

Indications from these trials that hog fuel-fired systems have inherent problems led to the development of an IEA program at the International Flame Research Foundation to study some of the fundamental properties of an alternative combustion technology, pulverized firing. The experimental work was completed and a final report was received last July.

Plans for 1986/87 call for the evaluation of a fifth boiler unit employing a novel shredded wood-firing system, similar to the IEA work, and a correlation of the data from the four boilers previously evaluated. Both of these studies will be funded by the Bioenergy Development Program, with Scientific Authority resting at CCRL.

Pilot scale trials have been conducted on a new technique for dewatering biomass. The current focus is on primary sludge dewatering to yield a combustion feedstock, while resolving a major environmental disposal problem for the industry. The contractor for the first phase of the work, the Pulp and Paper Research Institute of Canada, provided some of the funding. If this work is successful, royalty sharing of the technologywill occur. The work also may have application to hog fuel, shredded wood and low-grade coal.

A pilot-scale system, rated at 250 kW, is now being installed at CCRL to develop combustion performance guidelines for commercial and industrial chip-fired and other processed wood-fired units.

COAL AND COKE CONSTITUTION

The enhancement of coking propensities of naturally oxidized/weathered bituminous coals from Western Canada was previously achieved via the water-gas shift reaction ($CO + H_2O$). A new technique for treating weathered coals with heavy oil derived from bitumen or petroleum sources in the presence of hydrogen has shown promise in preliminary experiments involving relatively mild temperatures and pressures. This technique is being examined in some detail using a variety of naturally weathered coals from Western Canada.

Additional work on the characterization of oxidized coals by various spectroscopic techniques has been done. A particularly interesting study dealing with a ^{15}N solid state NMR investigation of adsorbed pyridine^{-d5} on fresh and oxidized coals has shown that the amount of adsorbed pyridine can be related to the concentration of carboxyl groups in coal. Fourier transform infrared (FTIR) and secondary ion mass spectrometry (SIMS) have been especially valuable in characterizing oxidized coals.

The addition of inexpensive carbonaceous material to high fluid swelling coal for the production of metallurgical coke of high stability

index is economically desirable. A coking study by blending high-volatile Canadian coal with delayed or fluid coke from Athabasca bitumen is being investigated to determine the improvement of the coke strength stability index. Resultant coke obtained so far by blending Athabasca bitumen coke in a bench scale coke oven meets the ASTM stability strength index. This technique may be an inexpensive alternative to the blending of high-volatile Canadian coals with low-volatile North American coals which is presently used. The sulphur content of the blended coal is below 1%.

Weathered coals from Western Canada can be a problem in pulverized fuel boilers. To gain a better understanding of the nature of the unburnt carbon produced by weathered coals a series of combustion experiments on laboratory oxidized coal samples was carried out using a drop-tube furnace. Results show markedly different trends for coals of different geological age and petrographic composition.

A joint research project with the University of Ottawa on the kinetics of coke formation in hydrocarbon fractions has been extended. A mini-autoclave at hydrocracking conditions is used for this study. Detailed results have been published in contract report "Fundamental studies and process development for upgrading of bitumen and heavy oil".

EMERGING ENERGY UTILIZATION SYSTEMS

Effort is directed at expediting the application of fluidized bed combustion (FBC) technology to meet Canada's unique energy needs. As in most western nations, a primary application is in the environmentally-benign utilization of high-sulphur coal. However, additional applications include co-firing of coal and wood waste in the pulp and paper industry, utilization of coal washery rejects, and combustion of liquid or solid residues from heavy oil upgraders. The diverse nature of these applications necessitates federal support to ensure that the technology advances to maturity in an acceptable time frame.

Major objectives of the CCRL program are:

- to demonstrate the environmental benefits of FBC boilers in an industrial setting;
- to develop a databank on the combustion performance of a range of Canadian coals and other solid fuels to aid designers of FBC equipment;
- to develop a databank on the performance of various Canadian limestones as sulphur sorbents;
- to support other agencies in the development of FBC technology by appropriate means.

IN-HOUSE R&D ON FLUIDIZED BED COMBUSTION

Pilot-Scale Program

CCRL Mark II bubbling bed FBC pilot plant

The CCRL Mark II fluidized bed combustor is a versatile pilot-scale research facility which was installed at ERL in 1980. Important features are a combustor cross-section of 380 mm x 400 mm, variable in-bed heat transfer surface, provision for either over-bed or in-bed feed, separate weigh feeders for fuel and sulphur sorbent, and provision for reinjection of fly ash from a multicyclone dust collector. Since its commissioning, the Mark II facility has been operated using a variety of coals and other fuels to develop a bank of combustion performance data which will ultimately be required by designers of full-scale systems. Much of the pilot-scale work has been in direct support of the CFB Summerside demonstration, which is described later.

In the past year pilot-scale combustion evaluations were carried out with bituminous coal washery rejects from the Prince mine in Nova Scotia, with a low-sulphur lignite from Saskatchewan to determine the sulphur capture potential of the natural mineral matter, and with some biomass materials. Unfortunately, the combustor's fuel feed system is not well suited to most forms of biomass. In addition, work was begun to explore the combustion of heavy liquids, such as pitch residues from heavy oil upgrading. The first step is to establish a suitable method of fuel feed, and several concepts are being explored, using residual oil as fuel.

CCRL circulating FBC pilot plant

A second generation fluidized bed concept, known as circulating FBC, has been demonstrated to have advantages over bubbling-bed FBC in terms of more efficient sulphur capture and increased ability to cope with unreactive fuels. Since it appears likely that circulating FBC will be employed in most large-scale FBC applications in Canada, it was decided in 1982 to equip CCRL with a pilot-scale combustor of this type.

A detailed design was prepared by contract. Main features of the facility are:

- combustor inside diameter of 400 mm,
- combustor height of about 7 m,
- variable heat extraction from the combustor by means of retractable bayonet tubes, and
- capability to feed coal, limestone, and ultimately, biomass and liquid fuels.

All major components, such as the combustor and cyclone assembly, blowers, baghouse, conveyors, cooling tower, ash handling equipment and instrumentation have been procured. Substantial building modifications are required, and these are in the final stages of design. Preparation of foundations and building modifications are scheduled to commence early in the summer of 1986. Concurrently, final structural and piping drawings of

the pilot plant must be prepared, probably by contract. Erection of the facility can then commence.

Bench-Scale Program

Coal reactivity parameters

The wide range of coals available in Canada which may ultimately find application in FBC systems makes it highly desirable to be able to obtain quickly and economically some measure of their relative performance in an FBC combustor. Accordingly CCRL undertook to develop a bench-scale FBC and an empirical procedure for ranking coals and other fuels in terms of reactivity.

The apparatus was commissioned in 1982. Subsequently a procedure was developed in which a sample of fuel is batch-fed to the pre-heated combustor, and the rate of CO_2 evolution is used as a measure of reactivity. A sophisticated flue gas analysis system coupled with computerized data processing provide a rapid, inexpensive test procedure, and results are evaluated in terms of a parameter called the mean carbon residence time.

To calibrate the procedure, an extensive series of tests has been conducted with five commercial coals having well known reactivity characteristics with respect to conventional combustion techniques. Fuel charges of different weight and size consist were examined over a range of temperatures and a report presenting the results is in the editorial stages. Reactivity tests have also been carried out with a variety of biomass fuels, and with petroleum coke.

SO_2 sorbent reactivity

Early work on sulphur capture in fluidized bed combustion showed that limestones and dolomites vary greatly in their ability to react with SO_2, e.g., to achieve a given level of sulphur capture, stone from one deposit might require a Ca/S ratio of 2, whereas stone from another deposit might require a Ca/S ratio of 5. Differences are related primarily to the porosity and hardness of the stone, as they affect the surface area available for reaction with SO_2.

In cooperation with CCRL, CANMET's Mineral Sciences Laboratories (MSL) undertook to develop a database of the sulphation capacities of various Canadian limestones which are likely to be utilized in fluidized bed combustion. Having established that thermogravimetric analysis is not a reliable method of evaluation because it does not simulate the dynamic conditions of a fluidized bed, MSL developed a fluidized bed bench-scale apparatus and a procedure which closely simulates full-scale conditions. About 30 Canadian limestones were evaluated in this apparatus and the results were verified against full-scale experience. Additional tests were carried out in support of the AOSTRA/CANMET/Industry Upgrading Residue Utilization Project, and in collaboration with scientists from Norway and Sweden.

Further work in 1984 investigated the feasibility of enhancing the sulphation capacity of low reactivity limestones by various means. The most successful of these proved to consist of grinding the limestone to less than 0.15 mm, then pelletizing to the 2 to 6 mm size required for satisfactory operation of the fluidized bed. The pelletized material has larger pores hence more surface area than the native stone and thus achieves a sulphation capacity of about 50%, compared with 15 to 40% for the native stones. This effectively reduces the issue of limestone reactivity to a matter of the cost of grinding and pelletizing the less reactive deposits.

In the past year it was established that ash constituents of coal may enhance or retard the sulphation capacity of limestones. Iron compounds, very common in coal ash, generally have a negative catalytic effect. It is concluded that, for accurate results, limestone sulphation capacity should be determined in the presence of ash from the coal with which the limestone will be fired. The MSL limestone evaluation procedure has been modified accordingly.

Bench-scale circulating FBC

Circulating FBC is perceived as the most promising technology for the utilization of residues such as coke and pitch from the upgrading of tar sands and heavy oil. However, these materials contain relatively high concentrations of alkali and vanadium, which may cause boiler tube corrosion.

Beginning in FY 1984/85, the Mineral Sciences Laboratories undertook to investigate the deposition of vanadium, sulphur and alkali, the corrosion caused by them, methods to capture or stabilize them, and if possible, the recovery of vanadium and nickel from the ash. A 50-kW circulating FBC, 100 mm in diameter has been built. Progress has been slow because of equipment difficulties but the experimental program is now underway.

Analysis of carbon in FBC residues

When firing coal, it is necessary to determine the carbon content of the solid residues for calculating boiler efficiency. In the case of a fluidized bed boiler utilizing limestone for sulphur capture, the ash streams contain up to 40% CaO, which is a strongly reactive desiccant even at 450°C. This constitutes a potential source of error in the procedure for carbon determination since the samples may take up atmospheric moisture during sample collection, sample preparation, or even during ashing of the sample in a muffle oven. Moisture pick-up during ashing can be avoided by performing an acid extraction to remove carbonates and reacted CaO prior to the ashing step, and this has been adopted as the normal procedure in determining carbon content in FBC residues. However, this does not eliminate possible error due to moisture pick-up during sample gathering or preparation.

Absolute results can be obtained using a thermogravimetric/ differential thermal analysis technique. CCRL has been collaborating with

the Mineral Sciences Laboratories in developing an understanding of the mechanisms taking place. The rate at which samples pick up moisture has been determined for a suitable range of temperature and relative humidity conditions, and the results have made it possible to prescribe procedures for sample collection, storage and preparation which minimize error. Work continues on the development of a reliable, low-cost analytical procedure.

CONTRACT R&D ON FLUIDIZED BED COMBUSTION

Queen's University - Fluidized Bed Combustion

Under contract, Queen's University has been conducting extensive and varied research on FBC since 1981, using a pilot-scale combustor essentially identical to the CCRL Mark II facility. The present contract, covering two years, encompasses about $450K of work to be completed by March 1987.

To date combustion tests have been completed with Lingan coal (a bituminous coal from Nova Scotia) and Irish Cove limestone. These are the feedstocks that were used in the Point Tupper 10 000-h corrosion test program. The main objective was to confirm the relatively low combustion efficiencies of 80 to 85% that were achieved in the 1 m^2 test combustor at Point Tupper. Some combustion tests were also carried out with a North American anthracite, to help clarify the mechanisms of char combustion.

Much of the work plan for the present contract relates to mathematical modelling of FBC. Queen's University presently has work underway to study the formation of a volatiles plume in the bed, to study flue gas behaviour and combustion in the freeboard, and to measure particle residence time in the combustor by means of a radioactive tracer. The resulting information will provide useful input to the Queen's mathematical model for FBC, which is being used by members of the IEA Implementing Agreement for Cooperation in the Field of Fluidized Bed Combustion for Industrial or District Heating Boilers, as the starting point in development of a computer-assisted method for designing FBC boilers.

Direct work on the Queen's mathematical model is also continuing. An attempt is being made to incorporate into the main model a more realistic plume model which allows for finite devolatilization times. In addition, a doctoral program of bench-scale work on the behaviour of single large particles in the combustor, and a masters program investigating elutriation in a cold model, are underway. Under another doctoral program residence time of particles in the bed is being studied.

Queen's University - ASPEN Simulation

ASPEN is a comprehensive computer model for simulating industrial processes. Its main value is in design optimization. Through the Unsolicited Proposal Program, Queen's University was contracted in 1984 to simulate the Summerside FBC boiler plant, using the ASPEN program, and thus provide a powerful, reliable tool for costing and optimizing new FBC installations.

Work on this contract has progressed steadily; it is expected that the final steps of comparing the model results with actual plant data and preparing the final report will be completed early in 1987.

Polymath Corp. - Circulating FBC Tests with Syncrude Coke

A contract sponsored by CANMET in 1981 demonstrated that Syncrude coke could be burnt efficiently, with excellent sulphur capture, using circulating FBC technology. Since the utilization of such fuels is of continuing interest to governments and industry, it was deemed desirable to follow up the initial work with a more comprehensive pilot-scale study, which would employ Fort McMurray limestone as the sulphur sorbent, and would provide a more complete materials balance, including information on the fate of heavy metals.

In March 1985 a contract for such a study was awarded to Polymath Corp., which subcontracted the pilot-scale testwork to A. Ahlstrom Ltd. of Finland. About 50 tons of Syncrude coke and 30 tons of Fort McMurray limestone were shipped to Finland for the combustion tests, which were successfully completed in January 1986. The final report is expected in May 1986.

Technical University of Nova Scotia - Burning Rate of Single Coke Particles

This contract was let in the hope of gaining information that would assist in mathematical modelling of FBC. Suncor coke was chosen as the feedstock because it is easy to obtain particles in the desired size range of 10 to 25 mm, and because it was expected that, because it is low in volatiles, there would be little fragmentation. The experimental procedure was to inject coke particles of known dimensions and weight into a preheated fluidized bed combustor, after a given time quench the combustion process, retrieve the coke particles, and re-weigh them. Burning rate was then to be calculated from weight loss, surface area and time at combustion temperature.

The experimental work has been completed, but it appears that results may be inconclusive for several reasons. One is an unexpected degree of particle fragmentation. Another is carryover of large particles into the recycle leg at velocities well below their calculated terminal velocities, with the result that only overall burning rates specific to the apparatus can be calculated. A final report is expected early in 1986.

University of British Columbia - Circulating Bed Combustion of Pitch and Tar Materials

In 1985 the University of British Columbia submitted an Unsolicited Proposal to conduct a program of combustion tests in a 150-mm diam. pilot-scale circulating FBC. Proposed feedstocks include coal, wood waste and two types of residues from heavy oil upgrading. Since circulating FBC combustion of residues is perceived to be of considerable interest to the heavy oil/tar sands industry, CCRL, upon review of the proposal, recommended acceptance. A work statement has been finalized and

it is expected that a contract will be in place by the beginning of 1986/87. The contract value is approximately $130K over a two-year time frame.

Engineering Evaluation of Fluidized Bed Boiler Demonstration Plant at CFB Summerside, P.E.I.

The fluidized bed boiler demonstration at CFB Summerside has been in operation since December 1982 and is described later. During that time a wide range of operating problems has been encountered and successfully resolved, the most serious of these being erosion of heat transfer surfaces exposed to the bed. To ensure that this body of experience is thoroughly documented for the benefit of other potential users of the technology, CCRL undertook to prepare, by contract, two comprehensive reports. One will be a history of boiler tube erosion, together with an account of the preventative measures taken and their effectiveness. The other will be a history of plant operation, covering all aspects other than erosion.

A detailed work statement was prepared, and formed the basis for a Request for Proposal issued by Supply and Services Canada. Bidding took place in two stages. First, statements of capabilities were solicited from a large number of potential performers, and from the seven responses received, a short list of the four best potential contractors was prepared. These four subsequently submitted detailed proposals which were then evaluated according to pre-established selection criteria. It is expected that DSS will award a contract to the successful bidder by April 1986. The contract is expected to be completed in six months, at a cost of about $75K.

University of New Brunswick - Gas Sampling at Point Tupper AFBC Facility

CCRL's direct involvement in the 10 000-h fluidized bed corrosion test program at Point Tupper, Nova Scotia is described in greater detail later. At this point it is sufficient to say that, to help resolve an apparent anomaly in the combustion air/flue gas balance of the Point Tupper facility, CCRL sponsored a contract under which the University of New Brunswick conducted on-site gas analyses, in the bed and in the freeboard. To accomplish extraction of gas samples from the bed, the contract required that a special water-cooled probe be built, which was then used to trace consumption of the fluidizing air by the combustion process. It was established that some fluidizing air was bypassing the combustion zone through the refractory lining, and this information permitted appropriate corrections to be made to the materials balance. The contract cost $25.5K and the final report has been received.

DEMONSTRATON OF FLUIDIZED BED COMBUSTION

FBC Heating Plant at CFB Summerside

Since 1977, EMR has been collaborating with DND in the construction and demonstration of a fluidized bed heating plant at CFB Summerside, P.E.I. EMR's technical input to the project has been almost entirely through CCRL, which coordinated the design contracts, and since

completion of the plant in December 1982, has been planning and conducting the demonstration program.

The plant consists of two boilers, each rated at 18 t/h of steam. They were designed to burn high-sulphur Eastern Canadian coal, with at least 80% sulphur capture by means of limestone addition to the bed. An additional requirement was that they be capable of co-firing wood chips to provide up to 30% of the heat input at any load.

During the first and half of the second heating seasons (82/83 and 83/84) efforts were concentrated on overcoming operating difficulties, primarily in materials handling, calibration of the automatic controls, operator training, and boiler acceptance tests, all with coal as the only fuel. By May 1984 the boilers had been tested with three different Cape Breton coals having sulphur contents ranging from 4 to 6%, and guarantees of capacity, efficiency and emissions control had been met with all of them. Also in May 1984 some brief tests showed that over 50% of boiler capacity could be achieved firing wood chips alone.

However, during the past year significant difficulties were encountered with erosion of heat exchange surfaces exposed to the bed, and of the fly ash reinjection system serving the mechanical collector. In January 1985 one boiler furnace tube failed due to erosion; in May 1985 the other boiler's induced draft fan was destroyed due to a failure in the fly ash reinjection system, caused by erosion. Total boiler operating hours in each case were about 6000.

To overcome these difficulties, substantial modifications were made to both boilers during the past summer. The tube erosion problem was addressed by removing most of the refractory from the bed waterwalls, and applying instead closely-spaced studs, about 10 mm diam. by 20 mm long, from the level of the distributor plate to a height of nearly 2 m. The in-bed tubes in the secondary bed were protected by welding 10 mm diam. rods longitudinally along them, spaced circumferentially about 20 mm apart. Bends in the waterwall tubes to provide openings for ignitors, stokers, etc., have been protected by both studs and refractory. Boiler No. 2 was subsequently operated for about 2500 h with very encouraging results; inspection revealed minor, localized erosion of the studs and rods, and virtually no further erosion of the tubes. In addition, boiler performance has improved dramatically because of the additional heat transfer surface made available by removal of the waterwall refractory. Loads up to 125% of maximum capacity rating are readily achieved, and excess O_2 in the flue gas has been reduced from about 12 to 8%.

To overcome the erosion problems with the double-lock hopper, high velocity fly ash reinjection systems serving the mechanical collectors have been replaced on each boiler with a novel L-valve system. Fly ash from the mechanical collector now flows by gravity down two 150-mm pipes to the two reinjection ports, where a blast of air moves the material into the combustor against the static pressure of the bed. This system has also worked very well. Its two main advantages are:

1) the lock-hopper bleed lines to the breeching, which were instrumental in the erosion of the induced draft fan last year, have been eliminated, and

2) fly ash is transported at low velocity up to the reinjection ports, hence these ports are the only components subjected to an erosive environment. They have shown no deterioration in the 2500 h that one boiler has operated since this system was installed.

Two other significant modifications deserve mention. One was the addition of about 75% more bubble caps to the distributor plates in the preferential bed, which has resulted in more positive fluidization under cold conditions, and an easier, more rapid startup. Furthermore, it is now possible to utilize 6 mm x 0 limestone, which is less expensive than the 2.4 x 0.8 mm limestone required previously. The other was the replacement of the manually-operated transfer gate between the preferential and secondary beds with a small permanent opening. This has proved adequate for lighting up the secondary bed from the preferential bed, and has eliminated difficulties with jamming of the transfer gate.

The present heating season will complete CANMET's formal demonstration program on the FBC boilers at Summerside. However, performance, particularly with respect to erosion, will be monitored for some years to come. It is planned to replace the in-bed tubes during the summer of 1986 (18 tubes per boiler) and this will be used as an opportunity to compare the erosion resistance of some alloys with that of mechanical protection such as rods and studs.

Point Tupper 10 000-h FBC Corrosion Study

In order to evaluate the corrosion/erosion performance of candidate boiler tube materials under the severe conditions typical of a utility FBC steam generator, EMR provided most of the funding for what is to date the most comprehensive FBC corrosion test program in the world. Other participants were Nova Scotia Power Corporation, which ran the program, and Combustion Engineering Canada Ltd., which designed and built the test equipment and made a financial contribution as well.

The program exposed a range of ferritic and austenitic alloys to temperatures ranging from 500 to 700°C in a FBC combustor having a cross-section of 1 m^2. A total of about 800 specimens were exposed for periods up to 10 000 h, in 1000-h increments.

CANMET's Physical Metallurgy Research Laboratories (PMRL) are responsible for the metallurgical evaluation of the specimens. The Energy Research Laboratories, through CCRL, were involved in the project management and in a scientific advisory capacity concerning control and measurement of combustor performance. In the latter context, considerable effort was spent in a detailed review of analytical procedures and algorithms for materials and heat balance. CCRL also sponsored a contract under which flue gas composition in the bed and the freeboard was analyzed. The full program of specimen exposure was completed in the summer of 1985, and the project will be formally completed at the end of

1985/86. However, PMRL expects that it will take another two years of in-house work to complete the metallurgical analysis of all the specimens and analyze the data.

Circulating FBC Utility Boiler Demonstration at Chatham, N.B.

In August 1984, Treasury Board approved EMR Coal Division funding of a major demonstration project; the construction of a 20 MWe circulating FBC utility boiler at the Chatham generating station of New Brunswick Electric Power Commission (NBEPC). Besides being the largest FBC boiler yet built in Canada, and the first to operate at the high steam pressure and temperature conditions required of utility boilers, this unit will be unique in that it will be co-fired with New Brunswick high-sulphur coal and oil shale. The latter feedstock serves both as supplementary fuel and, because of its inherent calcium content, as supplementary sulphur sorbent.

The project is being managed by NBEPC, and the contract for design and construction of the circulating FBC boiler was awarded to Combustion Engineering Canada Ltd. in collaboration with Lurgi GmbH. Site preparation was begun in the spring of 1985 and construction is now nearing completion. Commissioning of the boiler is scheduled for late summer 1986.

CCRL involvement consists of membership in the Management Committee which directs the project, and chairmanship of the Technical Committee which is responsible for detailed planning of the demonstration program. There have been numerous meetings of both committees and further technical involvement is planned when the demonstration program gets under way. CCRL is also represented on the Steering Committee for a contract, sponsored by the Canadian Electrical Association, which is investigating the utilization of residues from circulating FBC boilers.

TECHNOLOGY TRANSFER IN FLUIDIZED BED COMBUSTION

IEA Agreement on AFBC

In 1980, under the auspices of the International Energy Agency, nine nations including Canada signed the "Implementing Agreement for Cooperation in the Field of Atmospheric Fluidized Bed Combustion in Industrial or District Heating Boilers". Canada's participating projects are all CCRL projects, namely, the CFB Summerside demonstration, the CCRL in-house R&D program, and the R&D program contracted to Queen's University. Therefore the Canadian representative to the Agreement has also been from CCRL.

Besides sharing information on their participating projects, the members of the Agreement have undertaken to develop a mathematical model of fluidized bed combustion, which hopefully can be evolved into a powerful tool for designing FBC boilers. Canada's contribution to this effort has been a model developed at Queen's University as part of a doctoral program. Scientists in Denmark, Sweden and the Netherlands are presently running the model to compare its predictions with results from their own combustors.

Two sets of technical and Executive Committee meetings were held in 1985; one in May, in Paris, France, the other in November, in Halifax, Nova Scotia. In addition to the members of the IEA Agreement, about 30 representatives of Canadian industry and research organizations attended the technical meeting in Halifax, and subsequently were sent copies of all papers presented or tabled at the meeting. The members of the Agreement were also taken on a tour of the Chatham circulating FBC demonstration. All arrangements for the three-day meeting were handled by CCRL.

INDUSTRIAL COMBUSTION PROCESSES

The role of the Industrial Combustion Processes Section is to aid Canadian industries and utilities in the process of converting from premium fuels to indigenous and often low quality coals. In many cases, these coals are from newly-developed deposits which have unknown characteristics and reliable data on their combustion heat transfer and emission characteristics are non-existent. The CCRL coal combustion research program reflects the increasing importance of coal in our domestic energy requirements and also supports Canadian coal exporters in their drive to secure a reasonable share of the world market. An industry/government collaborative program has been established in which the utilities and coal suppliers participate under the CANMET Minerals and Earth Science Program. An in-house research program has also been established to increase the fundamental knowledge and expertise in coal combustion.

CONVENTIONAL COMBUSTION

The basic objective of conventional coal combustion is to study the combustion performance, heat transfer and emission characteristics of Canadian coals and rejects for conventional power generation and industrial use, both in Canada and in support of the export market. Specifically to:

- produce a periodically updated reference databank of the combustion performance and emission characteristics of commercially important Canadian coals;

- collaborate with industry in the determination of significant combustion performance characteristics of newly developed coal deposits for electrical power generation and industrial use;

- assess the effects of coal cleaning on the flame heat transfer, deposition and emission characteristics of Canadian thermal coals for utility and industrial applications;

- conduct fundamental studies of the ignition, devolatilization and combustion burnout of unreactive Canadian coals and reject materials.

Low-grade Coal for Electrical Generation

The general objectives of this project are to evaluate the combustion, slagging and fouling properties of coals from Canadian coal

deposits for use in power utility boilers and to minimize emissions from conventional coal combustion furnaces by control of flame properties through burner and furnace design, chemical additives, flue gas clean up and coal feed comminution. Specific objectives of each coal combustion project undertaken are to:

- determine the combustion and handling characteristics of the coal;
- evaluate the combustion performance at various feed fineness and excess air levels;
- characterize the particulate and gaseous pollutants generated during combustion;
- assess the slagging and fouling potential of ash constituents on radiant heat transfer surfaces and superheater tubes respectively;
- determine the fly ash resistivity characteristics and the ease of fly ash collection by electrostatic precipitation;
- develop combustion charts for each coal or coal blend studied.

The equipment used to investigate these properties is a pulverized coal-fired utility boiler, which embodies two opposed low-swirl burners and has a full-load firing rate of 2.5 GJ/h. The twin burners can be located in three basic positions on the furnace to vary the combustion chamber residence times. It is estimated that at 90 kg/h feed rate and 30% excess air, the residence time can be varied from a minimum of 1 s to a maximum of 2.7 s depending on where the burners are located.

During 1985, 32 coal combustion trials were performed in the pilot-scale utility boiler. Six of these trials were undertaken as a cost-shared coal combustion evaluation using an Eastern Canadian coal. Eight trials were undertaken as part of an in-house program to study the effect of comminution and residence time on coal combustion properties. The remaining 18 trials were undertaken to support an International Energy Agency (IEA) Coal Cleanability and Combustion Characterization Project to generate a detailed database on quantifying the fuel performance benefits associated with coal cleaning. This IEA work is continuing as an in-house project. The in-house assessment of boiler performance, as related to comminution and residence time, has been delayed due to higher priority projects. Six reports on cost-shared projects were completed and issued to the companies concerned, and a further cost-shared report is in progress.

Coal as a Substitute for Oil in Industry

To facilitate the use of coal in place of oil in industrial combustion systems, data must be obtained which compare the combustion and heat transfer characteristics of coal with those of fuel oil under similar aerodynamic conditions. The CCRL tunnel furnace (1 m diam. and 4.25 m long) has a refractory-lined precombustion chamber (1.2 m long). It is designed to fire pulverized coal, light and heavy fuel, natural gas and

coal-liquid mixtures. It has a thermal input of about 2 GJ/h and has a continuous access slot along its length for the insertion of flame probes.

These probes can measure a range of parameters which define spatial temperature, flow and concentration profiles within the furnace together with emission levels at the furnace exit. Heat transfer, both convective and radiative, can be measured along the flame length. It is also possible to partially refractory-line the furnace to simulate a number of industrial process heater configurations ranging from boilers (unlined) to kilns (80% lined). Thus, the furnace has the flexibility to undertake burner comparative studies, coal vs fuel oil or natural gas, and industrial configuration changes.

During 1985, 14 combustion trials were conducted to generate a data package for a furnace modelling contract and also to aid in the development of a novel coal-water slurry burner nozzle.

NON-INTRUSIVE COMBUSTION PROBES

There has been a significant effort in the development of non-intrusive diagnostic techniques at CCRL. These probing techniques are intended to replace the conventional methods of taking measurements in a flame. The current methods of measuring temperature and species concentration require that a probe be immersed in the flame to the test point. The mere presence of the probe in the flame causes a disturbance to the velocity and temperature fields. As such the measurement recorded may not be representative of the situation in the flame. This problem coupled with the inherent errors in the measurement technique itself can result in large errors when using the classicial measurement methods. Furthermore, the errors tend to be largest in the areas of greatest interest to the combustion scientist such as the regions of recirculating flow.

The optical diagnostic methods eliminate these measurement errors and have the added bonus of providing a better quality measurement. Because the optical techniques use light, they do not disturb the combustion process occurring in the test section. High power pulsed-lasers are generally used as the probe beams. These lasers have an 'ON' time of about 10 ns and oscillate at a frequency of about 10 Hz. As a result the measurement is frozen in time and vast amounts of data can be collected at any one test point in a very short time. Measurements taken with these non-intrusive techniques allow for the calculation of probability distribution functions and turbulence quantitites such as Reynolds shears and stresses. This better quality of measurement will (through modelling techniques) give the scientist a better understanding of the physical processes occurring in the flame.

This technique, termed Coherent Anti-stokes Raman Spectroscopy (CARS), can be used to measure temperature and species concentration in a combusting environment. A laser Schlieren technique is used to visualize the phenomena occurring in flames generated in the laboratory. The laser doppler anemometry (LDA) technique is envisioned for use in the measurement of gas velocity and partical size distribution.

The development of the CARS technique has progressed on two fronts: (1) special optics are required to generate the laser probe beams and to measure the resulting CARS beam; (2) sophisticated computer hardware and software are required for the high speed acquisition and analysis of the CARS signals. Both areas of endeavour have progressed to the point of demonstration.

The characteristics of the source-side optics have been studied, using equipment and software developed under contract. The data acquired during the characterization experiments were also used to verify the analysis software. The two-probe laser beams have been synchronized and made to overlap in the test section of a bench-scale combustor. The complete optical arrangement for the generation of CARS signals has been prepared and is undergoing demonstration experiments.

The detection side electro-optics, including the parallel interface to the computer, have been installed and characterized. This interface consists of sophisticated computer hardware and software. The development of the interface has been carried out under contract. The hardware consists of special long-line drivers for the high-speed transmission of parallel information over the long distance between the optics laboratory and the computer. The software has been developed to perform two functions: (1) since there is a need for the transmission of large quantitites of parallel information, special software has been developed under contract to handle this high-speed transmission and to manage the large data files; (2) the necessary software has been developed for the analysis of the CARS spectral profiles. There are two data analysis techniques currently being studied for the determination of gas temperatures in a flame. One technique uses curve fitting methods to fit the experimental CARS spectral profiles to a theoretically generated spectral profile. The other method uses fast-fitting techniques. Studies are currently underway to determine the trade-off between loss in accuracy of the technique and enhancement of speed of analysis. The transfer rate of 10 spectra per second has been demonstrated. During these demonstration experiments special spectra were captured which were used to demonstrate the utility of the two data analysis programs. The weighting scheme to be used to determine the average temperature with the fast-fitting technique is currently being studied.

The necessary electronics for the synchronization of the source and detection side electro-optics have been installed. The CARS setup is currently undergoing experiments to demonstrate the technique. Some refinements have been identified for the optical arrangement and are being studied for implementation.

Experiments have been run to determine the viability of the Schlieren flow visualization technique in coal flames. This technique uses an argon ion laser to back light the flame. By using high speed photographic techniques and optical filters the influence of the flame on the laser light can be recorded on film. These pictures give an indication of the flow structures in the flame and will aid in studies of the flame mixing processes. By using the appropriate optics, the combustion process of individual coal particles can also be studied.

Through experimentation it has been determined that due to the characteristics of the laser light, Schlieren optics may not be used and as a result alternative optics are being developed for use with the laser Schlieren experiment. These alternatives are presently being tested in a small-scale coal burner.

CONTROLLED MIXING COMBUSTION HISTORY REACTOR

In order to understand better the reaction history of individual burning coal particles, CCRL has designed and built a furnace, termed a controlled mixing history reactor (CMHR). This device can simulate an environment which is typical of that encountered by coal particles as they pass through a flame, but without the added complication of aerodynamic flow patterns found in coal furnaces and combustors.

Because of the variability of the burning characteristics of different coals, a rapid yet simple method of evaluating coal reactivity is needed and it is anticipated the CMHR will fill this need. The furnace consists of a vertical ceramic tube heated from the outside by glow bar heaters. Pulverized coal ($\sim$100 um) is carried from a fluidized bed feeder where it passes down the heater tube in a flow of air. The residence time of the coal is less than 1 s and the feed rate is about 20 mg/s. The coal particles are subjected to a heating rate of the order of 10^4 K.s^{-1}.

The heat and mass transfer phenomena in the furnace have been modelled extensively using physical and computer models. A variety of recommendations have been made to improve the performance of the furnace based on these studies. These recommendations include changes to the geometry and operation of the furnace. These models have also been used to calculate particle temperatures for a variety of particle sizes and for a variety of flow conditions in the furnace. In this way the optimum conditions can be determined for the range of particle sizes considered for the furnace.

CONTRACTS

1. "Performance prediction of the CCRL tunnel furnace for coal combustion"

The objective is to improve the existing computer model and to expand its capability to include low-volatile coals. The end result will be a well documented program which will be used to complement the pilot scale combustor and to improve the accuracy of the scale up computations.

The program has been improved by incorporating user friendly routines and current models describing the physical processes in the coal flames. However, there is a scarcity of data to use for comparison with the output of the computer program. Experiments have been run in the CCRL tunnel furnace to generate data to be used for the validation of the computer program. Experiments were then run using reference coals and low-volatile coals. These experiments were put together in the form of a data package to be used for the validation of the computer program. Comparison of the predicted data with the measured data is being undertaken by the contractor.

COAL-LIQUID MIXTURE COMBUSTION

The use of coal to replace premium fuels such as gas and oil is an objective of Canadian energy policy but this replacement has been inhibited by the inconvenience of handling solid fuel and by its environmental implications. EMR's strategy for energy intends to remove this inhibition by bringing new coal utilization technologies that have both economic and environmental advantages over premium fuel alternatives to a stage of development useful to industry. A program of development and commercialization of fuels made from mixtures of coal with liquids, with the twin objectives of easy, economic coal handling and minimized environmental impact has therefore been a major EMR/CANMET objective for the past several years.

Specifically, the objective is to develop and evaluate coal-liquid mixture (CLM) preparation and combustion technology as an alternative to the use of premium liquid and gaseous fuels in Canadian utility and industrial applications and where conventional coal combustion technology cannot be readily used. The program will:

- establish a database of the combustion, heat transfer and ash deposition characteristics of a number of CLM fuels through contract and in-house research, and in collaboration with foreign agencies;

- study, by contract, the potential derating effects of the conversion of oil-designed boilers to CLM fuels;

- provide technical support to the coal/water fuel (CWF) demonstration programs being sponsored by EMR's Coal Division at the Maritime Electric Generating Station, Charlottetown, P.E.I.;

- participate, on behalf of Canada, in the International Energy Agency (IEA) CLM Implementing Agreement and its annexes in the development of both in-house and contract programs to resolve the problems of reduced burner life through abrasive wear, poor atomization performance and carbon conversion efficiency as well as resolution of the relationships between slurry rheology, handling characteristics and atomization quality;

- participate with industry in other programs which would endeavour to develop CLM technology for process heating purposes.

New Brunswick Electric Power Commission, Chatham, N.B. - Generating Station Demonstration of CWF Technologies

In April 1982, EMR, the New Brunswick Electric Power Commission (NBEPC) and Cape Breton Development Corporation (CBDC) entered into a collaborative agreement to demonstrate the preparation of CWF and its utilization in utility boilers.

This agreement provided for the construction of a 4 t/h CWF pilot plant in Sydney, N.S. It also specified that burners should be developed and tested in the 12.5 MWe unit No. 1 front-wall fired boiler and the 22

MWe tangentially fired unit located at the Chatham, N.B. generating station. The project was administered by a management committee comprised of representatives of EMR Canada, NBEPC, CBDC, the Nova Scotia Power Corporation (NSPC) and AB Carbogel, the CWF process developer. Technical input to the project was through a technical committee, which in addition to management committee members, includes representatives of the National Research Council (NRC), Ontario Hydro, New Brunswick Research and Productivity Council (NBRPC), Ontario Hydro, and the Centre for Energy Studies of the Technical University of Nova Scotia. Burners were developed and installed on each of the two Chatham units and the test program on each unit was completed in late 1984. Reporting of the demonstration was completed in June 1985.

Maritime Electric, Charlottetown, P.E.I. Generating Station

An agreement between Maritime Electric, NBEPC, CBDC and EMR was signed September 1, 1985 to demonstrate CWF combustion technology in an oil-designed 20 MWe front-wall fired boiler. Planning is progressing well, with the acquisition of long delivery items such as pumps, motors, storage tasks and fabric filter dust collectors being given priority. Three companies were selected for CWF burner supply and each were supplied with CWF for a short demonstration. Final burner selection was made in March 1986 and the five burners are currently being manufactured for installation on the boiler in August 1986. It is expected the test program will be completed by the end of 1986.

CONTRACT R&D

Contract R&D on the application of CLM technology is also designed to support and contribute to the ongoing demonstration program.

Canada Cement Lafarge have successfully converted their wet process cement kilns to on-site prepared CWF, thereby displacing natural gas economically. CANMET and NRC have contributed to the development of wear-resistant ceramic atomizers for this application which have improved combustion and atomizer life. The company has made the commercial decision to continue using CWF in the plant as long as it remains economically attractive. The final report on the contract is due in mid-1986.

The Iron Ore Company of Canada demonstrated firing an industrial furnace using CBDC's CWF during November 1985. Two types of burners were used and some combustion related problems had to be overcome. The company is presently evaluating the tests with CANMET technical assistance and a contract report is expected by March 31, 1986.

The combustion of high ash (6%) CWF from another commercial North American supplier has been completed under CANMET contract in the tangentially-fired 22 MWe Unit 2 at Chatham. A new burner developed by the boiler manufacturer was used and far better combustion and boiler performance were observed than during the earlier Chatham tests. This is attributable to the burner rather than the fuel. The tests corroborated earlier findings that CWF ash does not behave like pulverized coal ash and almost all of it is entrained rather than deposited in the furnace bottom

(5% bottom/95% fly ash for CWF vs 30% bottom/70% fly ash for pulverized fuel). This is important since the Charlottetown unit does not have provision for bottom-ash removal since it is designed for oil firing. The report on these tests is due March 31, 1986.

A contract to study the performance of the NRC/CANMET ceramic wear-resistant CWF atomizer has been completed in Unit No. 1 at the Chatham N.B. Generating Station. Also evaluated during the boiler testing was a fabric filter dust collector containing three different fabrics, as well as various modifications to a recently developed CWF burner. The data from these tests will be directly useful to the Charlottetown CWF project, where, because of the downtown location of the plant, environmental concerns are very important. This contract report is due in June 1986.

Another contract was undertaken to assess the state-of-the-art of CWF burner development in North America. The Chatham project has shown that the burner/CWF rheology/atomization quality/relationships are not known, and many burner manufacturers are making claims which cannot be quantified. This contract will document what the major suppliers are now producing.

ABATEMENT OF COMBUSTION-SOURCE EMISSIONS

The use of stack gas scrubbers to control SO_x and NO_x emissions is reported to decrease thermal efficiencies by 4% to 7%, to increase the capital cost of the new plant by 25% to 30%, to increase plant labour costs by a factor of two, and to be a probable source of water pollution. One potentially, low-cost alternative to stack gas scrubbers for pulverized coal-fired boilers involves simultaneously inhibiting the formation of NO_x and enhancing the capture of SO_x during combustion using either dry ash or wet ash (slagging) burner systems.

The dry ash systems include the following generic concepts:

(a) staged-air burners with sorbent addition to the coal;

(b) staged-air burners with sorbent injection around the flame;

(c) staged-air burners with sorbent injection in the upper furnace;

(d) fuel reburning with sorbent injection in the upper furnace.

The wet ash or slagging systems include:

(a) cyclone-type combustors;

(b) toroidal-vortex flow combustors; and

(c) entrained flow reactors.

These are all essentially multi-staged burners, in which up to 80% of the input ash is drained off during the primary combustion stage under sub-stoichiometric conditions.

Research and development under this project is directed toward in-furnace control strategies and are structured so that most elements are performed under contract with the private sector.

CONTRACT RESEARCH

Gagetown Demonstration

Two retrofit pulverized-coal burners incorporating staged combustion and limestone injection for simultaneous reduction of NO_x and SO_x emissions are installed in a 17 MWt hot water boiler at CFB Gagetown. Following commissioning this year on a Maritime coal, the unit will be used for demonstration of reliability and emission control while burning different Eastern Canadian coals and sorbents.

The novel burners were installed under a $975K CANMET contract with Volcano Inc. and are designed to reduce acid rain emissions by 50% from a 3% sulphur coal. The demonstration trials will be conducted over the next two heating seasons in cooperation with Environment Canada.

Chatham Small-scale Burner Facility

This facility was constructed last year, with funds provided by EMR Coal Division, at the Chatham Generating Station of the New Brunswick Electric Power Commission (NBEPC). When the unit becomes operational in June 1986, NBEPC will initiate work under a CANMET contract for $188K to study fundamental mechanisms related to the generation and control of NO_x and SO_x from Eastern Canadian coals. This contract is scheduled for completion in September 1986.

Boundary Dam Demonstration

The Saskatchewan Power Corporation (SPC) is conducting the first Canadian demonstration of upper-furnace sorbent injection for SO_x control in a lignite-fired boiler. The boiler, rated at 150 MWe, located at Boundary Dam Generating Station has been converted to low NO_x combustion. Costs of the $2.2 million project are being co-funded by SPC and Combustion Engineering Canada Ltd. (61%), the Canada/Saskatchewan Heavy Oil and Lignite Agreement (11%), the Canadian Electrical Association (9%), CANMET (9%), and Environment Canada (10%).

CANMET funds were allocated to a project element to evaluate the combustion and NO_x/SO_x emission characteristics from the newly-opened Shand deposit. The results will be used in the design of two new 300-MWe boilers which will be located at the mine site. A report on the Boundary Dam trials is due in August 1986.

Rockwell Burner

This is a slagging burner concept in which SO_x is absorbed in molten ash and NO_x is controlled by staged combustion. If the coal ash has sufficient calcium or alkali present, additions of sorbent are unnecessary. TransAlta Utilities is interested in demonstrating this technology at Wabamum Generating Station and CANMET funding of $238K has been provided to support design of a prototype burner which would be assessed using funds from a consortium comprised of TransAlta and four US utilities. Pilot-scale tests at Rockwell indicate that 70% of the coal sulphur can be trapped in the slag and the NO_x emissions can be restricted to less than 150 ppm.

TECHNOLOGY TRANSFER

Canadian Electrical Association

The Canadian Electrical Association with pending funding from the EMR Coal Division, has set up an Expert Panel on Emissions Control Technology to evaluate and recommend research proposals dealing with acid gas control from utility boilers. The Panel, in addition to combustion gas reactions and flame modifications techniques, will also assess tail gas clean-up or wet scrubber processes. CANMET, which is represented on the Panel, actively participates in evaluating combustion-related proposals, but does not actively review concepts that involve wet- or dry-scrubbers.

Wabamum Demonstration Project

CANMET has provided extensive scientific input into a planned demonstration project involving the retrofitting of Rockwell slagging burners on a 70-MWe boiler at Wabamum Generating Station in Alberta. Potential participants with TransAlta Utilities are the Canadian Electrical Association, the Alberta Office of Coal Research and Technology, Energy, Mines and Resources Canada and a consortium of four US utilities. Pilot plant research has demonstrated that Alberta subbituminous coals can be burned with substantial reductions in NO_x and that SO_x emissions can be controlled below proposed Canadian guidelines without the use of a sorbent.

Trace Element Emissions

The results of a trace element emissions study on four Canadian coal-fired utility boilers, co-funded by CANMET, the Canadian Electrical Association and Environment Canada, were discussed and disseminated in a series of seminars in three Canadian cities. Participants were invited from federal and provincial government departments, utilities, boiler and pollution equipment manufacturers, academia and public interest groups.

Under an International Energy Agency Agreement on Low NO_x Coal Combustion, CANMET is collaborating on a research project with co-funding from agencies in Denmark, Sweden and the United States. The first two stages of the project involved a definition of the dominant mechanisms for conversion of fuel nitrogen to NO_x and the application of this research to the conceptual design of a staged-mixing burner incorporating sorbent

injection for simultaneous control of NO_x and SO_x. Planning has started on the third stage which will involve validation of the NO_x/SO_x suppression concept during demonstration trials using a utility boiler in each of the participating countries and a continuing exchange of information as each trial progresses. The third stage will be initiated as soon as funding arrangements in each country are approved.

CARBONIZATION RESEARCH

In spite of the soft markets and decreasing prices for metallurgical coals, Canada has continued to expand both coal production and exports over the past few years. Most of Canada's coal exports are high-grade coking coals from Western Canada. To provide technical support to Canada's metallurgical coal producers the Energy Research Laboratories continues to provide expertise, laboratory and pilot plant facilities for comprehensive carbonization and cokemaking investigations.

CANMET, as a member of the Canadian Carbonization Research Association, provides all experimental facilities and scientific and technical personnel for assisting in planning and carrying out research of immediate interest to both the coal and steel industries. ERL scientists also plan and conduct in-house and contract research activities often of a more national interest. Carbonization research programs being conducted at ERL are detailed below.

ADDITIVES TO COKE OVEN CHARGES

Previous studies have shown that pitch and bitumen-like additives such as CANMET hydrocracked residuals or commercial pitch materials can be added to some high inert coals to improve coke quality. In the present study investigations have been extended to include less expensive materials such as decant oil. Initial results indicated that the use of additives to a poor high-volatile bituminous (hvb) coal did not improve coke quality. However, coke quality did not deteriorate from that of good coke when inexpensive additive was blended with a poor hvb Appalachian coal and used to replace a good hvb coal in a good coking blend. Further additions of medium-volatile bituminous (mvb) coal from Western Canada did not improve the ASTM stability, but did improve the coke strength after reaction (CSR), as did replacement of the good hvb with poor hvb plus additive. When additives were put into a coking blend containing 18.6% poor coking mvb coking coal from Western Canada, coke quality was better than with no additives. No observable differences were observed between the pitch and an inexpensive additive.

In another study primary tar was collected from the centre of a coking charge during carbonization and added to a poor coking coal to investigate its effect on coke quality. Although tar was collected from three coke oven tests there was insufficient quantity for a full scale coke oven test. The tar was used with a thermal coal to produce briquettes that were subsequently carbonized. Comparison of briquette crushing strengths for a good coking coal and thermal coal, with and without tar, indicated the tar did not improve the strength sufficiently to continue this program.

REPRODUCIBILITY OF COKE OVEN RESULTS

ERL has an ongoing program to ensure that industry can rely on the accuracy and precision of results from their analytical and pilot plant facilities. Recently, repeated testing of a blend was undertaken in the rebuilt Ottawa 460-mm oven to determine the repeatability of coke oven results. Since there was concern about the influence of oxidation on results repeat tests were conducted 14 days apart to ensure consistency in testing procedure that should more clearly identify problems in coking results caused by delays between coal preparation and testing. All results appear to be reproducible except for maximum coking pressure. This repeatability study will be extended to the other pilot plant ovens.

TEST OVEN COKING

The objectives of this program are to gain a better understanding of the physical process of coking in a slot-type oven and to better predict coke quality and gas pressures in both pilot and industrial coke ovens from the combined effects of coal type, bulk density, static loading, and plastic layer area. In this program the hot coke is pushed into a metal chamber for dry quenching and the amount of coking from the sole, roof and doors is measured. Analysis of coke from various heights in the test oven showed coke apparent specific gravity and hardness varied linearly and ASTM stability non-linearly with depth of coal in the oven. The slopes of the linear plots varied with the bulk density of the charge. At high bulk densities static loading on the oven affects oven wall pressure as shown by pressures of 13 kPa and 8.3 kPa for full and half height charges respectively for one coal blend. Work is continuing on other blends to relate test oven and industrial results.

CAGE TESTS IN ALGOMA COKE OVENS

Cage testing at Algoma was completed from November 25 to 29, 1985. The tests were conducted in 5-m ovens, No. 9 battery, operating at 20-h net coking time. Cages were installed at three levels below the coal line for all three charge holes. Temperature and pressure data were collected for the same locations. Fourteen tonnes of coal, two tonnes of wharf coke, and 29 cages with coke were collected and shipped to Ottawa for investigation.

COKE MICROSCOPY

Coke microscopy is being used increasingly at ERL to investigate the coking behaviour of various macerals and components of coking coals or blends. The parts of coal that melt during carbonization provide bonding for the inert entities and develop optically anisotropic units. The size and shape of these units may be quantitatively determined and proved to be predominantly a function of coal rank. As coal oxidizes the types of anisotropy change and become smaller in the coke. Coke microscopy is being used at CANMET to identify the ratio of ractive to inert macerals in Western Canadian coals. It is also being used to screen pitch and additive materials used to improve coke strength. Useful pitches interact with the coal to produce different anisotropic units and in some cases can reverse the effects of mild oxidation.

FACTORS AFFECTING THE RHEOLOGY OF WESTERN CANADIAN COALS

Work at ERL and under contract has shown that existing thermal rheological models using dilatation and fluidity cannot be used reliably to predict the quality of coke from Western Canadian coals. Dilatation measurements at non-standard conditions (larger particle size and higher heating rates) of various wash fractions of Western Canadian and Appalachian coals showed that coals having dilatations less than 10 under standard conditions gave the greatest relative improvement using non-standard conditions. However, Appalachian coals consistently have higher dilatations than Western Canadian coals.

Free swelling index (FSI) measurements are not seriously affected by particle size and are more comparable for similar ranks of good coking Appalachian and Canadian coals. Blending of wash fractions of Appalachian and Western Canadian coals having the same rank generated artificial samples having virtually identical size and petrographic characteristics (suggesting identical coke strengths). FSI were comparable but dilatations were 183 for the Appalachian coal and only 35 for the Canadian coal.

Plots of dilatation versus vitrinite content diverge with increased vitrinite content for the suite of samples from the Appalachian and Western Canadian coals of the same rank. Proximate and ultimate analyses of the samples suggest there may be differences in the chemistry of the vitrinites of the two coals. Anisotropic coke textures from the Western Canadian and Appalachian coals coked in a pilot test oven were similar for similar ranks of coals suggesting that at some stage of the carbonization process the coal-coke transformation of the two coal types becomes similar.

PREDICTION TECHNIQUE

A prediction technique applicable to Western Canadian coking coals was developed jointly by in-house and contract work. It was developed from manual petrographic methods through semi-automated analyses to an automated method based on the reflectogram of all coal macerals. Existing petrographic methods were modified to determine the amount of reactive macerals on a coal by coal basis using semi-automated reflectance measurements and applying a reactives cut-off reflectance determined by back calculation of stabilities from actual ERL test oven data. For prediction purposes relationships developed between R_0 max and $R_{cut\text{-}off}$ allow for easy calculation of reactive macerals hence coke strength.

Application of automated counting techniques to this method have not been completely refined but an automated method derived using regression analysis has been developed for Western Canadian coals. In this system, in which there is no human intervention an automated reflectogram partitioned into V-step classes can predict coke strength to three stability units. Development of the hardware system should make it possible to generate very accurate coke strength predictions for Canadian coals on automated equipment in about 30 min.

CONVENTIONAL COKEMAKING IN SLOT-TYPE OVENS

CANMET's technical-scale coke ovens are extensively used by the coal and steel industry to evaluate the coking properties of coking coals and blends having potential commercial applications. Results of coke oven trials are often supplemented by small-scale tests to measure dilatation and by laboratory analyses to determine the chemical, rheological and petrographic properties of both coal and coke. These facilities are relied upon by the coal industries to evaluate and market their coal resources and by the steel companies to evaluate and select the best combination of coals and blends for both purchasing and operating purposes. During the past year ERL performed 112 coke oven trials, 39 of which were on cost recovery. These were supplemented by 54 coke oven trials conducted at CRL, of which 49 were on cost recovery.

PART II

SYNTHETIC FUELS RESEARCH LABORATORY

HIGHLIGHTS

The Synthetic Fuels Research Laboratory continued its lead role in activities related to the upgrading and conversion of bitumen, heavy oils, refinery residua and coal for the production of synthetic fuels suitable for transportation and residential heating. These in-house activities were complemented by cooperative projects with industry, universities, provincial agencies and the US Department of Energy, consisting of 38 ongoing contracts.

The in-house and contracting-out projects were carried out by 51 full-time employees including 14 research scientists, 34 engineering and scientific support staff and 3 chemists. The 1985/86 budget allocated to the laboratory was as follows:

	$K
Salaries	2003
Capital	966
Operating	755
Contracts	4176
TOTAL	7900

Outputs for the year indicated a high level of productivity:

36 laboratory reports for journal publication, oral presentations and industrial confidential reports
7 patents were issued and 6 patent applications were filed
19 technical presentations at conferences
10 published conference preprints

The first CANMET Oil and Gas Conversion Contractors' Review Meeting was held in Toronto, November 20-22, 1985. This significant meeting was organized to aid the transfer of technology and ideas generated within the contract R&D program, and to provide a forum of information exchange among government, industry, para-public organizations and universities interested in new and emerging technologies related to oil and gas conversion. The meeting was attended by 158 delegates from Canada, US, France and Finland. Five sessions covering various topics were chaired by representatives from industry, the National Research Council, provincial R&D groups, universities and CANMET.

Another major achievement in 1985 was the startup and commissioning of the CANMET Hydrocracking Demonstration Plant in Petro-Canada's Montreal refinery. Personnel were seconded to the demonstration plant for three-month periods to assist in the startup while in-house research facilities performed various experiments to support the commissioning activities.

The demonstration plant was mechanically completed in August 1985. The unit has been successfully commissioned and has operated in the hydrovisbreaking mode without additive to process vacuum residues from various feedstocks. Apart from minor start-up challenges, the reaction, separation and fractionation sections have all been proven mechanically. Considerable technical information has been gathered on fluid dynamics, operations, etc. that will help to expedite the operation in the CANMET hydrocracking mode. The additive preparation section has not been fully commissioned because of mechanical problems.

The bitumen and oil recovery activity has seen the AOSTRA/industry Oil Sands Demonstration Centre developed to the engineering/procurement and construction stage. This concept was superseded by a special-case concept of demonstrating the Taciuk process. AOSTRA is now negotiating contract terms with EMR and industry participants.

In the development of upgrading technologies for bitumen, heavy oil and residua, various in-house and contracting-out projects of a fundamental nature were carried out to develop a better understanding of the behaviour of various feedstocks and their components under hydrocracking conversion conditions and reactor hydrodynamics. Eight three-week pilot plant experiments were completed in support of the demonstration plant.

In coprocessing, the bench-scale units continued to generate valuable information for economic evaluations and to provide additional technical data for eventual technology transfer. Fourteen project elements and five contracts were carried out during the year. Of particular significance were the data obtained from coprocessing of high-volatile bituminous coals.

The construction of the coprocessing pilot plant is progressing slowly. Delays were encountered with internal building restructuring and major modifications to the existing hydrogen supply system.

BITUMEN AND OIL RECOVERY SECTION

DEMONSTRATION OF NEW TECHNOLOGY FOR RECOVERY OF ATHABASCA BITUMEN

The Athabasca oil sands have surface mineable reserves which, depending on oil prices, are equivalent to about three times those of conventional crude oil in Western Canada. Production of synthetic crude oil from these reserves could more than offset declining oil production in Alberta. However, recovery operations based on mining must compete with stimulated in situ recovery of heavy oil and bitumen, enhanced recovery of conventional oil and production of conventional oil from arctic and eastcoast offshore reservoirs. The need for a better process for extraction of bitumen from mined oil sands has been identified as a critical gap requirement.

The concept of an Oil Sands Demonstration Centre in the Fort McMurray area was developed by the Alberta Oil Sands Technology and Research Authority (AOSTRA) in concert with industry and EMR to the engineering/procurement/construction stage. This concept of providing core facilities to process developers and owners of oil sand leases was superseded by a special-case concept of demonstrating the Taciuk process on a lease where the operator could use the Taciuk coker distillate as a diluent to transport bitumen produced by in situ steam stimulation.

The Taciuk process has been developed in Canada for combined thermal extraction and partial upgrading of bitumen from mined oil. It was identified as a prime candidate for demonstration, not only because of its performance in pilot plant operations but also because of its unique features. Compared with a combination of hot water/flexicoking, the Taciuk process operates at higher process efficiency, is insensitive to both ore quality and grade, uses much less water and obviates the intractable environmental and loss problems associated with ponding of effluents. Moreover, the process is amenable to smaller initial scale, incremental expansion and integration with in situ operations.

Independent technical and economic studies were completed for construction and operation of a demonstration plant and of a modular commercial-scale plant. Initiation of work on a 90 t/h demonstration program, with a total budget of about $100 million is anticipated in 1986 with costs and revenues from coker distillate and downstream royalty/licence revenue to be shared by AOSTRA, EMR and industrial participants.

CRITICAL GAP IN SITU RECOVERY R&D

The resources of bitumen and heavy oil which are only accessible by in situ technology are an order of magnitude larger than those which are surface mineable and are therefore of world-scale interest.

All of the new commercial operations in the oil sands utilize steam stimulation processes and in general produce from prime reservoirs. The economic risks are significantly lower, at every stage of development, than for current mining technology because production revenues during incremental scale up provide capital and tax allowances on an ongoing basis. Moreover, the scale up itself and even production from operating wells are responsive to economic and market exigencies.

Although commercial in situ operations exist for recovery of bitumen and heavy oil, the technology is in an early stage of development. Critical gap, novel and generic research is required over a spectrum covering reservoir characterization to match reservoirs with processes having a high probability of success; physical and numerical modelling to evaluate process concepts and sensitivities and to both predict and monitor production performance; evaluation of steam additives and ways in which they may be used to enhance microscopic displacement of oil and macroscopic sweep efficiency by displacing fluids; development of both thermal and non-thermal in situ processes for heavy oil which are generally marginal because of thinness, presence of bottom water and gas caps; development of

thermal in situ processes for the Athabasca resources which, although characteristically thick with high bitumen saturation, are intractable because they have virtually no dissolved gas and are impermeable until the bitumen has been heated; compatibility of injected fluids with reservoir fluids and minerals; development of communication for injected fluids between wells in bitumen reservoirs; fracturing of unconsolidated oil sand reservoirs; more economic generation of steam using ancillary solid fuels and untreated water produced with oil; and remote monitoring of the spatial distribution of induced fractures, injected fluids and displaced oil so that in situ processes may be monitored and controlled.

The development of in situ processes for Athabasca oil sands is particularly important for the long term because about 80% of the resources reside there, apart from those in the even more accessible carbonate triangle. In the short term, development of processes for marginal heavy oil reservoirs is important.

CONTRACTS

1. "Steam injection experiments in scaled physical models, Phase I - Development of scaling criteria, construction and experimental verification"

A low pressure scaled simulator was designed and constructed to verify operational performance in the simulation of enhanced oil recovery from marginal heavy oil reservoirs. Development of a numerical simulator for use with the physical simulator was initiated.

2. "Ibid, Phase II - Simulation of novel steam processes for marginal heavy oil reservoirs"

Modifications of steam in situ processes and the use of additives are being simulated for application to Lloydminster-type heavy oil reservoirs characterized by thin pay zones, bottom water or gas caps.

3. "Numerical simulation of steam injection in bitumen and heavy oil reservoirs, Phase I - Methodology for 2-dimensional dynamic simulation"

Conventional static grid systems are both inefficient and not will suited application to in situ recovery in the presence of vertical fractures or use of horizontal wells. Methodology for dynamic front tracking of frontal zones has been developed.

4. "Alkaline waterflooding as an enhanced recovery process for heavy oils"

This 50/50 contract extended knowledge of the mechanisms and problems to be anticipated in caustic waterflooding of heavy oil reservoirs especially in Saskatchewan. Statistical design and analysis increased experimental efficiency and allowed rigorous interpretation. Clearly, more research on fluid/reservoir interactions is required. Core recoveries were almost as good as with steam but the process sensitivities must be understood thoroughly for successful field application.

5. "Influence of reservoir matrix on the mechanisms and kinetics of the in situ combustion process for heavy oil"

This work is, by far, the most extensive undertaken on the effect of clays and sand on coke laydown and activation energies during thermal decomposition of petroleum residues. The work was conducted and interpreted meticulously. However, further thermogravimetric analyses at high pressure and development of variable block size numerical simulators to follow the thermal decomposition of heavy oil in regions of steep thermal gradients was identified. Clearly, in situ combustion processes are not understood as well as they should be.

6. "Evaluation of steam additives and clay stabilizers for enhanced heavy oil processes"

The objective of this 50/50 contract is to improve the recovery of heavy oil from reservoirs in Alberta and Saskatchewan. Frequently these reservoirs fail to produce at commercially acceptable rates due to impairment of reservoir permeability. The experimental work is elucidating the role of steam additives and clay stabilizers in preserving reservoir permeability, enhancing fluid injectivity and maintaining oil production. Studying the interactions of these additives and stablizers is an important goal.

7. "Fuel options for enhanced hydrocarbon recovery"

This multi-client study indicated that utilization of coal in oilfield applications as an ancillary fuel may be the most cost effective and risk free alternative for conversion of coal to crude oil.

8. "Wet oxidiation of produced water and ancillary fuels for oilfield applications, Phase I - Kinetics, conceptual designs and economics"

This work significantly advances published knowledge about the chemistry, thermodynamics and kinetics of wet oxidation with particular reference to oilfield applications. A concept of high thermal flux density operation was developed and patented.

PROCESS DEVELOPMENT SECTION

FUNDAMENTAL STUDIES AND PROCESS DEVELOPMENT OF BITUMEN, HEAVY OIL AND RESIDUUM UPGRADING

Fundamental reactor studies completed this year include pilot plant voidage measurements carried out using a travelling gamma scanner at gas rates approaching those in commercial reactors. In order to achieve such high gas recirculation rates, up to four gas pumps were employed by linking equipment from both plants. Based on these data, voidages to be expected in commercial size hydrocracking reactors were predicted.

Valuable hydrodynamic data on flow regimes and bubble size have been collected and analyzed using gamma scanning techniques on pilot scale equipment. A new deconvolution method was developed for interpretation of the data.

An experimental program to measure density of heavy oils at high temperature and pressure using the gamma densitometer was commenced. The feasibility of using this technique for measuring hydrogen solubility is also being assessed.

An optical microscope hot stage microreactor was commissioned and will be used to study coking reactions under process conditions.

Preliminary solid state NMR studies of asphaltenes were made to investigate the compositional changes occurring during hydrocracking. ERL's new NMR equipment was fully commissioned, and after correction of some initial magnet problems, the unit now exceeds manufacturers specifications.

Work on mesophase formation from asphaltenes, and coking of coal using Fourier transform infrared (FTIR) were completed as part of a study of coking reactions involved in hydrocracking processes.

CONTRACTS

1. "Residence time distribution in model three-phase flow columns"

Liquid tracer techniques were developed in a 30-cm diam. column for air-water and air-varsol systems. A new steel 60 cm-diam. column was constructed and put into operation. Liquid dispersion measurements in air-water and air-solvent were compared for the two column diameters and were shown to be in agreement with previous correlations for the effect of column diameter on dispersion.

2. "High temperature EPR measurements of heavy oils and components"

As part of a program to investigate the chemistry and mechanisms of heavy oil upgrading by hydrocracking and related processes, a contract was awarded to study radical formation from heavy oils at high temperatures. This contract identified spin trapping as a viable means of identifying free radicals produced during thermal decomposition of heavy oil components. A second contract was initiated to study radical formation in more detail as a function of temperature. This work is due for completion at the end of 1986/87.

3. "Kinetic studies of coke formation in hydrocarbon fractions"

Previous work had been conducted to study the kinetics of coke formation during pyrolysis of heavy oil and components. In order to extend this work to coke formation under hydrocracking conditions, a micro-autoclave system was constructed and the kinetics of coking were studied under hydrogen pressure. The rate of coke formation was considerably lower under hydrogen pressure compared with pyrolysis under

nitrogen atmosphere. Experiments to assess the effect of elemental sulphur on coke formation during the pyrolysis of heavy oil fractions were also completed. A second phase of this work was commenced in order to study the effect of hydrogen sulphide on coke formation and to extend the previous studies to different types of heavy oil.

4. "Rapid pyrolysis of feed and hydrocracked pitch"

This work involves a study of the rapid pyrolysis of hydrocracked pitch using a unique process whereby the pitch is mixed very rapidly with a solid heat carrier. Using this process the pitch will be converted to more valuable lighter hydrocarbon products. When sufficient experimental data have been collected, the viability of the process can be assessed. Work to date has involved the development of a feed system for the pitch and an electrostatic precipitator for product collection.

5. "Assessment of bio-technology for heavy oil upgrading"

This contract involves a feasibility study for the application of bio-technology to upgrading heavy oils and related materials. A detailed literature survey is underway and the assessment will be completed in 1986/87.

PROCESS DEVELOPMENT OF HYDROCRACKING TECHNOLOGY

An extensive program of autoclave studies was completed as part of the hydrocracking additive development program. A number of very promising new and modified additives with improved coke inhibiting activity were identified. Improved autoclave operating procedures also enabled hydrogen consumption data to be obtained. The information generated during this study, coupled with pilot plant data have led to a much improved understanding of the role played by the additive in inhibiting coke formation.

ERL participated in a joint EMR/Petro-Canada additive quality control task force which assessed many additive characterization techniques for potential application in the demonstration plant. In-house work in support of this demonstrated the value of FTIR and thermogravimetric techniques for the characterization of the additive. Other solid characterization studies included microscopic examination of additive and reactor solids from pilot plant experiments.

ERL also participated with Petro-Canada in the startup of the demonstration plant in Montreal. Personnel were assigned for three-month periods and in addition to advising on and monitoring the operation of the unit, were involved in petrographic analysis of reactor solids and interpretation of gamma densitometric data for reactor hydrodynamic measurements.

Work on kinetic and reactor modelling continued and included a comparison of pitch conversions from pilot plant experiments using a continuous stirred tank reactor (CSTR) and tubular reactors; development of a model to predict solids concentration profile in the hydrocracking

reactor; and an assessment of the importance of back mixing in the hydrocracking process.

SUPPORT OF THE COMMERCIALIZATION OF THE CANMET HYDROCRACKING PROCESS

A total of eight pilot plant runs were performed in order to support the operation of the CANMET Hydrocracking Demonstration Plant recently constructed in Montreal. The work involved optimization of process conditions and characterization of new feedstocks. Details of the work performed are confidential.

Reliable experimental values for the heat of reaction were obtained for the first time in small pilot-scale equipment using a specially designed insulated stirred tank reactor instead of a tubular pilot plant reactor.

COAL LIQUEFACTION SECTION

ADVANCED COAL LIQUEFACTION RESEARCH

The objective of this project is to investigate by an appropriate contracting-out program novel or advanced coal liquefaction approaches having potential to reduce synthetic fuel costs. In coal liquefaction there is a need to develop new technolgy which can make coal-derived liquids more competitive with natural crude oil derived hydrocarbons. Modified direct coal liquefaction technology and advanced pyrolysis processes could offer cost effective alternative liquid fuels to meet future Canadian needs. Recognizing the long lead times required for implementation and the human expertise needed, CANMET's objective is the research, development and eventual demonstration of this strategic technology. This will help in the adoption of the proper policies to establish a new resource/technology industry.

All of the research work in this project is carried out by contractors under the CANMET fully-funded and shared-cost coal liquefaction contract programs. There has been national participation from British Columbia to Nova Scotia. Projects are starting or ongoing addressing direct hydroliquefaction of low and high rank coals as well as fundamental research areas. Commercialization aspects are also being addressed through techno-economic studies.

SHARED-COST CONTRACTS

1. "Critical evaluation of the hardware development for the Sandwell Centrax process"

The objective was to evaluate the mechanical design, theory and fundamental operation of the Centrax separator and to help identify technical uncertainties related to time and cost for scale up. The final report contains a comparison of commercially available centrifuges and describes and critically examines the Centrax process components.

2. "Liquefaction of Nova Scotia Coals - Phase VI"

This phase on the direct liquefaction of Nova Scotia coals involved modification of the existing single-stage bench-scale coal liquefaction unit to a two-stage unit. Twenty-five experiments were conducted using Lingan Harbour seam coal with hydrogenated anthracene oil as solvent. Experiments were performed in a once-through mode using different hydrogenation catalysts. Experimental results have shown that coal space velocity, total pressure and catalytic reactor temperature significantly affect product composition and hydrogen consumption. Two-stage thermal/catalytic operations using Prince Hub seam coal produced lighter products than Lingan Harbour seam coal.

The next phase of this contract will concentrate on process optimization, coal reactivity and catalyst evaluation studies. On completion of the thermal/catalytic studies, the first-stage thermal dissolver will be converted to a catalytic dissolver.

FULLY-FUNDED CONTRACTS

1. "Techno-economic comparison of the Sandwell Centrax solid-liquid separation process with the Kerr-McGee critical solvent deashing process as part of an integrated two-stage liquefaction process"

This project will provide a techno-economic assessment of the Sandwell Centrax solid/liquid separation process applied as a separation technique in an integrated two-stage coal liquefaction process. It involves reviewing proprietary data supplied by Sandwell and critically evaluating the performance of the Centrax process compared with the Kerr-McGee critical solvent deashing (CSD) process. The study will help identify unresolved technical problems, research needs and difficulties of scale up for the process.

2. "Hydropyrolysis of Eastern Canadian Coals"

CANMET's 1 kg/h flash hydropyrolysis (FHP) unit was commissioned at the end of 1983 at the Ontario Research Foundation (ORF) in Mississagua. The unit ran successfully using Western Canadian subbituminous coal. However, various attempts to run the unit using Eastern bituminous coal met with failures due to the coking nature of the bituminous coals.

A new program to overcome the above problem was developed and tested in a batch mode. Parameters which define the processability of the coking coal were established and experimental work using the large FHP unit commenced. Significant improvement was made with respect to process operability but in some instances the processing is not smooth due to the buildup of soft char in the reactor. Work is continuing.

3. "Characterization of coal liquefaction residues"

Residues from coal liquefaction and CANMET coprocessing experiments were analyzed petrographically to determine the fate of the coal and oil reactants. The residues consisted of unreacted coal, altered

coal macerals and oil-derived intermediates, and intractable products (coke). The type and proportions of these components reflected both the reaction severity and the nature of the reactants.

The residues were toluene or THF insoluble extracts of the products from short residence time batch coprocessing experiments, bench-scale continuous two-stage coprocessing experiments, and coprocessing of Canadian coals varying from lignite to bituminous. The products from experimental research on novel coprocessing catalysts were also analyzed. A significant contribution to understanding the origin of coke in these residues was made through the combined use of scanning electron microscopy/energy dispersive X-ray (SEM/EPAX) elemental analysis and petrography.

COPROCESSING RESEARCH AND DEVELOPMENT

The objective of this project is to investigate the concept of simultaneously processing slurries of coal and bitumen or heavy oils at the bench-scale as an extension of the CANMET hydrocracking process. The project addresses the fundamental research effort at ERL in the simultaneous processing of coal and bitumen or heavy oils. This coprocessing concept has generated considerable national interest. In Eastern Canada, the combination of Nova Scotia coals with conventional crude residuals or imported heavy oils has potential for large scale applications. In Western Canada, the low rank plains coals of Alberta or Saskatchewan lignites are prime feedstocks in combination with tar sand bitumens or heavy oils.

Much greater liquid yields have been obtained compared with a direct coal liquefaction process and process performance has been shown to approach that of hydrocracking the heavy oil only. Most of the research work is being carried out in the Coal Liquefaction Section. This includes bench-scale continuous-flow experiments using different coals and heavy oil fractions; the experimental characterization of coprocessing liquid products; and solvent characterization for optimum operation.

EXPERIMENTAL PROGRAM

Coprocessing Using Hydrogen Sulphide (H_2S) as a Promoter

H_2S was used as a promoter in the coprocessing of a subbituminous coal and heavy oil under a wide range of severities in a CSTR bench-scale unit. In general the use of H_2S resulted in a higher distillate as well as higher coal and pitch conversions when compared with iron sulphate. The improved product yield in the presence of H_2S is more pronounced at moderate severities. These results confirm the positive effect of H_2S reported earlier in batch autoclave studies.

Estimation of Iron Concentration in Hydrocracking and Coprocessing Additives Using Thermogravimetric Analysis (TGA)

The use of TGA for the analysis of CANMET additives was investigated. It was demonstrated that the proximate analysis and the iron

content of an additive can be determined in less than 20 min. The results obtained in this work are shown to be comparable to those obtained using the inductively coupled plasma (ICP) method.

Use of FIMS in the Characterization of Coprocessing Liquids

A field ionization mass spectrometry (FIMS) technique was applied to determine number and weight average molecular weights (MW) of coprocessing solvents and distillate products. Analysis of FIMS data has provided some detail with regard to the chemical structure of these complex mixtures. FIMS was also used to determine MW of Cold Lake vacuum bottoms (CLVB) fractions obtained by a gel permeation chromatography (GPC) separation technique. In general, MW of CLVB and its fractions as determined by FIMS were lower than those obtained using a vapour phase osmometer (VPO).

Two-Stage Coprocessing

Experimental work on two-stage coprocessing using an Alberta coal and Cold Lake vacuum bottoms was carried out. Operating conditions that border the coking region were investigated extensively. This series of runs identified the most severe operating conditions that can be employed in a single stage CANMET coprocessing reactor. The experimental work showed that two-stage coprocessing improves operability by separating coal solubilization into bitumen from the hydrocracking of the bitumen containing solubilized coal. It was also found that two-stage coprocessing produces lighter products than single stage under comparable conditions. A patent application has been filed.

Coal Solubilization in Heavy Oils/Bitumen

The solubilization of a subbituminous coal into vacuum bottoms under high temperature and pressure in short reaction time was investigated using a bench-scale continuous-flow unit. The solubilization rates were examined with respect to process variables such as temperature, pressure, residence time, and gas flow rates. Product analyses using solvent extraction and petrography showed that the solubilization of coal in bitumen produces hybrid species which are THF insolubles but isotropic.

Thermodynamic Properties of Coprocessing Distillates

No thermodynamic data for coprocessing fluids exist in the literature. Experimental data on the vapour pressure and vapour-liquid equilibrium of hydrocarbon fractions produced during coprocessing are essential for the proper design of process equipment.

Unlike the normal investigation of thermodynamic properties under mild temperature, the current investigation deals with the thermodynamic data elevated temperatures and pressures under which chemical reactions take place. An experimental system was assembled and experimental work was carried out. The results identified significantly non-ideal behaviour of coprocessing products.

Investigation of Coal and Oil Type on Coprocessing Performance

A report was completed on the effect of coal type and coprocessing medium process performance during coprocessing. The report contains data on four subbituminous coals, two lignites and two high-volatile bituminous coals. The report also contains data on four coprocessing media, two from conventional crude and two from heavy oil and bitumen.

Coprocessing Using High-Volatile Bituminous Coals

An investigation of the behaviour of high-volatile bituminous coals is continuing. A series of continuous-flow runs was completed using Illinois #6 coal. Another series was completed on Prince coal from Eastern Canada. Data from 21 experimental runs were generated and a report is in preparation. Batch autoclave experiments were carried out on three bituminous coals and one subbituminous coal in order to compare the behaviour of the coals as a function of rank. The coking propensity of these systems was examined petrographically. A report on the batch experiments is under review.

Long Duration Bench-Scale Experiment

A long duration continuous-flow run was carried out to investigate steady state achievement as well as long term performance under optimum conditions. The run was successful for more than 100 h at conditions.

Novel Reactor Concept for Coprocessing

A new operational concept using two different catalysts in a novel reactor was investigated for coprocessing. Patent documentation is in preparation.

Coprocessing Kinetic Studies

A series of experiments was performed to add to the database available for detailed investigation of CANMET coprocessing kinetics. Further contract work is planned for next fiscal year to analyze the data generated.

Design and Construction of a Hot-Charge Batch Autoclave

Tubing-bomb reactors (9/16" ID) frequently used to liquefy coal in solvents such as tetralin and anthracene oil proved unsuitable for coprocessing experiments. A new hot-charge batch autoclave was designed and contracted to perform coprocessing experiments. Initial results indicate the distillate yields equivalent to those of a continuous-flow reactor are possible using this hot-charged autoclave. The unit will be used to study the compatibility of various coals and solvents under different operating conditions.

Design and Construction of a Micro-Continuous Coprocessing Unit

In support of the existing two bench-scale continuous coprocessing units, a micro-continuous system was designed and construction has started. The piston pump designed for this system is capable of delivering slurries containing up to 40 wt % coal at 5-100 cc/h. This unit is expected to be operational in the fall of 1986 and will be used mainly to screen coals and solvents for use in larger scale studies.

Petrographic Analysis and Scanning Electron Microscopy of Coprocessing Residues

Standard samples including altered coal, bitumen coke, coal-derived coke and coprocessing residue were generated under identical reaction conditions. Petrographic analysis was performed to characterize these residues and to identify the source of anisotropic solids. Scanning electron microscopy (SEM) was performed to verify the results of petrographic analysis.

Based on the petrographic character of the residues produced from standard samples together with semi-quantitative elemental data from SEM, coal- and pitch-derived solids were identified in a residue produced by coprocessing Forestburg coal and Cold Lake vacuum bottoms.

CONTRACTS

1. "Evaluation of atmospheric flash pyrolysis of coprocessing residues"

The objective is to examine the feasibility of producing liquids from coprocessing residues (+525°C product) by atmospheric flash pyrolysis in a fluid bed reactor. The feeding technique will be tested and process yields under typical flash pyrolysis conditions will be measured. This will provide significant information on a possible route for residue utilization. This study addresses part of the overall evaluation of coprocessing as a viable commercial technology.

2. "Techno-economic study of CANMET coprocessing technology - 20,000 bbl/d syncrude from Cold Lake crude"

A technical-economic feasibility study of small-scale plants to upgrade Cold Lake crude by either CANMET coprocessing or hydrocracking was initiated. The study will compare two coprocessing cases with hydrocracking in terms of the estimated available price per tonne of feedstock (coal plus crude oil). The available feedstock price is to be calculated from gross revenue less operating costs and a capital charge. Tests will show the sensitivity of the results to natural gas price, product value, rate of return and capital cost. The study is confidential.

3. "Investigation of the use of spherical oil agglomeration in the beneficiation of low rank Canadian coals as an integral part of CANMET coprocessing"

High ash content in low-rank Canadian coals reduces their commercial value. Process developers are making intensive efforts to remove ash by the selective agglomeration of coal particles. A new contract was initiated and a unique technology was developed to overcome the shortcomings of existing processes. Two patent applications have been filed.

CONSTRUCTION AND OPERATION OF A COPROCESSING PILOT PLANT

Bench-scale and preliminary pilot-plant experiments have indicated considerable promise for coprocessing mixtures of coal and heavy oil. To develop this process to a stage where it can be commercialized, a 240 kg/d pilot plant is being constructed in addition to the existing heavy oil hydrocracking facilities which are operated to support commercialization of CANMET hydrocracking.

Whereas the bench-scale facilities are being used to investigate the effect of the process variables on the product quantities and qualities in short experimental runs, the large pilot plant will be used to solve problems that normally result from long experimental runs lasting up to 60 days. As well, the pilot plant will be able to generate more accurate yield data than are normally possible with smaller bench-scale units. It will also enable the production of much larger quantities of products needed for the detailed assessments required for commercialization.

EXPERIMENTAL PROGRAM

Construction

Internal building modification and support structure construction were required in order to build the new pilot plant. Installation of vessels and pumps can commence during the first quarter of 1986/87. Major modifications were made to the existing hydrogen supply system. The new system is more compact than the old thereby freeing up a bay for the processing equipment. The new system includes new diaphragm compressors and hydrogen supply to two adjacent buildings.

Design and Procurement

Design criteria were established and a slurry recycle pump and pipeline were designed for transporting the heavy oil/coal slurry from the slurry preparation area located several rooms away. Detailed design of equipment and procurement of instruments for solids handling in the slurry preparation area are almost completed.

CONTRACTS

1. "To supply piping and instrumentation and layout drawings for PP3 pilot plant"

The objective was to provide engineering documentation including piping and instrumentation drawings. An instrument index and layout drawings began in July 1984 and was completed in July 1985.

2. "To develop, design and construct a pilot plant electronic instrumentation system - Phase I"

A detailed work statement was written to provide instrument loop and wiring diagrams and cabinet and panel designs. Phase I of this contract was awarded and work will commence at the beginning of 1986/87. Phase II will involve installation of instruments.

ANALYTICAL SECTION

The Analytical Section provides the ERL research projects with analytical services for petroleum, petroleum type products and coal liquids used and generated in the research pilot plants. Types of products routinely analyzed range from bitumens and heavy oil residual fractions to light distillates, naphthas and hydrogenation product gases. Occasionally various other materials such as catalysts, shales, biomass materials and residues are also received for analysis.

Analyses are done in five general areas:

(a) elemental analysis (C, H, N, O, S, and metals),

(b) standard product tests as performed routinely in industry, e.g., ASTM test methods,

(c) separations by distillation or chromatography,

(d) chemical component analysis (GC, GC/MS, NMR, etc.),

(e) gas analysis (hydrogenation recycle gases).

SUMMARY

During calendar year 1985, the Analytical Section performed and reported some 23 000 analyses on approximately 6250 samples. Most of the work was carried out in direct support of ERL in-house research projects. About 6% was conducted under collaborative interlaboratory programs and for outside clients such as other government departments, universities and other research laboratories.

IN-HOUSE RESEARCH PROJECTS

Most of the section's work involved analytical support of bitumen processing (60%) with most of that effort to satisfy the requirements of the CANMET hydrocracking pilot plant (50%) and the rest (10%) to research in catalytic hydroprocessing and characterization of bitumens and distillate products.

The coal research programs received 32% of the section's efforts, essentially in support of research in coal liquefaction. The CCRL combustion research programs required 2% of the section's efforts.

OUTSIDE ACTIVITIES

An important part of the Analytical Section's efforts involves collaboration in interlaboratory testing programs. These interlaboratory tests are necessary to maintain a high level of quality in the precision and accuracy of the analyses performed by the laboratory. The section collaborates in the CGSB Cooperative Fuels and Lubricants Monthly Exchanges and in other interlaboratory programs. Programs conducted in 1985 in which the section participated included exchanges of hydrocracking pilot plant samples with Petro-Canada laboratories in support of the CANMET hydrocracking demonstration project and in the exchange of coal liquefaction products with the Coal Research Department of the Alberta Research Council.

Section personnel also participated in the activities of the CGSB and ASTM, two standards writing organizations which are involved in preparation of specification standards and standard test methods for petroleum products. A project was undertaken by the Analytical Section to determine the heats of combustion of various petroleum fuels and to compare the experimentally determined values with those estimated using different empirical estimation equations. A report of the results was presented to both the CGSB and ASTM.

Analyses were performed for a number of outside clients, mainly CANMET's Mining Research Laboratories, other government departments and crown corporations (NRC, DND, DPW, Environment Canada, Consumer and Corporate Affairs, Transport, etc.) and for the New Brunswick Electric Power Commission under the terms of the contract with NBEPC. These outside activities represented about 6% of the section's output.

NEW DEVELOPMENTS 1985

New instruments were obtained for the analysis of ultralow sulphur and nitrogen in naphthas and distillates. These instruments extended the section's capabilities to perform elemental analysis more efficiently and at lower levels.

New NMR and GC instruments obtained during the previous fiscal year were brought into service with considerable difficulties. The suppliers provided the required warranty service to remedy the problems, such that the instruments were finally only brought into service in February 1986. Carbon-13 NMR analyses will thus be available on a regular basis starting in early 1986.

A computer system for analytical data management was acquired at the end of the previous fiscal year and was installed in the summer 1985. The software for the operation of a Laboratory Information Management System (LIMS) was created using the services of the Computer Science Centre. The LIMS database system became operational January 1, 1986. The database system will help manage the large amounts of analytical information generated by the section in providing reports in a more effective and timely manner.

A research contract is underway for the development of a rapid GC/MS method for the determination of the various saturate and aromatic hydrocarbons in petroleum fractions ranging from naphthas to heavy gas oils. This method, to support research in upgrading of synthetic crudes, is expected to be available in March 1986.

TRAINING

Section personnel participated in a total of 27 person-days of training in 1985 in the areas of laboratory safety and first aid, quality assurance in chemical analysis, and spectroscopy.

ANALYTICAL SERVICES/BREAKDOWN BY CLIENT - 1985

Client	No. of Samples	No. of Analyses	Cost ($K)
Synthetic Fuels Research Laboratory			
Process Development Section	2 392	11 794	295.6
Coal Liquefaction Section	1 974	7 061	187.9
Analytical Section Collaborative Tests	148	292	15.4
Hydrocarbon Processing Research Laboratory	1 212	2 504	61.7
Combustion and Carbonization Research Laboratory	138	305	10.5
Mining Research Laboratories	19	42	1.0
New Brunswick Electric Power Commission	40	600	10.7
Others (government departments, universities, etc.)	328	637	10.2
TOTAL	6 251	23 235	593.0

PART III

HYDROCARBON PROCESSING RESEARCH LABORATORY

HIGHLIGHTS

In 1985/86 HPRL in-house research and contracted-out studies concentrated on developing technology for the production of saleable liquid fuels with particular emphasis on those concepts showing promise for commercial application in Canada. Bench-scale studies were conducted on the primary conversion of bitumen, heavy oil, coal, oil/coal mixtures, natural gas and their byproducts and residues into suitable feedstocks for refinery operations. Secondary upgrading of all types of primary liquids derived from these processes focussed on the production of specification transportation fuels.

In-house projects carried out by 37 full-time employees including 15 engineering and scientific support staff, 3 physical scientists, 2 chemists and 17 research scientists were complemented by a fully operational contracting-out program consisting of 74 ongoing contracts.

The 1985/86 budget allocated to support these internal and external programs was:

	$K
Salaries	1453
Capital	975
Operating	705
Contracts	2566
TOTAL	5699

and resulted in the following outputs:

- 2 patents issued
- 6 patent applications filed
- 18 refereed publications
- 14 published conference preprints
- 23 technical presentations at conferences
- 16 technical presentations at universities and research institutes

During 1985/86 a fully operational contracting-out program technically administered by HPRL's Hydrocarbon Conversion Section was established. Also, the HPRL Safety Committee was restructured to conform with the requirements of the Canada Labour Code to promote a realistic approach to and maintain an active awareness of issues related to safety in a laboratory environment.

Projects related to catalysis resulted in research advances and the completion of several facilities which will further HPRL's standing as a centre of expertise for design and evaluation of catalysts and catalytic processes for the primary and secondary upgrading of Canada's hydrocarbon resources to specification liquid fuels.

Specifically, experimental studies carried out in the past several years on a low severity process for the production of specification diesel fuel from synthetic crude middle distillate complemented by time on stream studies conducted last year have indicated that the process shows promise for near term commercial application. A plan is being developed with the Office of Technology Transfer (OTT) to involve the private sector in a strategy for the scale up of this technology. Also, catalysts were formulated which demonstrated the ability to reduce the viscosity of heavy oils to meet interprovincial pipeline specifications.

An important benefit was realized with the development under contract and transfer through OTT to the general research community of computer software which can readily be adapted to pilot plant reactor systems possessing hardware capabilities for automated control. A new automated microreactor system for hydroprocessing studies on conventional and synthetic distillates as well as a microbalance reactor for the evaluation of catalysts and catalytic processes to convert residual pitch to saleable liquids were installed.

A pilot plant facility for the preparation of additives employed in advanced processes for the primary conversion of bitumen, heavy oil and oil/coal mixtures to hydrocarbon liquids was completed. As well, a senior HPRL scientist provided on site advice and consultation to aid in the commissioning of the additive preparation unit at the CANMET Hydrocracking Demonstration Plant in Montreal.

A novel process for the conversion of natural gas to methanol promoted in cooperation with OTT has drawn private sector interest and a strategy is being developed to actively involve the industrial community in further plans for potential commercialization of this technology. The commissioning of automated systems for the conversion of natural gas to premium quality transportation fuels was completed. The design phase of a bench scale entrained bed gasifier, which will be employed to study the characteristics of non-reactive carbonaceous rejects as feedstocks for gasification to synthesis gas for the production of liquid fuels or fuel gas for power generation, was carried out under contract. In addition a new analytical procedure for screening low cost adsorbents for the removal of unwanted contaminants from product gases at gasification temperatures was developed.

In-house, contract and cooperative research programs in separation and characterization continued to be productive in 1985/86 producing a number of significant outputs. Within the scope of the Canada/US Memorandum of Understanding on Heavy Oil and Oil Sands a Saskatchewan reservoir was selected to study the effect of fire flooding on heavy oil properties. This work is being complemented by studies on bitumen samples from Alberta. In-house projects produced experimental characterization data which are essential to understanding the impact of processing conditions on the properties of controlled quality products obtained from synthetic crudes produced by existing commercial scale coker operations and by advanced conversion technologies. Residue utilization studies resulted in a patent application for the use of processing residues in roofing asphalts.

Secondary upgrading of synthetic distillates focussed on research involving both sorption and membrane technologies. Significant findings related to the use of zeolites for the removal of unwanted heteroatoms from synthetic crude distillates have prompted the initiation of the design of a bench-scale experimental system to study sorption processes. Membranes continue to show promise both in applications related to the treatment of effluent streams from bitumen/heavy oil recovery operations where they have demonstrated the ability to completely remove residual oil from certain produced fluids and in processes involving the production of high quality distillate streams, particularly the separation of etherification products from methanol streams which cannot be achieved using conventional refining distillation techniques.

HYDROCARBON CONVERSION SECTION

The Hydrocarbon Conversion Section is responsible for providing scientific advice on and overseeing the ERL 50/50 and 100% funded contracting-out R&D programs for the divisional director and laboratory managers by monitoring financial expenditures and directing technology transfer arising from the contracting-out program. A total of 163 contracts were technically administered in 1985/86.

The contracting-out program was designed to encourage interested organizations to apply their resources and expertise to the development of technology for utilization of Canada's natural energy resources. Considerable contributions of R&D ideas have been made through requests for proposals from the private industry sector. In some cases, novel concepts are being developed in response to unsolicited proposals from Supply and Services Canada. There are two types of research contracts:

(a) 100% funded - the government provides total funding of R&D projects on novel and innovative ideas. Both unsolicited proposals and requests for proposals are included in this category.

(b) 50/50 cost shared - the government shares a maximum of 50% of the total cost of the project with the contractor.

Projects under this program must meet the objectives defined by the CANMET Energy Conversion Program. In addition, research grants aregiven to Canadian educational institutions and private sector research laboratories for projects which meet the criteria of the EMR Research Agreement Program. HPRL also assists in the recommendation of awarding the Project Research Applicable in Industry Grants funded by the Natural Sciences and Engineering Research Council of Canada.

During 1985/86, HPRL funded 74 research contracts (50/50 and 100%) under four technologies at a total cost of $2.6 million, an increase of 18% over the previous year's budget. Thirty-three per cent of these contracts was awarded to private companies, 36% to para-public institutions, and 31% to Canadian universities. These contract projects

(Appendix D) covered a wide range of research areas of great relevance to Canada's needs. A total of 27 reports, 9 journal publications and 2 patent applications were produced from these contracts.

CATALYTIC HYDROPROCESSING SECTION

ASPHALTENE CONVERSION FOR VISCOSITY REDUCTION OF HEAVY OILS AND BITUMENS

The development and testing of catalysts continued for converting asphaltenes in heavy feeds such as Athabasca bitumen to smaller molecular fragments. The intention is to reduce sufficiently the product viscosity for direct pipelining. Special alumina supports having a wide range of pore structures and pore size distributions were prepared using an in-housemethod developed earlier. Catalysts prepared using these supports retained their large pore structures thus were capable of providing access to the large asphaltene molecules. Several such catalysts containing cobalt and molybdenum as active metals were evaluated using a bench-scale fixed-bed reactor. The results of these studies will be presented at the forthcoming 10th Canadian Symposium on Catalysis in June 1986. Results have shown that it is possible to reduce the viscosity of the bitumen by a factor of nearly 200, down to about 100 cSt at 38°C, from an initial value of about 18 900 cSt.

Viscosity reduction can be achieved by operating the fixed bed reactor at about 400°C and liquid hourly space velocity of about 0.5. The viscosity can be further reduced to 40 cSt by operating at a slightly higher temperature, about 425°C, which would meet the viscosity specifications for direct pipelining of the product for more extensive upgrading to transportation and other fuels.

LABORATORY SUPPORT FOR DEMONSTRATION PLANT STARTUP

Preparation and Evaluation of Additives for Hydrocracking Applications

The objective of this activity was to develop an additive databank for the CANMET hydrocracking and related processes. Additives were prepared using various coals and coal-derived materials. Theirperformance was evaluated with a base feedstock using a bench-scale reactor test facility. Also, a senior HPRL scientist was assigned to the CANMET Hydrocracking Demonstration Plant in Montreal to provide technical support for the startup of the additive unit.

PITCH CONVERSION LABORATORY EXPERIMENTS

Catalytic Pyrolysis of Pitch

Progress was made on the conversion of heavy residual pitch materials to distillate liquids for fuels, and to hydrogen gas for use by hydroprocessing units. A microbalance reactor was installed along with a safety wall to isolate personnel from hazards associated with its operation. A report "Catalyst technology for reactors used to hydrocrack petroleum residua" was completed.

CONTRACTS

1. "Upgrading of residual heavy oil by vacuum pyrolysis"

Vacuum pyrolysis was assessed as a method of upgrading oil sludges which are usually waste products from oil refinery processes. These sludges have high solid and moisture contents.

2. "Literature review on pitch utilization and technical proposal for a catalytic pitch conversion system"

The objective was to prepare an overview on economics and commercial utilization of pitch. The contract also provided a conceptual design of a bench-scale catalytic pitch conversion unit with emphasis on solving problems related to pitch feeding and reactor plugging.

DISPOSABLE CATALYSTS FOR HYDROGENATING BITUMEN AND SOLUBILIZING COAL

A series of hydroprocessing catalysts was prepared by ion exchange of a novel support with aqueous solutions of transition metals. These catalysts were tested in a semi-continuous reactor system for the coprocessing of coal and residual oil of petroleum origin. The operating pressure and temperature were chosen so that the hydrocracking reactions occurred at the threshold of coking. Based on the data generated from product characterization, the catalysts were ranked in terms of coal conversion, oil production, and removal of heteroatoms from the liquid products. It was found that some metal-exchanged hydrous titanates helped produce more pentane-soluble oil and less gas than commercial hydrotreating catalysts.

CONTRACTS

1. "Characterization of tin catalysts by Mössbauer spectroscopy"

Supported tin catalysts prepared for the in-house research program were characterized by Mössbauer spectroscopy to obtain valuable information on the chemical composition of their tin sites.

CONVERSION OF REFRACTORY AROMATICS IN DIESEL FUEL

A new approach by CANMET for upgrading transportation fuels from synthetic crudes uses highly active, low cost supported metal catalysts. Specification jet and diesel fuels may be produced from oil sands at lower cost by hydrogenating their aromatic components over open pore, nickel on silica-alumina catalysts of high metal loading. Special attention was given to determining the rate of deactivation of catalysts by sulphur in distillate feedstocks during time on stream experiments. The deactivation rate was found to depend strongly on the physical characteristics of the catalyst support and those with a bimodal open pore structure were more sulphur tolerant. Surface analysis revealed that such catalysts consist of large open macropores allowing the transfer of liquid reactants from the surface to internal micropores containing multiples of catalytic sites. The hydrogenation catalysts work effectively at 240°C allowing operation at

hydrogen partial pressures of 3.5 MPa to achieve almost complete conversion of aromatics. Predictions are such that catalysts may be used in standard refinery hydrotreaters provided that selection of feedstock cuts is made to avoid excessive sulphur concentrations.

HYDROTREATING COPROCESSED DISTILLATES

Several coal-derived distillates were hydrotreated in order to evaluate the performance of a Ni-Mo/Al_2O_3 catalyst for heteroatom removal. For feedstock and catalyst evaluation, statistical experimental design strategies have been initiated. Various catalyst supports were prepared for testing with model compounds. A project involving the use of fractal geometry for catalyst and coal characterization was developed.

CONTRACTS

1. "Compositional analysis of hydrotreated middle distillates from synthetic crudes by mass spectrometry"

Compositional analysis of hydrotreated middle distillates from synthetic crudes was carried out using low resolution mass spectrometry. The results were used to evaluate the effects of hydrogenation and cracking of hydrocarbons over specific catalysts.

2. "Analysis of synthetic crude middle distillate fractions by C-13 NMR"

Carbon-13 NMR analysis was used to monitor the conversion of aromatic hydrocarbons in in-house catalytic hydroprocessing experiments. Applications included kinetic and thermodynamic studies and catalyst deactivation work.

3. "Preparation of new metal catalysts supported on ZSM5 for the deoxygenation of organic compounds"

New zeolite-supported metal catalysts were prepared, characterized and tested for the deoxygenation of oxygen-containing model compounds and coal-derived liquids.

4. "The impact of nitrogen compounds on the processing of synthetic gas oil"

The effects of specific nitrogen-containing compounds on the processing of synthetic gas oil were evaluated. Changes in product composition and catalyst performance were assessed.

5. "Role of catalysts in heteroatom removal during hydroprocessing of model compounds"

A cell was developed to allow for simultaneous infrared and kinetic studies of catalytic hydroprocessing. The contract also provided a comprehensive literature review of the catalytic properties of Mo/Al_2O_3.

6. "Development of metal cluster catalysts for conversion of middle distillate fractions in synthetic fuels"

A series of bimetallic catalysts on silica-alumina supports was prepared using metal vapour synthesis techniques. The catalysts were characterized using various spectroscopic methods and will be used to study hydrocarbon conversions in synthetic distillates.

7. "Software development for automated research and development system in distillate upgrading"

A general process control/data acquisition software package was developed for bench-scale reactor systems. The software operates on a popular microcomputer so that reports and graphics are compatible with commercial software utilities. Catalyst evaluation may be conducted more efficiently and reliably. This package (PC Control) is now commercially available.

CATALYSIS RESEARCH SECTION

CONVERSION OF REFRACTORY AROMATICS IN DIESEL FUEL

The objectives were to measure the elemental composition of specific hydrotreating catalyst surfaces after processing as a complement to development of a low severity process for upgrading middle distillate from synthetic crudes and to hydrotreat model aromatic compounds representative of those found in synthetic crudes with thin film bimetallic catalysts.

Two Ni-Si-Al oxide catalyst types were characterized by surface spectroscopy prior to and following exposure to synthetic distillates containing sulphur. The results of this study will be presented at the 10th Canadian Symposium on Catalysis in June 1986. A technical report and journal manuscript are in preparation. The results indicate sulphur reacts with the nickel but hydrogenation activity is not severely reduced because of the high initial nickel loading and large macropore structure of the support. Preparation of thin films of Co-Mo-Al oxides (500 nm) on aluminum metal proved extremely rewarding. Exposure of specific films to reduction, sulphidation and thiophene vapour provided information on the catalytic activity of commercial hydrodesulphurization (HDS) catalysts. The HDS activity of the thin films have been found to exceed the commercial catalyst by many orders of magnitude (equivalent surface area basis). Two presentations highlighting these results were made at an international catalyst conference in Europe last October; reports are in progress and additional studies will be reported at the above mentioned symposium in June 1986. A contract awarded to the University of Western Ontario in support of this thin film investigation has provided valuable collaborative data.

CONTRACTS

1. "Hydroprocessing of aromatics using thin film Co, Mo-alumina catalyst surfaces"

This contract concentrated on the in situ surface characterization of hydroprocessed thin film Co-Mo-Al oxide catalysts prepared by procedures developed earlier. A catalyst transfer device and catalyst testing unit attached directly to a UHV chamber, equipped with small spot size XPS (200 μm), and optimized to examine thin film catalysts were designed and built. The testing unit allows catalyst performance evaluations up to 15 atm pressure and 600°C. The resulting data were beneficial in terms of improving hydroprocessing catalysts generally and specifically two HDS catalysts.

LABORATORY SUPPORT FOR HYDROCRACKING DEMONSTRATION PLANT STARTUP

Surface Characterization of Coal-Based Catalysts, Coals and Chars

This project dealt with the characterization of carbonaceous materials for use as catalyst supports on reactants in hydrocracking processes. The characterization was based on N_2 and CO_2 physi-sorption, mercury porosimetry and helium density measurement. It was found that correlations existed between pore structures/surface areas of the carbonaceous materials and their reactivities/coking propensities to the feedstocks. This characterization technique can thus be used as a tool for quality control to predict the performance of carbonaceous materials in certain processes as well as to replace costly and time-consuming screening tests.

PITCH CONVERSION LABORATORY EXPERIMENTS

Assessment of Synthetic Crude Gas Oils for Fluid Catalytic Cracking (FCC)

A fully automated microactivity test (MAT) unit with both fixed bed and fluid bed reactors has been installed. Upon completion of acceptance tests and commissioning runs this unit will experimentally evaluate and predict the performance of various non-conventional synthetic crude gas oils for FCC operations in Canadian refineries.

CONTRACTS

1. "Hydrogenation and its effect on fluid catalytic cracking unit feedstocks"

The objective was to evaluate the effect of hydrogenation of conventional and non-conventional gas oils on the yield of prime quality liquid fuels in FCC.

2. "The degradation study of a metals-tolerant catalyst by molecular probes"

The objective was to develop an understanding of the catalytic cracking process involving the use of a modern metals-tolerant catalyst. Microactivity tests were conducted on pure components and on their blends commonly found in heavy oils and synthetic crudes. Both product and molecular yields were determined for each MAT.

CONVERSION OF NATURAL GAS TO GASOLINE AND DIESEL FUEL USING A SYNTHESIS GAS ROUTE

Production of Diesel Fuel from Synthesis Gas

The objective is to develop Fisher Tropsch catalysts with increased product selectivity for producing high quality diesel fuel from natural gas to decrease Canada's dependence on imported crude and establish a blending stock for the hydrogen deficient distillate liquids. Studies on the conversion of synthesis gas into specification diesel fuel are being carried out both in-house and under contract. In house, the construction phase of a high pressure automated reactor system has been completed. All preliminary tests of the pressure equipment, heated and chilled enclosures, electrical and pneumatic connections showed very good results. All software and sequencing logic have been proven for fail-safe operation. A special, clean, vibration-free room with a controlled atmosphere was constructed to accommodate all control and analytical equipment, which greatly increased safety and reliability of operation. Following the construction of a novel reactor suitable for exothermic reaction, the synthesis gas conversion program is progressing to a second phase which emphasizes catalyst designing and testing along with reactor improvements.

Development of Catalysts and Catalytic Processes for Natural Gas Conversion

The objectives were to review the literature pertaining to surface chemical studies of catalysts used in synthesis gas reactions and to prepare, characterize and test four series of thin film synthesis gas catalysts containing iron and nickel. The literature review and catalyst preparation were completed. Exposure to synthesis gas and characterization by surface spectroscopy were not completed because of laboratory constructions, reactor system design and installation delays.

A new surface science analytical laboratory and relocation of the X-ray photoelectron spectrometer were completed in August 1985. This relocation has resulted in a facility of about 140 m^2 with the surface spectroscopic instrumentation housed in adjacent and interconnected rooms. The laboratory has provision for catalyst microactivity testing facilities to be constructed in 1986.

CONTRACTS

1. "Development and characterization of selected synthesis catalysts"

The objective was to prepare and characterize a family of Fischer-Tropsch catalysts to be tested in the recently constructed in-house facility.

2. "Direct production of gasoline range hydrocarbons from syngas in a dual bed reactor system"

The objective was to investigate direct conversion of synthesis gas into gasoline in one step through a dual-packed bed reactor system over

CONVERSION OF NATURAL GAS TO LIQUID FUELS USING ACETYLENE AS AN INTERMEDIATE

Direct Conversion of Methane to Liquid Fuels

Pyrolysis of natural gas at high temperature yields acetylene as the major product. Acetylene has been used as a petrochemical building block for years. Research focussed on selectively converting acetylene to fuel octane boosters, e.g., benzene, toluene, xylene. An experimental continuous flow tubular reactor and ancillary equipment have been established for catalyst testing. Shakedown runs on the experimental system are complete. A condensable, vapour, capillary analysis system, a light gas analysis system and a large number of analytical procedures have been established for quantitative product analysis. The effect of varying process parameters, e.g., temperature, space velocity and acetylene concentration on acetylene conversion and product selectivity has been investigated using a series of fluorinated alumina catalysts.

CONTRACTS

1. "Methane conversion to hydrocarbons in a hollow cathode arc"

The objective was to explore the potential of the hollow cathode arc for polymerizing methane to higher hydrocarbons. Experiments were performed at varying CH_4/Ar ratios, cathode dimensions, temperatures and pressures to evaluate the feasibility of this process. This work has demonstrated that saturated and unsaturated hydrocarbons (C_{20} range) can be obtained in quantitative yields (60%).

SEPARATION AND CHARACTERIZATION SECTION

EFFECT OF RECOVERY METHODS ON HEAVY OIL PROPERTIES

The Canadian participants (EMR and Saskatchewan Department of Energy and Mines) of a Canada/US cooperative tar sands project are studying the effects of fireflooding on heavy oil properties. A Saskatchewan reservoir (Eyehill) and appropriate primary recovery and tertiary recovery wells have been selected for study. Sampling and sample preparation have been completed. The project has been expanded to include Marguerite Lake (Alberta) bitumen samples that were initially produced by steam stimulation, then fireflooding.

In support of the above a method development has been initiated for the determination of molecular weight distributions that are quantitative and not influenced by sorption effects.

CHARACTERIZATION OF SYNTHETIC CRUDE, GASOLINE, DISTILLATE AND ASPHALT

An investigation is being made of hydrotreated synthetic crude middle distillates produced at different severities in order to assess the reactions that feedstock molecules undergo preferentially. This work is

relevant to the production of diesel fuel and to the choice of operating conditions needed to produce quality transportation fuels under economical process conditions. The study of coprocessing distillates produced under different reducing gases showed no deleterious effects of synthesis gas over hydrogen. Moreover, results indicate that synthesis gas is slightly advantageous over hydrogen for the conversion of polar materials.

Work on the utilization of refractory processing residues in road and roofing asphalt blends has continued and characterization for predicting compatibilities with various base stocks has become more sophisticated. The addition of these residues to roofing asphalt obviates the need for air blowing. A patent application has been filed. Another patent application was made concerning the utilization of visbreaking residues. A study on the effect of the addition of nitrogenous extracts from gas oils to asphalt blends was initiated.

CONTRACTS

1. "Effect of nitrogenous concentrates from synthetic crude on asphalt blends"

Nitrogenous concentrates were extracted from synthetic crude gas oil to produce a raffinate having improved processing qualities. Utilization of the undesired nitrogenous fraction (containing about 75% of the nitrogen and about 4% of the gas oil fraction) would enhance extraction processes. The effect on the quality of asphalt blends by adding these nitrogenous extracts is being investigated.

2. "Selective identification of olefins and paraffins in middle distillates of synthetic crude oils"

The objective was to improve characterization methods for identification of olefins and paraffins in middle distillates in order to provide a greater understanding of conditions affecting hydrotreating reactions of olefins.

3. "Compositional study of nitrogen and oxygen compounds in products of heavy oil primary and secondary upgrading"

The objective was to derive background information on problematic components such as various proton-donating and azo compounds in products of primary and secondary upgrading to improve analytical methods for the characterization of specific classes of polar compounds in naphthas, middle distillates and gas oils.

SEPARATION OF SYNTHETIC CRUDE FRACTIONS

During 1985/86, the physical parameters influencing the adsorption capacity of zeolites as well as the interaction between nitrogenous compounds were investigated. It was found that the drying pretreatment of the zeolites is by far the most important. The flowrate of solution as well as the form of the sorbent (pellets vs powder) is also of great importance. Work is continuing to optimize the operating conditions

and to extend the study to oxygenated components (mostly phenolics) found in coprocessing products. Emphasis will be given to new sorbents or sorbent blends from new zeolites.

Investigations on the application of reverse osmosis for the segregation of synthetic crude components have continued. Improved separations of aromatic-saturated components have been obtained. However, the most dramatic separations were obtained in the separation of methanol from etherification products that are octane boosting gasoline additives. This cannot be achieved by distillation due to the formation of azeotropes.

CONTRACTS

1. "The investigation of the supercritical extraction of sulphurous and nitrogenous components from synthetic crude fractions"

These extractions were investigated using carbon dioxide under various supercritical conditions. Carbon dioxide alone shows no selective extraction therefore small amounts of water and acidic acid are being added in attempts to attain selectivity. These extractions were studied usingAthabasca synthetic crude naphthas and gas oils.

2. "Treatment of synthetic crudes with metal chlorides and carbonyls"

The removal of nitrogenous and sulphurous compounds from synthetic crudes by complexation with transition metal chlorides and carbonyls has been investigated. Several processing results have been obtained on complexation and may be investigated in greater detail in the future.

3. "Segregation of problematic components in synthetic hydrocarbon fuel fractions using membrane separation technologies"

The objective was to separate nitrogenous and sulphurous components from naphtha by reverse osmosis. The work included the study of the affinity of the nitrogenous and sulphurous components as determined by liquid chromatography. These results were then used to select promising membrane candidates for the aromatic-saturate separation using reverse osmosis.

4. "Reverse osmosis separation of model compounds in heptane and toluene solutions"

The objective was to investigate the performance of reverse osmosis in aromatic, saturate, and naphthenic media with particular emphasis on the fractionation of deleterious components for transportation fuels. The results will lead to an improved understanding of the performance of reverse osmosis in aromatic-rich and aromatic-lean solutions. The results will be correlated with liquid affinity chromatography results generated at ERL with the goal of creating a comprehensive mathematical model.

5. "Separation of saturates and aromatics from syncrude middle distillates"

The objective was to evaluate solvent extraction as a method for producing high quality diesel and jet fuels from low quality synthetic crude middle distillates.

6. "A study into the separation of nitrogenous materials from naphtha fractions"

The objective was to screen various sorbents (zeolite, resins, clays) to adsorb selectively nitrogenous components from naphthas. The influence of temperature, pressure and flowrate on the adsorption capacity of zeolite 13X was also studied to determine optimum conditions. Different techniques of desorption will be used to regenerate the best sorbent.

7. "Adsorption of nitrogen compounds"

The objective is to measure adsorption and diffusion properties of certain nitrogenous compounds on various sorbents. Information such as adsorption capacities, diffusion rates, and equilibrium constants are related to the nature of the adsorbent and will be used to design better ones. A large number of adsorbents having different structures, surface acidity, surface areas, site polarizability, etc. are being studied. The technique is called "pulse transient method".

WATER RECOVERY FROM HEAVY OIL EMULSIONS

This project is concerned mainly with the application of membrane technologies (ultrafiltration and reverse osmosis). Preliminary work has indicated some economic advantages. However, two major problems have been identified - membrane surface fouling and thermal degradation of membranes. These problems are being addressed under new contracts.

A minor study is being made on the use of industrial wastes as sorbents such as high sulphur coals, high sulphur coal rejects and fly ash. As much as three times their weight in bitumen could be removed and still produce clear water. The effect appears to be due to multivalent ion salts on the surface of these sorbents such as ferric sulphate on coal. It appears that the combination of surfaces and multivalent ion salts is particularly effective in breaking emulsions and is being investigated under a new contract.

CONTRACTS

1. "Exploratory investigation of low pressure rotating dynamic membrane process for treating bitumen/water/mineral emulsions"

The objective was to evaluate the performance of a rotating dynamic membrane separation process for the production of boiler feed quality water from oilfield produced water. Results indicate that the separation process has large flowrates for a given surface area, effectively removes the oil and bitumen from the permeate, and has

excellent fouling resistance compared with polymeric membranes. Further, the operating pressures are much lower than those required for polymeric membranes. The process does not change the TDS content of the produced water and does not modify the hardness. The advantages of this process are its fouling resistance and easy cleaning, as well as its demonstrated high temperature operation.

PYROLYSIS AND GASIFICATION SECTION

REMOVAL OF SULPHUR COMPOUNDS AND SOLID PARTICLES FROM GASIFIER PRODUCT GAS

The objective of this project is to develop an in-house expertise in characterization of contaminants present in gasification products, e.g., particulates and acidic species as well as to develop low cost adsorbents for removal of acidic species from gasification products at high temperatures. In accordance with projected milestones three reports were prepared and published in refereed scientific journals. Also, a laboratory technique to screen various solids as potential adsorbents for removal of acidic species from hot gas was developed.

CONTRACTS

1. "Hot gas clean-up of gasification products"

LABORATORY GASIFICATION STUDIES OF LOW COST FEEDSTOCKS

Research focussed on the use of inexpensive catalysts such as ash from the combustion of lignite for gasification of low cost feedstocks. The aim is to decrease the severity of operation. Ash from the combustion of lignite was successfully tested as a potential catalyst for gasification.

PRODUCTION OF DIESEL FUEL AND HYDROGEN FROM SOLID RESIDUES

The main objective was to evaluate residual materials such as oil sand coke, petroleum coke, and pitch as potential feedstocks for production of transportation fuels, hydrogen and electricity. Reactivities of Suncor and Syncrude coke during gasification in fixed, fluidized and entrained beds were estimated.

CONTRACTS

1. "Gasification of oil sand coke and thermally hydrocracked pitch in an entrained bed gasifier"

COST COMPARISON OF OIL SHALE LIQUIDS, COAL LIQUIDS AND OIL SAND LIQUIDS

The objective was to assess liquid production potential of Canadian oil shales with particular emphasis on oil shales in the Maritime

provinces. Laboratory work on hydrogen retorting of New Brunswick oil shales was completed.

CONTRACTS

1. "Modification of an integrated oil shale retorting-coal co-combustion system"

ANALYSIS AND STANDARDIZATION SECTION

In 1985/86 this group of three professionals and six technicians provided analytical support to research and industrial clients by carrying out 40 000 determinations on 3000 solid and liquid fuels and related materials. These analytical services were complemented by continued contributions to national and international standards organizations and by coordination of the CANMET Service Program for the Evaluation of Coal Standards (CANSPECS) round robin coal sample exchange program.

Analytical support activities concentrated on the determination of the physical and chemical properties of feedstocks, products and residues from research projects related to the production, utilization and conversion of hydrocarbon fuels as well as coals submitted through the Canadian Commercial Coal Survey Program. The complex relationships which exist between these physical and chemical parameters were identified and verified with a view to assessing the progress of novel technologies or evaluating the market potential of Canadian coals.

Within Canada, public and private sector organizations employ both American Society for Testing and Materials (ASTM) and International Standards Organizations (ISO) procedures in order to evaluate coal quality.

These standards are continually reviewed and new procedures developed to respond to the need to assess wider ranges of coal quality or to evaluate properties which have an impact on novel technological applications.

To ensure that new and revised procedures implemented by ASTM and ISO are compatible with Canadian interests the Analysis and Standardization Section of ERL continued to contribute to the deliberations of these standards groups in an advisory and consultative role.

As a complement to participating in the activities of these organizations the section continued to coordinate the CANSPECS. This program distributes commercially produced Canadian coals to 50 laboratories within Canada and abroad for analysis of specified parameters of coal quality. The experimental data obtained are employed for the assessment of the analytical acceptability of proposed standards and the evaluation of laboratory performance with respect to existing standards.

ENGINEERING DESIGN AND SUPPORT SERVICES

SUMMARY

Engineering, design, construction and information services were provided to all areas of the division.

The equipment development shop completed 115 assignments requested by ERL as well as Mining Research Laboratories. Most were of an urgent nature for repairs and modifications to experimental and prototype equipment.

Twenty-four projects were identified which required discussions and subsequent planning with Public Works Canada. The following major items were carried out during 1985/86:

- renovations to Bldg. 7 to permit year round occupancy
- construction of mezzanine in Bldg. 6
- construction of compressor and sample storage rooms in Bldg. 6
- construction of mezzanine and control room in Bldg. 5
- installation of 400-kW emergency generator adjacent to Bldg. 4
- alterations and construction in Bldg. 4 for a new pilot plant and feed system
- renovations to rooms B10 and B11 in Bldg. 3 to accommodate a scanning Auger microscope
- design for alterations to rooms 120 and 121, Bldg. 2 for the circulating fluidized bed combustor and ancillaries.

The section was responsible for the preparation of graphs and schematics for inclusion in divisional reports.

The information services arm performed literary editing of all division reports, provided information services, organized numerous tours of the facilities and was responsible for compiling and editing the division's 1985/86 annual report.

APPENDIX A

ENERGY RESEARCH LABORATORIES

PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

ENERGY RESEARCH LABORATORIES PROFESSIONAL, TECHNICAL AND SUPPORT STAFF

B.I. Parsons*	B.Sc., Ph.D. (McGill), D.Phil. (Oxford)	Director
D.A. Reeve**	B.Sc., Ph.D. (Birmingham)	Director
G.D. Brown		Secretary

ADMINISTRATIVE SERVICES

L. Patrick	Admin. Officer
A. Baldock	Clerk
J. Gosende	Secretary
M. Grebenc	Clerk
J. Hogan (Term)	Clerk
P. Hughes	Clerk
D. Deans	WPO
S. Gilmour	Secretary
L. Forieri	Rec/Ship (Stores)
J. Haw	Secretary
W. Lauzon	WPO
M. Lyttle (Term)	WPO
G. McCallum	WPO
A. van Benthem (Term)	Clerk
B. Vincent (Term)	Clerk
M. Roy (Term)	Clerk
A. Splett	Clerk
D. Weatherall (Term)	Driver

ENGINEERING SERVICES

L.P. Mysak	Dipl. Mech. Tech. (Algonquin), B.A.Sc., M.Eng. (Ottawa), P.Eng.	Engineer
D.M. Arsenault		Millwright
J.M. Dowdall		Machinist
J.L. Harcourt		Inf. Officer
R.W. Taylor		Technologist

SYNTHETIC FUELS RESEARCH LABORATORY

J.M. Denis	B.A.Sc. (Ottawa), P.Eng.	Manager

Process Development

D.J. Patmore	B.Sc. (Bristol), Ph.D. (Alberta)	Res. Sci.
T.J.W. de Bruijn	B.Sc., M.Sc., Ph.D. (Delft)	Res. Sci.
J. Chase	B.Sc.Chem. (Acadia), B.Sc. Chem.Eng. (McGill), Ph.D. (Univ. of London)	Res. Sci.
W.H. Dawson	B.Sc. (McGill), Ph.D. (Western Ontario)	Res. Sci.
D.D.S. Liu	B.Chem.Eng. (N. Taiwan Univer.), Ph.D. (Dalhousie), P.Eng.	Res. Sci.

*Retired effective 10/01/86
**Appointed effective 02/01/86

Process Development (cont'd)

F.T.T. Ng	B.Sc. (Hong Kong), M.Sc., Ph.D British Columbia)	Res. Sci.
R.B. Logie	B.Sc. (New Brunswick), P.Eng.	Engineer
P.L. Sears	M.A., Ph.D. (Cambridge)	Res. Sci.
R.W. Beer		Technologist
A.J.G. Cooke	Dipl. Mech. Tech. (Algonquin)	Technologist
R.W. Devlin	Dipl. Forestry (Sault Ste Marie)	Technologist
R.S. Eagleson		Technologist
A.J. Kuiper	Dipl. Biochem. Tech. (Algonquin)	Technologist
P.E. Landry	Dipl. Mech. Tech. (Algonquin)	Technologist
R.N.L. Lycette		Technologist
G.J. McColgan	Dipl. Journalism (Algonquin)	Technologist
C.A.W. McNabb	Dipl. Mech. Tech. (Algonquin)	Technologist
P.J. Mulvihill	Dipl. Ind. Chem. (Algonquin)	Technologist
G.J. Noel	Dipl. Ind. Chem. Tech. (CGEP, Hull)	Technologist
V.R. Phillips	Dipl. Mech. Tech. (Algonquin)	Technologist
R.A. St. Louis	B.Sc. (Ottawa)	Technologist

Bitumen/Oil Recovery

D.K. Faurschou	B.A.Sc. (Toronto)	Res. Sci.
A.E. George	B.Sc., M.Sc., Ph.D. (Cairo)	Res. Sci.
J. Margeson	B.Sc. (Carleton), M.Sc. (Ottawa)	Res. Sci.

Analytical Section

R.J. Lafleur	B.A.Sc. (Waterloo), M.Sc. (Alberta), P.Eng.	Chemist
D.M. Clugston	B.Sc., Ph.D. (McMaster)	Chemist
V. Whelan	B.Sc. (Waterloo)	Chemist
E. Kowalchuk		Technologist
L. Brazeau	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
D.J.A. Dion	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
P.M. French	Dipl. Chem. Tech. (St. Lawrence)	Technologist
B. Grossman	Dipl. Chem. Tech. (Algonquin)	Technologist
K.M. Hollington	Dipl. Chem. Tech. (Algonquin)	Technologist
G. Kodybka	Dipl. Chem. Tech. (Algonquin)	Technologist
S. Laplante	Dipl. Chem. Tech. (CGEP, Hull)	Technologist
G.R. Lett	Dipl. Chem. Tech. (Algonquin)	Technologist
R.W. Dureau	Dipl. Chem. Tech. (Algonquin)	Technologist
G. MacDonald	Dipl. Chem. Tech. (Algonquin)	Technologist
N.R. McLean	B.Sc. (Concordia)	Technologist
D. Whitehead		Technologist
I. Clelland	(Petro-Canada employee)	Technologist
Wen-Fei Ng	(Petro-Canada employee)	Technologist
G. Drapeau	(Co-op student, Sherbrooke)	Technologist
J. Francoeur	(Co-op student, Sherbrooke)	Technologist

Coal Liquefaction

J.F. Kelly	B.Eng., Ph.D. (McGill), P.Eng.	Res. Sci.
S.A. Fouda	B.Eng. (Cairo), M.A.Sc., Ph.D. (Waterloo)	Res. Sci.
M. Ikura	B.Eng. (Himeji), M.Eng. (Osaka), Ph.D. (McGill)	Res. Sci.
P. Rahimi	B.Sc. (Iran), M.Sc. (Brock), Ph.D. (Alberta)	Res. Sci.
A.D. Agnew		Technologist
R.F. Campbell		Technologist
D.M. Dick		Technologist
J.E. Whiten		Technologist

COMBUSTION AND CARBONIZATION RESEARCH LABORATORY

G.K. Lee	B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.	Manager

Coal Treatment and Coke Processing

T.A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
R.G. Fouhse	B.Sc. (Saskatchewan), P.Eng.	Engineer
P.A. Couturier		Technologist
R.K. Graham		Technologist
P. Malaiyandi		Technologist
J.W. St. James	Dipl. Chem. Tech. (Algonquin)	Technologist
R.R. Bell		Coke Oven Tech.
R.F. Dowdall		Coke Oven Tech.
D.S. Ketchum		Coke Oven Tech.
V. O'Connor		Coke Oven Tech.

Carbonization Research

J.T. Price	B.Sc. (Calgary), Ph.D. (Western Ontario)	Res. Sci.
J.F. Gransden	B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario)	Res. Sci.
J.G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
G.H. Dicks	Dipl. Mech. Tech. (Algonquin)	Technologist
D.D. Cameron	Dipl. Mech. Eng. (Ryerson)	Technologist
K.F. Hampel	Dipl. Ind. Chem. (Algonquin)	Technologist
M.J. Malette		Technologist
N.R. Manery	Dipl. Min. Tech. (Ste Claire)	Technologist
N.J. Ramey	Dipl. Min. Tech. (Haileybury)	Technologist

Energy Conservation Technology

A.C.S. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
S.W. Lee	B.Sc. (Rangoon), Ph.D. (McMaster)	Res. Sci.
R.W. Braaten	B.Eng. (Carleton), P.Eng.	Phys. Sci.
F. Preto	B.A.Sc. (Toronto), Ph.D. (Queen's)	Res. Sci.
M. Wiggin	B.A.Sc. (Waterloo)	Engineer
K. Tait	B.Sc., M.Sc. (London) (Interchange Canada)	Res. Sci.

Energy Conservation Technology (cont'd)

D.E. Barker		Technologist
J.M. MacDonald	B.A. (Trent)	Technologist
D.C. Post		Technologist
H.P. Raghunandan	Dipl. Mech. Tech. (Algonquin)	Technologist
T.G. Sellers		Technologist
R.J. Lacelle		Elec. Tech.

Emerging Energy Utilization Systems

F.D. Friedrich	B.Sc. (Saskatchewan), M.Sc. (Queen's), P.Eng.	Res Sci.
E.J. Anthony	B.Sc., B.A. (open university) Ph.D. (Swansea), C.Chem.	Res. Sci.
D.L. Desai	B.E. (Sardar Patel), M.Eng. (Ottawa), P.Eng.	Engineer
I.T. Lau	B.Sc. (Cmengkunk), M.A.Sc. (Ottawa)	Engineer
V.V. Razbin	Dipl.Eng. (Higher Mechanical-Electrical Institute, Sofia, Bulgaria)	Engineer
W.J. Birtch		Technologist
D.H.J. McLaughlin		Technologist

Industrial Combustion Processes

H. Whaley	B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.	Res. Sci.
G.N. Banks	B.A. (British Columbia)	Res. Sci.
P.M.J. Hughes	B.Sc. (Waterloo), M.Sc. Mech. Eng. (Waterloo)	Res. Sci.
K.V. Thambimuthu	B.Sc. (Birmingham), M.Eng. (McGill), Ph.D. (Cambridge), C.Eng.	Res. Sci.
R.J. Philp	M.App.Sc. (Toronto), P.Eng.	Engineer
J.K.L. Wong	B.Sc. (Calgary)	Phys. Sci.
D.C. MacKenzie	Dipl. Eng. (Cambrian College)	Technologist
J. Rostkowski	M.Eng. (Tech. University of Warsaw)	Technologist
B.C. Post		Technologist
A. Salamon		Technologist
D.G. Savignac	Dipl.Mech.Tech. (Algonquin)	Technologist

Coal and Coke Constitution

B.N. Nandi	B.Sc., M.Sc. (Calcutta), Dr.Eng. (Karlsruhe)	Res.Sci.
J.A. MacPhee	B.Sc. (St. Francis Xavier), Ph.D. (British Columbia)	Res. Sci.
L.A. Ciavaglia	B.Eng. (Carleton), P.Eng.	Phys. Sci.
B.H. Moffatt		Technologist
S.E. Nixon		Technologist

Project Monitoring and Engineering Design

S.I. Steindl	Dipl.Eng. (Budapest), M.Sc. (Queen's), P.Eng.	Engineer

Quality Assurance

R. Prokopuk	B.Sc. (Alberta)	Phys. Sci.
R.K. Jeffery		Technologist
F.L. Wigglesworth		Elec. Tech.

HYDROCARBON PROCESSING RESEARCH LABORATORY

M. Ternan	B.A.Sc. (British Columbia) Ph.D. (McGill) P.Eng.	Manager

Hydrocarbon Conversion

D.P.C. Fung	B.Sc. (British Columbia), Ph.D. (Windsor)	Res. Sci.
M. Skubnik	B.Eng., M.Eng. (Bratislava), P.Eng.	Phys. Sci.

Pyrolysis and Gasification

E. Furimsky	Dipl.Eng. (Prague), Ph.D. (Ottawa)	Res. Sci.
A. Palmer	B.Sc. (Montreal)	Res. Sci.
Y. Yoshimura	Ph.D (Nagoya) (Visiting scientist from National Laboratory for Industry, Tsukuba, Japan)	
P.S. Soutar		Technologist
M.W. Channing	Dipl. Forest. Tech. (Sir Sanford Fleming)	Technologist

Analysis and Standardization

L.C.G. Janke	B.Sc. (Sir Wilfred Laurier), B.Ed. (Queen's)	Phys. Sci.
M.D. Farrell	B.Sc. (Carleton)	Phys. Sci.
J.Z. Skulski	Chem. Eng. (Wroclaw, Poland)	Chemist
J. Glasa	Cert.Matric (Bratislava)	Technologist
T.G. Moher	Dipl. Chem. Tech. (Algonquin)	Technologist
T. Psutka	B.Sc. (Carleton)	Technologist
H. Koethe	B.Sc. (Honours) (Queen's)	Technologist
D. Rioux		Technologist
M. Skaff		Technologist

Separation and Characterization Section

H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.
M.A. Poirier	B.Sc., M.Sc., Ph.D. (Montreal)	Res. Sci.
S. Coulombe	D.E.C., B.Sc., Ph.D. (Montreal)	Res. Sci.
B. Farnand	B.A.Sc., Ph.D. (Ottawa)	Res. Sci.
G. Jean	D.E.C., B.Sc., Ph.D. (Western Ontario)	Res. Sci.
P. Chantal	B.Sc., M.Sc., Ph.D. (Laval)	Res. Sci.
S.M. Ahmed	B.Sc., M.Sc. (India)	Chemist
G.T. Smiley	Dipl. Chem. Eng. (Ryerson)	Technologist
H. Barber		Technologist

Catalytic Hydroprocessing

J.F. Kriz	Dipl.Eng. (Prague), Ph.D. (Dalhousie), P.Eng.	Res. Sci.
M.F. Wilson	B.Sc., Ph.D. (St. Andrews)	Res. Sci.
M.V.C. Sekhar	B.Sc. (Madras), M.Sc. (ITT-Madras), Ph.D (Calgary)	Res. Sci.
C.W. Fairbridge	B.Sc., M.Sc. (Lakehead), Ph.D. (St. Andrews)	Res. Sci.
J. Monnier	B.Sc. (Laval), Ph.D. (McMaster)	Res. Sci.
E.C. McColgan		Technologist
M.R. Fulton	Dipl. Chem. Tech. (Algonquin)	Technologist
M. Stolovitsky	Dipl. Biochem. Tech. (Algonquin)	Technologist

Catalysis Research

J.R. Brown	B.Sc., Ph.D. (Western Ontario)	Res. Sci.
J.Z. Galuszka	B.Sc., M.Sc., Ph.D. (Jagiellonian, Cracow, Poland)	Res. Sci.
S.H. Ng	B.Chem.Eng. (Taiwan), Ph.D. (New Brunswick), Eng., Chem.	Res. Sci.
V.M. Allenger	B.A.Eng. (McGill), M.Sc. Chem.Eng. (Ottawa)	Res. Sci.
L.E. Galbraith	B.A. (Carleton)	Technologist
M. Légère		Technologist

STAFF CHANGES

Promotions and Transfers

Barber, H. from Analysis and Standardization, HPRL to Separation and Characterization, HPRL

Bonvie, E. from Administration to Analysis and Standardization, HPRL

Boyle, M.J. from Carbonization Research to MRL

Dicks, G.H. from Process Development, SFRL to Carbonization, CCRL

George, A.E. from CANMET Research Program Office to SFRL

Martineau, A. from Analysis and Standardization, HPRL to GSC

Millar, D. from Administration to Financial Services, CANMET

Pachulski, G. from Catalytic Hydroprocessing, HPRL to GSC.

Poirier, M. from Separation and Characterization, HPRL to Esso Petroleum Canada

Taylor, R.W. from Catalysis Research, HPRL to Engineering Services, ERL

Retirements

Parsons, B.I.

Resignations

Poirier, M.A.

Turner, M.

Letourneau, J.

Mallard, P.

Friedrich, P.

Hughes, C.

Cox, B.

Bussières, D.

New Employees

Lauzon, W.

McCallum, G.

Newhook, K.

Ketchum, D.

Skaff, M.

Rioux, D.

Gosende, J.

Lyttle, M.

van Benthem A.

Philp, R.J.E.

MacKenzie, D.C.

Rostkowski, J.

Légère, M.

Wiggin, M.

Chantal, P.

Palmer, A.

MacDonald, G.

APPENDIX B

REPORTS, PUBLICATIONS, PRESENTATIONS AND PATENTS

CANMET REPORTS

CANMET Report 85-8E	A new deconvolution method for analysis of probability density distribution spectra observed in gamma-ray interrogation measurements of multi-phase flows	D.D.S. Liu

CANMET SPECIAL PUBLICATIONS

SP85-4	Proceedings of the Coal Conversion Contractors' Review Meeting, November 14-16, 1984, Calgary, Canada	J.F. Kelly (editor)

DIVISION REPORTS

ERP = Energy Research Program
ERL = Energy Research Laboratories

JOURNAL SUBMISSIONS (J)

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ERP/ERL 85-39(J)	Mechanism of hydrodeoxygenation of ortho-substituted phenols	E. Furimsky J.A. Mikhlin D.Q. Jones T. Adley H. Baikowitz
ERP/ERL 85-47(J)	Hydroprocessing of coal-derived middle distillate	C. Fairbridge J.F. Kriz
ERP/ERL 85-50(J)	Hydrotreating coal-derived naphtha	C. Fairbridge B. Farnand
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ERP/ERL 85-52(J)	Direct condensable vapour analysis by capillary GC	V.M. Allenger D.D. McLean M. Ternan
ERP/ERL 85-54(J)	Oxidative regeneration of hydrotreating catalysts	Y. Yoshimura E. Furimsky

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ERP/ERL 85-57(J)	Catalytic effect of lignite ash on steam gasification of oil sand coke	E. Furimsky A. Palmer
ERP/ERL 85-59(J)	Thermal upgrading of Canadian low-rank coals with heavy residuum	D.P.C. Fung B.Y. Wong
ERP/ERL 85-65(J)	Steam gasification of Balmer coal in the presence of lignite ash	A. Palmer E. Furimsky
ERP/ERL 85-68(J)	Enhancement of plastic properties of inert-rich oxidized cretaceous coals via the water-gas shift reaction	B.N. Nandi J.A. MacPhee L.A. Ciavaglia
ERP/ERL 85-69(J)	Nickel metal catalysts on porous supports for hydrogenation of syncrude middle distillates	M.F. Wilson J.F. Kriz
ERP/ERL 85-75(J)	Mechanism of oxidative regeneration of molybdate catalysts	E. Furimsky Y. Yoshimura
ERP/ERL 86-07(J)	Fractal analysis of gas adsorption on Syncrude coke	C. Fairbridge S.H. Ng A.D. Palmer
ERP/ERL 86-20(J)	The influence of infrared radiation on acetylene conversion	V.M. Allenger D.D. McLean M. Ternan

ORAL PRESENTATIONS (OP)

ERP/ERL 85-31(OP)	Current coal-fired boiler technology in China	G.K. Lee I.T. Lau
ERP/ERL 85-36(OP)	La normalisation des produits pétroliers (Abstract only)	R.J. Lafleur
ERP/ERL 85-41(OP)	Catalytic pore size effects when hydro-cracking residual feedstocks (Abstract only)	M. Ternan
ERP/ERL 85-55(OP)	Production of diesel fuel from synthetic distillates by hydrogenation over nickel on porous supports (Abstract only)	M.F. Wilson J.F. Kriz
ERP/ERL 85-61(OP)	Hydroprocessing of distillates from oil sands over nickel metal supported catalysts	M.F. Wilson J.R. Brown J.F. Kriz

ERP/ERL 85-64(OP)	A review of surface spectroscopic techniques and their application to hydrodesulphurization (HDS) catalyst research at CANMET's Energy Research Laboratories (Abstract only)	J.R. Brown
ERP/ERL 85-71(OP)	Comparison of industrial and pilot-oven coking pressures and coke quality (Extended abstract)	J.F. Gransden J.T. Price
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ERP/ERL 86-11(OP)	La gazéification catalytique de differentes sortes de charbons par K_2CO_3 (Abstract only)	M. Ternan M.V.C. Sekhar
ERP/ERL 86-15(OP)	The Rockwell low NO_x/SO_x burner development	G.K. Lee
ERP/ERL 86-17(OP)	Reverse osmosis and the selective permeation and rejection of methanol from hydrocarbon mixtures (Abstract only)	B. Farnand H. Sawatzky
ERP/ERL 86-19(OP)	Surface structure and hydrodesulphurization (HDS) activity of thin film Co, Mo-alumina catalysts (Abstract only)	J.R. Brown

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ERP/ERL 85-42(OPJ)	Use of lignite as blending coal for blast furnace coke	B.N. Nandi J.A. MacPhee E. Chornet
ERP/ERL 85-43(OPJ)	Catalyst technology for reactors used to hydrocrack petroleum residue	M. Ternan R.H. Packwood

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ERP/ERL 85-60(OPJ)	Metal hydrous titanates for hydroprocessing mixtures of heavy oil and coal	J. Monnier J.F. Kriz
ERP/ERL 85-62(OPJ)	The effective diffusivity of residuum molecules in hydrocracking catalysts (Abstract only)	M. Ternan
ERP/ERL 85-63(OPJ)	CANMET coprocessing of low-rank Canadian coals	S.A. Fouda J.F. Kelly
ERP/ERL 85-66(OPJ)	Surface chemistry and HDS activity of thin film Co, Mo-alumina catalysts studied by XPS, SAM and GC (Abstract only)	J.R. Brown
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ERP/ERL 85-77(OPJ)	Reactions of thin films of cobalt-molybdenum-aluminum oxides-II-Reduction, sulphidation and hydrodesulphurization activities (Extended abstract)	J.R. Brown N.S. McIntyre D. Johnston L.L. Coatsworth
ERP/ERL 86-01(OPJ)	Adsorption des composés azotes des distillates moyens sur la zéolithe 13X: Etude de l'intéraction de composés modèles (Abstract only)	P.D. Chantal S.M. Ahmed G. Jean M. Desbiens H. Sawatzky
ERP/ERL 86-02(OPJ)	Valorization des charbons oxydés à l'aide de la réaction avec le monoxide de carbone et de l'eau (Abstract only)	J.A. MacPhee B.N. Nandi E. Chornet J.A. Ripmeester
ERP/ERL 86-03(OPJ)	Evaluation de détecteurs de chromatographie liquide pour la chromatographie d'exclusion des bitumes, huiles lourdes et asphaltenes	S. Coulombe M. Morin H. Sawatzky

ERP/ERL 86-04(OPJ)	Coprocessing using H_2S as promoter	P.M. Rahimi S.A. Fouda J.F. Kelly
ERP/ERL 86-08(OPJ)	Reaction of acetylene over fluorinated alumina catalysts (Abstract only)	V.M. Allenger D.D. McLean M. Ternan
ERP/ERL 86-09(OPJ)	Reverse osmosis fractionation of etherification reactor product streams during the production of octane boosting (Abstract only)	B. Farnand H. Sawatzky
ERP/ERL 86-10(OPJ)	Utilization of synthetic crude processing residues in asphalt blends (Abstract only)	H. Sawatzky
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ERP/ERL 86-14(OPJ)	Bubbling fluidized bed combustion of Syncrude coke (Extended abstract)	E.J. Anthony H.A. Becker R.K. Code R.W. McCleave J.R. Stephenson
ERP/ERL 86-21(OPJ)	Improving the performance of fluidized bed boilers at Canadian Forces Base Summerside	V.V. Razbin F.D. Friedrich

TECHNICAL REPORTS (TR)

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ERP/ERL 85-70(TR)	A mathematical model for fluidized bed coal combustion	F. Preto

ERP/ERL 85-72(TR)	Characterization of products from the upgrading of sorbitol using gas chromatography/mass spectrometry and gas chromatography/Fourier transform infrared spectrometry	S. Coulombe G. Jean P. Chantal S. Kaliaguine
ERP/ERL 85-73(TR)	Characterization of products from the conversion of furanic compounds to hydrocarbons on zeolite using gas chromatography/mass spectrometry and gas chromatography/Fourier transform infrared spectrometry	S. Coulombe G. Jean P. Chantal S. Kaliaguine
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ERP/ERL 85-76(TR)	Characterization of catalytic deoxygenation products over ZSM-5 catalysts	G. Jean S. Coulombe P. Chantal S. Kaliaguine

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ERP/ERL 86-16(R)	The design and development of an optical diagnostic system for the measurement of gas temperatures and species concentration	P.M.J. Hughes T. Parameswaran

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ERP/ERL 85-48(LS)	Gas holdup in bubble columns - A literature survey	T.J.W. de Bruijn

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ERP/ERL 85-03(INT)	Contract R&D technically administered by the Energy Research Laboratories - 1984/85	M. Skubnik
ERP/ERL 85-04(INT)	Evaluation of South African coal for combustion	B.N. Nandi
ERP/ERL 85-05(INT)	Membrane separation process for the removal of methanol from hydrocarbon mixtures including oxygenates	B.A. Farnand H. Sawatzky

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Coulombe, S., Farnand, B.A. and Sawatzky, H. "Destabilization of emulsions from Western Canadian bitumen recovery operations and characterization of isolated surfactants"; presented at 5th International Conference on Surface and Colloidal Sciences, Potsdam, N.Y., June 1985.

Fairbridge, C. "Catalyst characterization by pulsed adsorption techniques"; presented at Catalysis Discussion Group Meeting, Carleton University, Ottawa, May 1985.

Fairbridge, C. "Fractal surfaces"; ERL Seminar Series, Ottawa, Dec. 1985.

Farnand, B.A., Soucy, G. and Sawatzky, H. "La prédiction de la separation par l'osmose inverse à l'aide de la chromatographie liquide"; presented at 53rd ACFAS Conference, Chicoutimi, Quebec, May 1985.

Friedrich, F.D. "History of erosion in the FBC boilers at CFB Summerside"; presented at Technical Session, IEA Agreement on Atmospheric Fluidized Bed Combustion, Halifax, N.S. Nov. 21, 1985.

Friedrich, F.D. "The CCRL combustion research program"; presented at Bavarian Energy Technology Study Group, Nepean, Ontario, Aug. 1985.

Hayden, A.C.S. "Venting of combustion appliances"; presented at 10th Annual Joint ASME/EPA/APCA Information Exchange on Stationary Source Combustion; Raleigh, North Carolina; Dec. 1985.

Hayden, A.C.S. "Chimney problems and R&D needs for venting systems in Canada"; presented at Joint Industry-Government Seminar on Chimney Systems in Canada, Toronto, Jan. 1985. (80 attendees from across Canada)

Hayden, A.C.S. "Techniques and technologies to improve oil furnace performance"; presented at Annual Meeting, Home Energy Group, Peterboro, Ontario, May 1985.

Hayden, A.C.S. "Overview of CCRL Energy Conservation Activities"; presented at NACMMR Oil and Gas Committee, Toronto, June 1985.

Hayden, A.C.S. "Chauffage au gaz - les technologies nouveaux et efficaces"; Génie mécanique, Université de Québec à Chicoutimi; Jan. 1985.

Hunter, N.R., Gesser, H.D., Morton, L.A. and Fung, D.P.C. "The direct conversion of natural gas to methanol by controlled oxidation at high pressure"; presented at 35th Canadian Chemical Engineering Conference, Calgary, Oct. 4-8, 1985.

Ingrey, S., Brown, J.R. and Galbraith, L.E. "An Auger/ESCA study of Ga/As surfaces"; presented at 1st International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii, Dec. 16, 1984.

Jean, G., Bonvie, E. and Sawatzky, H. "Separation of synthetic crude nitrogenous compounds"; presented at 5th International Conference on Surface and Colloidal Sciences, Potsdam, N.Y., June 1985.

Jean, G., Bonvie, E. and Sawatzky, H. "Séparation des composés azotés dans les distillats pétroliers par adsorption"; presented at 53rd ACFAS Conference, Chicoutimi, Quebec, May 1985.

Kelly, J.F. "CANMET coprocessing technology"; special presentation at Symposium on Chemistry of Coal Liquefaction and Catalysis, Hokkaido University, Sapporo, Japan, March 17-20, 1985.

Kelly, J.F. "Development of coprocessing technology - A Canadian synthetic fuels opportunity"; presented as the 1985 ERCO Award Lecture at the 35th Canadian Chemical Engineering Conference, Calgary, Oct. 6-9, 1985.

Kim, S.D., Kwon, T.W. and Fung, D.P.C. "Reaction kinetics of coal pyrolysis and char gasification"; presented at 7th Miami Internal Conference on Alternative Energy Sources, Miami, Florida, Dec. 9-11, 1985.

Kriz, J.F., Fairbridge, C. and Wilson, M.F. "Upgrading of distillates derived from oil sands and coal"; Heavy oil and tar sands: producing, upgrading and economics (sponsored by Enhanced Recovery Week), Los Angeles, CA., Dec. 9-10, 1985.

Lafleur, R.J. "La normalisation des produits pétroliers"; presented at 53rd ACFAS Conference, Chicoutimi, Quebec, May 1985.

Lafleur, "Review of the analytical services provided by the Analytical Section"; presented at ERL Seminar Series, Jan. 1986.

Lang, S.B., Ikura, M. and Brunet, J. "A continuous warming computer-controlled calorimeter using a pyroelectric thermometer"; presented at 6th International Meeting on Ferroelectricity, Kobe, Japan, Aug. 12-16, 1985.

Lee, S.W. "Particulate emissions from domestic oil furnaces related to middle distillate fuel quality"; presented at Brookhaven National Laboratory, Long Island, New York, Aug. 1985.

Lipsett, J.J., Noble, R.D. and Liu, D.D.S. "Time series analysis of gamma densitometry signals"; presented at 6th Symposium on X- and Gamma-ray Sources and Applications, Ann Arbor, Michigan, May 1985.

Liu, D.D.S., Patmore, D.J., Tscheng, J.S.H., and Jain, A.K. "Upgrading of heavy oil and residuum by the CANMET hydrocracking process: Comparison of pitch conversions from experiments using CSTR and tubular reactors"; presented at Winter Annual Meeting of the American Institute of Chemical Engineers, Chicago, Ill., Nov. 1985.

Liu, D.D.S., Patmore, D.J. and Lipsett, J.J. "Hydrodynamic behaviour of gas liquid two-phase flows at elevated temperature and pressure"; presented at 35th Canadian Society of Chemical Engineering Conference, Calgary, Oct. 1985.

MacPhee, J.A., Nandi, B.N., Ripmeester, J.A. and Ratcliffe, C.I. "Étude du mécanisme de l'oxydation d'un charbon bitumineux"; presented at 53rd ACFAS Conference, Chicoutimi, Quebec, May 1985.

Monnier, J. and Kriz, J.F. "Catalytic hydroprocessing of mixtures of heavy oil and coal"; presented at Symposium on Catalytic Processes in Coal Conversion, Division of Petroleum Chemistry, 190th ACS National Meeting, Chicago, Ill., Sept. 8-13, 1985.

Monnier, J. and Kriz, J.F. "Catalytic hydroprocessing of mixtures of heavy oil and coal"; Catalysis Discussion Group Meeting, McGill University, Montreal, Sept. 20, 1985.

Monnier, J., Quilliam, M.A. and Anderson, R.B. "Hydrogenolysis of n-hexadecane on iron and its inhibition by carbon monoxide"; presented at Symposium in memory of Paul H. Emmett on the surface science of catalysis, Div. of Colloid and Surface Chemistry, 190th ACS National Meeting, Chicago, Ill., Sept. 8-13, 1985.

Mysak, L.P. and Ternan, M. "Hysteresis caused by dimensional changes of porous solids during mercury porosimetry"; presented at 5th International Conference on Surface and Colloidal Sciences, Potsdam, New York, June 24-28, 1985.

Mysak, L.P. and Ternan, M. "The influence of high merecury pressures on the internal dimensions of catalyst pores during porosimetry measurements"; Catalysis Discussion Group Meeting, McGill University, Montreal, Sept. 20, 1985.

Nandi, B.N., MacPhee, J.A. and Ciavaglia, L.A. "Assessment of coal for combustion"; presented at Conference on the Structure and Reactivity of Coal; London, England; March 25-27, 1985.

Packwood, R.H. and Ternan, M. "Catalyst technology for reactors used to hydrocrack petroleum residua"; NATO Advanced Study Institute, Chemical Reactor Design and Technology, London, Ontario, June 1-12, 1985.

Price, J.T. and Pearson, D.E. "Reactivity of inertinite of Western Canadian coals"; presented at Annual General Meeting, CIMM, Vancouver, April 1985.

Sekhar, M.V.C. "Asphaltene conversion using large pore catalysts"; Catalysis Discussion Group Meeting, Carleton University, Ottawa, April 15, 1985.

Simmons, R., Notzl, H. and Wilson, M.F. "Development of improved synthetic crude processes and the production of transportation fuels"; CANMET Oil and Gas Conversion Contractors' Review Meeting, Toronto, Nov. 20-22, 1985.

Ternan, M. "Catalyst pore size effects when hydrocracking residual feedstocks"; Advances in Catalytic Chemistry - Symposium honoring Michel Boudart, Salt Lake City, Utah, May 20-24, 1985.

Ternan, M. "Performance of alumina supported catalysts of varying pore size when hydrocracking heavy oils"; presented at NOVA-Husky Research Laboratories, Calgary, May 24, 1985.

Ternan, M. "Effects of diffusion in catalyst pores during residuum hydrocracking"; presented at Petro-Canada, Process Research and Development Laboratory, Calgary, May 24, 1985.

PATENTS

ISSUED

Belinko, K., Packwood, R.H., Patmore, D.J. and Ranganathan, R. "Two stage process for demetallizing and hydrocracking bitumen or heavy oils", France Patent 81 13986, March 17, 1986 and Venezuelan Patent allowed June 1985.

de Bruijn, T.J.W., Kriz, J.F. and Silva, A.E. "Dry mixed coal-metal salt additive for heavy oil hydrocracking", Canadian Patent allowed Sept. 10, 1985.

George, A.E. and Poirier, M.A. "Clarification of black water obtained during recovery of bitumens and heavy oils", US Patent 4,519,915, May 28, 1985.

Khulbe, C.P., Belinko, K., Pruden, B.B., Ranganathan, R. and Patmore, D.J. "Hydrocracking of bitumen, heavy oils and coal slurries using syn-gas", France Patent allowed Dec. 5, 1985.

Khulbe, C.P., Ranganathan R. and Pruden, B.B. "Hydrocracking of heavy oils/fly ash slurries", France Patent 81 06859, Feb. 17, 1986.

Liu, D.D.S. "Multiple measuring control volume laser doppler anemometer", US Patent 4,437,503, Aug. 27, 1985.

Ranganathan, R., Patmore, D.J. and Silva, A.E., "Hydrocracking of heavy hydrocarbon oils with high pitch conversion," Great Britain Patent 2,108,522, June 19, 1985.

Ternan, M. and Parsons, B.I. "High porosity catalyst", Canadian Patent 1,189,052, June 18, 1985; US Patent 4,558,301, Dec. 10, 1985.

Wan, J.K.S. and Kriz, J.F. "Hydrodesulphurization of hydrocracked pitch", US Patent 4,545,879, Oct. 8, 1985.

APPLIED FOR

Farnand, B.A., Poirier, M.A. and Sawatzky, H. "Process for selective removal of emulsion stabilizers from bitumen water emulsions", Canadian Serial No. 473,496, Feb. 4, 1985; US Serial No. 737,422, May 24, 1985.

Farnand, B.A. and Sawatzky, H. "Membrane separation process for the removal of methanol from hydrocarbon mixtures including oxygenates", CANMET Case 49, Sept. 1985.

Fouda, S. and Kelly, J.F. "Tailoring the coprocessing medium for the simultaneous conversion of coal and heavy oil", Kirby, Shapiro, Eades and Cohen File 24873.

George, A.E. and Poirier, M.A., "Removal of nitrogenous compounds from petroleum processing products using bromine-treated ilmenite", US Serial No. 812,444, Dec. 23, 1985.

Ikura, M. and Kelly, J.F. "Two-stage coprocessing of coal and bitumen" Kirby, Shapiro, Eades and Cohen File 24735.

Kriz, J.F. "Process for hydrocracking heavy oils under severe conditions using a mixed catalyst", Canadian Patent Application 484,505, filed June 19, 1985; US Patent Application 769,720, filed Aug. 27, 1985.

Mikhlin, J.A., Capes, E.E., Divanji, H.S. and Coleman, R.D. (assigned to CANMET) "Oil agglomeration beneficiation process for low-rank or oxidized coals". CPDL application, 1985.

Mikhlin, J.A., Capes, C.E., Divanji, H.S. and Coleman, R.D. (assigned to CANMET) "Method for liquefaction of low rank or oxidized coals with oil agglomeration beneficiation as an integral part of the liquefaction process". CPDL application, 1985.

Poirier, M.A. "Roofing asphalt composition containing hydrocracked pitch", US Patent Application 733,781 and Canadian Patent Application 476,859, 1985.

Poirier, M.A. "The utilization of visbreaking residues for production of road asphalts", File 24137-1, 1985.

Poirier, M.A. "A process for the separation of sulphur compounds in bitumen, heavy oil and synthetic fuel distillates", Canadian Patent Application 484,079, 1985.

Rahimi, P.M., Fouda, S.A. and Kelly, J.F., "The use of H_2S as a promoter in CANMET coprocessing", Kirby, Shapiro, Eades and Cohen File 24646.

APPENDIX C

REPRESENTATION ON TECHNICAL COMMITTEES

INTERNATIONAL

AIR POLLUTION CONTROL ASSOCIATION
- APCA TS-2.3, Residential Fuel Combustion (chairman)..... A.C.S. Hayden
- APCA TS-2.2, Industrial Fuel Combustion (secretary)..... A.C.S. Hayden
- APCA Ottawa Chapter (secretary)..... S.W. Lee
- APCA Quebec Section Executive (past chairman)..... R.J. Lafleur
- Air Pollution (member at large)..... R. Prokopuk

BRITISH FLAME RESEARCH COMMITTEE (member)..... G.K. Lee

CANADA/JAPAN COAL LIQUEFACTION PROGRAM (Canadian coordinator) D.A. Reeve
- Working Group (member)..... M. Ikura

FUEL (London) (Eastern regional editor)
- International Editorial Board (Canadian editor)..... A.E. George

INTERNATIONAL CONGRESS ON CATALYSIS (1988)
- Advertising and Publications Committee (chairman)..... M. Ternan
  (member)..... J. Monnier
- Technical Program Committee (member)..... J.F. Kriz

INTERNATIONAL COMMITTEE ON COAL PETROGRAPHY
- Petrography (working member)..... B.N. Nandi
- Petrography of Organic Sediments (member)..... B.N. Nandi
- Subcommittee on Industrial Application of Coal Petrography (member)..... B.N. Nandi

INTERNATIONAL COMMITTEE ON COAL RESEARCH (member)..... D.A. Reeve

INTERNATIONAL ENERGY AGENCY
- Fossil Fuels Working Party (member)..... D.A. Reeve
- Coal Research Executive Committee (member)..... D.A. Reeve
- Coal-liquid Mixture Implementing Agreement..... H. Whaley
- Atmospheric Fluidized Bed Combustion Agreement..... F.D. Friedrich
  ..... E.J. Anthony
- Low NO_x Coal Combustion of Pulverized Coal Agreement.... G.K. Lee
- Coal Combustion Sciences Implementing Agreement..... G.K. Lee
  ..... H. Whaley
  ..... P.M.J. Hughes
- Organizing Committee - International Conference on Coal Science..... J.T. Price
- District Heating Implementing Agreement..... M. Wiggin
- Advanced Heat Pump Implementing Agreement..... M. Wiggin

INTERNATIONAL FLAME RESEARCH FOUNDATION
- Aerodynamics Panel (member)..... H. Whaley
- Flame Chemistry Panel (member)..... E.J. Anthony
- Joint Committee (member)..... G.K. Lee
- Pulverized Coal Panel (member)..... H. Whaley
- Oil and Gas Panel (member)..... A.C.S. Hayden

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)
- ISO/TC-27 Solid Mineral Fuels Canadian Advisory Committee (Chairman)..... L. Janke
- ISO/TC-27/SC-2 Brown Coals & Lignites (secretary)..... L. Janke
  (member at large)..... R. Prokopuk
- ISO/TC-27/SC-2/WG-15 Coal Abrasion (member)..... R. Prokopuk
- ISO/TC-27/SC-3 Coke (member)..... J.F. Gransden
- ISO/TC-27/WG-12 Plasticity (member)..... T.A. Lloyd
- ISO/TC-102/SC-3 Physical Testing of Iron Ores (chairman). J.T. Price
- ISO/TC-109 Domestic Oil Burners (member)..... A.C.S. Hayden
- ISO/TC-146/SC-1 Air Quality - Stationary Source..... Emissions (member)..... H. Whaley

NORTH ATLANTIC TREATY ORGANIZATION (NATO)
- NATO Advanced Study Institute on Chemical Reactor Design and Technology, London, Ontario (1985) Organizing Advisory Committee (member)..... M. Ternan

INTERNATIONAL DISTRICT HEATING AND COOLING ASSOCIATION
- International Relations Committee (chairman)..... M. Wiggin

US/CANADA MEMORANDUM OF UNDERSTANDING FOR COOPERATION ON RESEARCH AND DEVELOPMENT IN TAR SANDS (OIL SANDS) AND HEAVY OIL
- Executive Committee (Canadian chairman)..... B.I. Parsons*
  (adviser)..... D.K. Faurschou

SWEDEN/CANADA MEMORANDUM OF UNDERSTANDING ON ENERGY CONSERVATION TECHNOLOGY
- District Heating Coordination..... M. Wiggin

US/CANADA INTERAGENCY WOOD COMBUSTION
- Research Group (member)..... A.C.S. Hayden

UNITED NATIONS INFOTERRA INTERNATIONAL DIRECTORY OF SOURCES
- (environmental expert member)..... R. Prokopuk

WOOD HEATING ALLIANCE
- Engineering Committee (member)..... A.C.S. Hayden
- Emissions Testing (member)..... R.W. Braaten

UNITED STATES OF AMERICA

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
- Air Pollution Control Division General Committee (member)..... H. Whaley
- Combustion and Fuels Technology Research Committee (member)..... G.K. Lee
- Research Committee on Corrosion and Deposits from Combustion Gases (member)..... G.K. Lee

*Replaced by D.A. Reeve 02/01/86

Honors and Awards Committee, Papers Review, Fuels Division (member)..... H. Whaley
Air Pollution Control Division, Papers Review Committee (member)..... H. Whaley
American Power Conference Organization Committee (member)..... H. Whaley
Percy Nicholls Award Committee (member)..... G.K. Lee

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
Committee D-2 Petroleum Products and Lubricants (member)..... R.J. Lafleur
Committee D-5 Membership Secretary..... L. Janke
Committee D-5 Executive (member)..... L. Janke
Committee D-5 (member)..... M.D. Farrell
Committee D-5 Coal, Coke, Gaseous Fuels (member at large) R. Prokopuk
Committee D-32 Catalysis (members)..... C. Fairbridge
..... S.H. Ng
Committee D-34 Waste Disposal (member)..... E.J. Anthony
Committee D-38 Utilization of Waste Materials (member)... E.J. Anthony
Committee D-22 Environmental Monitoring and Assessment (member)..... R. Prokopuk
Subcommittee D-5-07 Physical Properties of Coal (member)..... T.A. Lloyd
Subcommittee D-5-22 Physical Testing of Coke (member).... T.A. Lloyd
Subcommittee D-5-28 Petrographic Analysis of Coal (members)..... B.N. Nandi
..... J.C. Jorgensen
Thermodynamic Performance of Solid Fuel Appliances..... R.W. Braaten

NATIONAL ENGINEERING FOUNDATION
Fuels for Tomorrow Conference Organizing Committee (member)..... G.K. Lee
Fouling and Slagging from Fuel Impurities Conference Organizing Committee (member)..... G.K. Lee

UNITED STATES OF AMERICA FOREST PRODUCTS RESEARCH
Society Editorial Review Board (member)..... D.P.C. Fung

UNITED STATES DEPARTMENT OF ENERGY
CLM Standards and Practices Committee (member)..... H. Whaley
CLM Combustion Subcommittee (chairman)..... H. Whaley

CANADA - FEDERAL

CANADIAN GENERAL STANDARDS BOARD
Committee 3-GP, Petroleum Test Methods Subcommittee (member)..... M.F. Wilson
Committee on Middle Distillate Fuels (member)..... A.C.S. Hayden
Subcommittee on Heating Fuels (chairman)..... A.C.S. Hayden
Committee on Gasoline and Alternative Automotive Fuels (member)..... A.C.S. Hayden
Committee on Petroleum Products (member)..... R.J. Lafleur
Committee on Test Methods (member)..... R.J. Lafleur

Committee on Identification of Medical Gas Cylinders, Pipelines and Flush-type Valves (member)..... L.P. Mysak
Committee on Pressure Gauges (member)..... L.P. Mysak

ENERGY, MINES AND RESOURCES CANADA
Alberta/Canada Energy Resources Research Fund Waste
Waste Heat Recovery R, D&D Sub-program (member)..... M. Wiggin
Canada/New Brunswick Coal-Oil Shale Combustion Agreement
Technical Committee (chairman)..... F.D. Friedrich
Canada/Saskatchewan Heavy Oil/Fossil Fuels Agreement
Management Committee (member)..... B.I. Parsons*
(adviser)..... D.K. Faurschou
Technical Advisory Committee (member)..... M.F. Wilson
Canada/Nova Scotia Power Corporation Agreement re
Fluid Bed Test Facility at Point Tupper, N.S.
Management Committee (member)..... F.D. Friedrich
CANMET Hydrocracking
Liaison Committee (chairman)..... J.M. Denis
Patents and Publications Committee (member)..... J.M. Denis
Patent Coordination (representative)..... D.J. Patmore
Research and Development Committee (members)..... J.M. Denis
..... D.J. Patmore
Reactor Modelling and Simulation Committee (members).. T.J. de Bruijn
..... D.D.S. Liu
CANMET Coprocessing Policy Committee (member)..... J.F. Kelly

ENVIRONMENT CANADA
FBC Technology Environmental Advisory Committee
(member)..... E.J. Anthony

INTERDEPARTMENTAL
Committee on Building Energy R&D (member)..... A.C.S. Hayden
Committee on Research on Indoor Air Quality (member).... A.C.S. Hayden
Committee on Fuels and Lubricants (members)..... M.F. Wilson
..... S.W. Lee
Lead in Gasoline (member)..... A.C.S. Hayden
Fuel Committee (member)..... F.D. Friedrich
Management Committee for CANMET Hydrocracking
(chairman)..... J.M. Denis
Committee on Retrofit Devices and Additives (member).... A.C.S. Hayden
Task Force on Stack Height Estimation (member)..... H. Whaley
Committee on Liquid Fuels in Transportation (member).... A.C.S. Hayden

NATIONAL RESEARCH COUNCIL ASSOCIATE COMMITTEE ON SCIENTIFIC CRITERIA FOR ENVIRONMENTAL QUALITY
Committee on Emissions from Residential Combustion
Appliances (chairman)..... A.C.S. Hayden

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*Replaced by D.A. Reeve 02/01/86

CANADA - MISCELLANEOUS

AOSTRA/INDUSTRY/EMR
- Heavy Oil Pipelineability Study (member)..... A.E. George
- Oil Sands Demonstration Centre Management Committee (member)..... D.K. Faurschou
- Upgrader Selection Study (member)..... J.M. Denis
- Upgrader Residue Utilization Study Management Committee (member)..... F.D. Friedrich

ATLANTIC COAL LIQUID MIXTURE WORKING GROUP (member)..... H. Whaley

ATLANTIC GROUP FOR RESEARCH AND INDUSTRIAL MATERIALS
- (EMR representative)..... M. Ikura

CANADIAN ELECTRICAL ASSOCIATION
- Advisory Panel on Emissions Control..... G.K. Lee
- Project on Circulating AFBC Waste Characteristics (technical adviser)..... E.J. Anthony
- Project on Flame Scanners for Coal Firing Monitoring (technical adviser)..... P.M.J. Hughes

CANADIAN CARBONIZATION RESEARCH ASSOCIATION
- Board of Directors (member)..... D.A. Reeve
  (secretary)..... J.T. Price
- Technical Committee (member)..... J.F. Gransden
  (secretary)..... A.T. Lloyd

CANADIAN COAL PETROGRAPHERS GROUP (member)..... J.G. Jorgensen
(secretary)..... B.N. Nandi

CANADIAN GAS ASSOCIATION
- Standards Committee (member)..... G.K. Lee
- Seasonal Performance of Gas-Fired Appliances..... A.C.S. Hayden
- Industrial and Commercial Gas Burners..... F. Preto
- Industrial and Commercial Gas Package Boilers..... F. Preto

CANADIAN HOME BUILDERS ASSOCIATION
- Task Force on Future Space Conditioning Systems (member)..... A.C.S. Hayden
- Committee on Controlled Ventilation and Heat Recovery (member)..... A.C.S. Hayden
- Committee on R2000 Technical Requirements (member)..... A.C.S. Hayden
- Technical Research Committee (members)..... A.C.S. Hayden
  ..... F. Preto

CANADIAN INSTITUTE OF ENERGY (director)..... F.D. Friedrich
- Ottawa Branch (treasurer)..... E.J. Anthony
- Ottawa Branch Executive Committee (member)..... S.W. Lee

CANADIAN SOCIETY FOR CHEMICAL ENGINEERING
- Ottawa-Hull Section Executive (chairman)..... M.I. Ikura
  (vice-chairman)..... J.D. Chase
  (secretary)..... J. Monnier
  (member)..... V. Allenger

CANADIAN SOCIETY FOR CHEMICAL ENGINEERING (cont'd)
- Continuing Conference Program Subcommittee
  - Local Section (representative)..... J.F. Kriz

CANADIAN STANDARDS ASSOCIATION
- Committee on Oil Heating Systems (member)..... A.C.S. Hayden
- Subcommittee on Chimney Dampers (member)..... A.C.S. Hayden
- Air Pollution Control (executive)..... H. Whaley
- Incinerator Performance (member)..... F.D. Friedrich
- Steering Committee on Fire Safety..... A.C.S. Hayden
- Oil Burning Equipment (member)..... A.C.S. Hayden
- Retrofitting of Oil Burners (member)..... R.W. Braaten
- Sampling Emissions and Measurements (chairman)..... H. Whaley
  (member)..... R. Prokopuk
- Emissions and Efficiency of Solid Fuel Appliances
  (member)..... R.W. Braaten
- Committee on Energy Evaluation of Houses (member)..... A.C.S. Hayden
- Subcommittee on Analytical Techniques for Housing
  (member)..... A.C.S. Hayden
- Sampling Emissions and Measurements (chairman)..... H. Whaley
  (member)..... R. Prokopuk
- Task Group on Controlled Ventilation in Housing
  (member)..... A.C.S. Hayden
- Installation Code for Solid Fuel Appliances (member)..... R.W. Braaten
- Committee on Wood-fired Appliances (member)..... R.W. Bratten
- Committee on Solid Fuel Fired Space Heaters (member)..... A.C.S. Hayden
- Committee on Energy Evaluation of Houses (member)..... A.C.S. Hayden
- Committee on Masonry Chimneys and Fireplaces (member).... A.C.S. Hayden
- Executive Management Committee on Venting Systems
  (member)..... A.C.S. Hayden

CHEMICAL INSTITUTE OF CANADA
- Catalysis Division (secretary-treasurer)..... J.F. Kriz
- Ottawa-Hull Section Executive Committee
  (ex-officio member)..... J. Monnier

HOUSING AND URBAN DEVELOPMENT ASSOCIATION OF CANADA (HUDAC)
- Future Space Conditioning Requirements (chairman)..... A.C.S. Hayden
- Controlled Ventilation and Heat Recovery (member)..... A.C.S. Hayden
- Technical Research Committee (member)..... A.C.S. Hayden

HYDROCARBON RESEARCH CENTRE - UNIVERSITY OF ALBERTA
- Board of Directors (member)..... B.I. Parsons

NATIONAL COAL CONVERSION COMMITTEE
- Executive Committee (member)..... M. Ikura

NATIONAL HEAT PUMP COORDINATING COMMITTEE (chairman)..... M. Wiggin

UNDERWRITERS LABORATORIES OF CANADA/CANADIAN STANDARDS ASSOCIATION
- Joint Committee on Wood Burning Appliances (member)..... A.C.S. Hayden

APPENDIX D

CONTRACTS, RESEARCH AGREEMENTS AND COST RECOVERY WORK

CONTRACTS

Contract title	Contractor	Scientific authority	Status
Compositional analysis of hydro-treated middle distillates from synthetic crudes by mass spectrometry	Petro-Canada Inc.	M. Wilson	In progress
The impact of nitrogen compounds on the processing of synthetic gas oil	Petro-Canada Inc.	J. Monnier	Completed
Characterization of virgin and hydrogenated liquids from spouted bed pyrolysis of Canadian coals	University of British Columbia	M. Skubnik	In progress
Study of hydrodesulphurization reactions on thin film cobalt molybdenum catalyst surfaces	University of Western Ontario	J. Brown	Completed
Development of rapid GC/MS method using a Finnigan 3400 GC/MS instrument for type characterization of hydrocarbons	Zenon Environmental Inc.	R. Lafleur	In progress
Analyses of synthetic crude middle distillate fractions by C-13 NMR	Carleton University	M. Wilson	In progress
Préparation de nouveaux catalyseurs à base de métaux supportes sur ZSM-5 pour la désoxygenation de composés organiques	Laval University	J. Monnier	In progress
Hydrogenation and its effects on fluid catalytic cracking unit feedstocks	Petro-Canada Inc.	S. Ng	Completed
Treatment of pitch with methanol	Sandwell Beak Research Group	D. Fung	Completed
Software development for automated R&D system in distillate upgrading	Sharon Professional Services	C. Fairbridge	Completed
Role of catalyst in heteroatom removal during hydroprocessing of model compounds	University of Alberta	C. Fairbridge	Completed

Contract title	Contractor	Scientific authority	Status
Literature review on pitch utilization and technical proposal for catalytic pitch conversion system	Hatch Associates Ltd.	S. Ng	Completed
Valorisation des résidus d'huiles lourdes par pyrolyse sous vide	University of Sherbrooke	J. Monnier	Completed
Upgrading of synthetic crude distillates with commercial hydrotreating catalysts	Stearns Catalytic Ltd.	M. Sekhar	In progress
Primary thermal upgrading of residua to transportation fuels	Petro-Canada Inc.	D. Fung	In progress
Dearomatization of synthetic crude	University of Ottawa	J. Kriz	In progress
Development of metal cluster catalyst for conversion of middle distillate fractions of synthetic fuels	University of Toronto	M. Wilson	In progress
The degradation study of metals-tolerant fluid catalytic cracking catalyst by molecular probes	Petro-Canada Inc.	S. Ng	In progress
Preparation and catalytic activity of supported group V B and VI B metal clusters	University of Calgary	C. Fairbridge	In progress
Experimental evaluation of catalyst deactivation caused by asphaltene adsorption	New Grade Energy Inc.	M. Sekhar	Under negotiation
Characterization of tin catalysts by Mossbauer spectroscopy	Concordia University	J. Monnier	Completed
Catalytic hydrocracking of heavy oils in a layered fixed bed	New Grade Energy Inc.	J. Kriz	Under negotiation
Development and evaluation of catalysts for hydrogenation of raw Cold Lake pitch	Guelph Chemical Laboratories Ltd.	M. Ternan	In progress
The separation of saturates and aromatics from syncrude middle distillate	Petro-Canada Inc.	S. Coulombe	In progress

Contract title	Contractor	Scientific authority	Status
The compositional study of nitrogen and oxgen compounds in products of heavy oil primary and secondary upgrading processes	Petro-Canada Inc.	S. Coulombe	Completed
Reverse osmosis separation of model compounds in heptane and toluene solutions	Zenon Environmental Inc.	B. Farnand	In progress
Selective identification of olefins and paraffins in middle distillates of synthetic crude oils	Petro-Canada Inc.	S. Coulombe	In progress
The investigation of the supercritical extraction of sulphurous and nitrogenous components from synthetic crudes	Technitrol Canada Ltd.	H. Sawatzky	Completed
Analytical methods development and characterization requirements for projects on resource characterization	Alberta Research Council	R. Lafleur	In progress
A study into the separation of nitrogenous materials from naphtha fractions	The Cambrian Engineering Group Ltd.	G. Jean	In progress
Treatment of synthetic crudes with metal chlorides and metal carbonyls	Petro-Canada Inc.	H. Sawatzky	Completed
Segregation of problematic components in synthetic hydrocarbon fuel fraction using membrane separation technologies such as reverse osmosis	Memtek Corporation	B. Farnand	Stopped
Adsorption of nitrogen compounds	Laval University	G. Jean	In progress
Exploratory investigation of low pressure rotating dynamic membrane process for treating bitumen/water/mineral emulsions	SNC Inc.	B. Farnand	Completed
Quality and applications of asphalt derived from upgraded heavy crude	Esso Petroleum Canada	H. Sawatzky	In progress

Contract title	Contractor	Scientific authority	Status
Selective extraction of nitrogen constituents from fluid catalytic cracking feedstocks	Petro-Canada Inc.	H. Sawatzky	In progress
Processability and reactivity of heavy ends	Petro-Canada Inc.		In progress
Membrane processing of oil field produced water for enhanced oil recovery (EOR) steam generation	Zenon Environmental Inc.	B. Farnand	In progress
The effect of nitrogenous concentrates from synthetic crude on asphalt blends	Petro-Canada Inc.	H. Sawatzky	Completed
Detailed study of the influence of experimental conditions on retention time in size exclusion chromatography of bitumens/heavy oils/asphaltenes	RFP	S. Coulombe	Under negotiation
Separation of sulphurous components in synthetic crude fraction	Geotechnical Resources Ltd.	P. Chantal	In progress
Separation and characterization of surfactants present in emulsions in enhanced recovery process	C.A. Shook Consulting Ltd.	H. Sawatzky S. Coulombe	Under negotiation
Reverse osmosis separation of methanol from ethers and unreacted olefins	Zenon Environmental Inc.	B. Farnand	Under negotiation
A techno-economic evaluation of conventional, synthetic and oxygenated gasoline blending components	Petro-Canada Inc.	H. Sawatzky	In progress
Development of a process for treating oil-water-mineral emulsions from in-situ recovery operations	Zenon Environmental Inc.	H. Sawatzky	In progress
Processing studies of bitumens/heavy oils produced by recovery methods of diverse nature	Saskatchewan Research Council	H. Sawatzky	Under negotiation

Contract title	Contractor	Scientific authority	Status
Gaz de synthése/essence synthétique	Centre de Recherche Industrielle du Quebéc	G. Jean	Completed
Conversion du methane en essence automobile par réaction d'une cathode creuse	University of Quebec at Chicoutimi	V. Allenger	Completed
Technical and economic assessment of producing distillate fuels via an electricity based acetylene process - Phase II	SNC Inc.	D. Fung	Completed
Direct production of gasoline range hydrocarbons from synthesis gas in a dual bed reactor system	University of Saskatchewan	S. Ng.	Completed
Direct partial oxidation of methane to methanol over designed heteropoly catalysts	University of Waterloo	J. Brown	In progress
Conversion of methane over selected solid catalysts	Petro-Canada Inc.	V. Allenger	In progress
Product optimization of the direct conversion process of natural gas to methanol by controlled oxidation	University of Manitoba	D. Fung	In progress
Development and characterization of selected synthesis catalysts	University of Saskatchewan	J. Galuszka	Completed
Direct catalytic conversion of natural gas to higher hydrocarbons	British Columbia Research Council	J. Galuszka	Terminated
Project Gasolsyn	Concordia University	G. Jean	In progress
Investigation of process conditions for the synthesis of liquid distillates from light olefins and methanol	Petro-Canada Inc.	B. Farnand	In progress

Contract title	Contractor	Scientific authority	Status
Thermally coupled pressure swing adsorption for natural gas conversion to liquid fuels	Highquest Engineering Inc.	D. Liu	In progress
Conversion of methane into methanol using methanotrophs	Gemini Biochemical Research Ltd.	D. Fung	In progress
Catalytic conversion of natural gas to hydrocarbons	FE to NRC	F. Ng	Completed
Methane conversion using a hollow cathode	University of Quebec	G. Jean	Under negotiation
Gasification of oil sands coke	University of British Columbia	D. Fung	Completed
Conversion of coal rejects to liquid fuel via indirect liquefaction	Westar Mining Ltd.	E. Furimsky	Completed
Gasification reactivities of ultrasonically treated coal rejects	Carleton University	B. Nandi	Completed
Upgrading of Nova Scotia oil shales for potential uses	Technical University of Nova Scotia	L. Janke	Completed
Evaluation of processing options for the oil shales of Ontario	Watts, Griffis and McOuat Ltd.	M. Skubnik	Completed
Modification of integrated oil shale retort system	Research and Productivity Council, N.B.	E. Furimsky	Completed
Hot gas clean up of gasification products	University of British Columbia	A. Palmer	In progress
Entrained gasification of Syncrude coke	Texaco Inc.	E. Furimsky	Completed
Gasification of Canadian anthracite coal in fluidized bed reactor	University of British Columbia	D. Fung	In progress

Contract title	Contractor	Scientific authority	Status
Preparation of oil sand coke-water slurry for entrained bed gasifier	Carleton University	A. Palmer	In progress
Process evaluation of an integrated retorting co-combustion system	Monenco Consultants Ltd.	E. Furimsky	In progress
Pyrolysis of New Brunswick oil shale and coal in fluidized bed reactor	Research and Productivity Council	A. Palmer	Under negotiation
Hydrotreating of liquids derived from New Brunswick oil shale deposits	RFP	M. Sekhar	Under negotiation
Wet oxidation from in-situ oil recovery - Phase I	Ontario Research Foundation	D. Faurschou	Completed
Steam injection experiments in a scaled physical model	University of Alberta	D. Faurschou	Completed
Numerical simulation of steam injection in bitumen and heavy oil reservoirs: Phase I - Development of methodology for a 2-dimension dynamic grid simulator	University of Toronto	D. Faurschou	Completed
Influence of the reservoir matrix on the mechanism and kinetics of the in-situ combustion process for heavy oil recovery	Gulf Canada Ltd.	D. Faurschou	Completed
The use of surfactant waterflooding as an enhanced recovery process for heavy oils	Gulf Canada Ltd.	D. Faurschou	Completed
Evaluation of steam additives and clay stabilizers for enhanced heavy oil recovery process	Gulf Canada Ltd.	A. George	In progress
Impact of drilling and completion fluids on the productivity of heavy oil recovery processes	Gulf Canada Ltd.	D. Faurschou	In progress

Contract title	Contractor	Scientific authority	Status
Steam injection experiments in scaled physical models for simulating marginal reservoirs	University of Alberta	A. George	In progress
Remote monitoring of frontal movements - EMR contribution	AOSTRA	D. Faurschou	Under negotiation
Fuel options for enhanced oil production	L.A. Smith & Assoc.	D. Faurschou	Completed
Numerical simulation of steam injection in bitumen and heavy oil reservoirs: Phase II - Development of methodology for a 3-dimension dynamic grid simulator	University of Toronto	D. Faurschou	Under negotiation
Steam recovery processes with addition of no-condensible gases - A mechanistic study	Geotechnical Resources Ltd.	D. Faurschou	Under negotiation
UMATAC process demonstration (AOSTRA-Industry demonstration - EMR contribution	AOSTRA	D. Faurschou	Under negotiation
Residence time distribution studies for scale-up of the CANMET hydrocracking process - Phase II	University of Waterloo	T. de Bruijn	In progress
Continuation de l'étude sur la nature de coke provenant des charbons rang peu élévé et des huiles lourdes	University of Sherbrooke	J.A. MacPhee	Completed
Kinetic studies of coke formation in hydrocarbon fractions of different bitumens under various conditions - Phase II	University of Ottawa	B. Nandi	Completed
High temperature EPR studies of the thermoloysis of heavy oil and its components	University of Guelph	F. Ng	In progress
Biological methods of upgrading of bitumen, heavy oil and residue	University of Waterloo	F. Ng	In progress

Contract title	Contractor	Scientific authority	Status
Preliminary feasibility study of a rapid pyrolysis process (Ultrapyrolysis) to produce ethylene, valuable chemical intermediates or high quality gas from CANMET hydrocracker bottoms and typical CANMET hydrocracker feedstock	Ensyn Engineerig Assoc. Inc.	P. Sears	In progress
Kinetic studies of coke formation in hydrocarbon fractions of different bitumens under various conditions, Phase III	University of Ottawa	B. Nandi	In progress
Dual energy gamma-ray densitometer	Atomic Energy of Canada Ltd.	D. Liu	Under negotiation
Investigation of the use of spherical agglomeration in the beneficiation of low rank Canadian coals as an integral part of direct liquefaction process	SNC Inc.	R. Mikula	Completed
A study of the liquefaction of Nova Scotia coals - Phase VI	N.S. Research Foundation Corp.	P. Rahimi	Completed
Continuation of the evaluation of Hat Creek coal for coal liquefaction	B.C. Research Council	S. Fouda	Completed
Techno-economic comparison of the Sandwell Centrax solid-liquid separation process with the Kerr McGee critical solvent deashing process as part of an integrated two-stage liquefaction process	The Mitre Corporation	J. Kelly/ M. Ikura	In progress
Characterization of solid residue from coal liquefaction processes	University of Regina	W. Dawson	Completed
Liquefaction studies of Nova Scotia coals - Phase VII	N.S. Research Foundation Corp.	P. Rahimi	In progress

Contract title	Contractor	Scientific authority	Status
Hydropyrolysis of Eastern Canadian coals	Ontario Research Foundation	M. Ikura	In progress
Critical evaluation of the hardware development for the Sandwell Centrax process	McMaster University	M. Ikura	Completed
Evaluation of the Sandwell Centrax process for the separation of solids and recovery of liquid products from ten different slurry samples	Sandwell Beak Research Group	S. Fouda	Completed
Investigation of the use of spherical agglomeration in the beneficiation of low rank Canadian coals as an integrated part of CANMET coprocessing process	SNC Inc.	M. Ikura	In progress
Techno-economic study of CANMET coprocessing technology	Partec Lavalin Inc.	M. Ikura/ J. Kelly	In progress
Evaluation of atmospheric flash pyrolysis of coprocessing residues	University of Waterloo	S. Fouda	In progress
To develop, design, construct and install a pilot plant electronic instrumentation system, Phase I	Monenco Consultants Ltd.	J. Chase	Under negotiation
To develop, design, construct and install a pilot palnt electronic instrumentation system, Phase II	RFP	J. Chase	Under negotiation
Beneficiation of low rank Canadian coals with heavy residua - Phase II	Gulf Canada Ltd.	D. Fung	Completed
Ion microscope studies of the oxidation of coal on a microscope scale, Phase III - Study of coal surfaces by SIMS	University of Western Ontario	J.A. MacPhee	Completed
To carry out cage tests in the coke ovens at Algoma Steel Corporation Limited	Algoma Steel Corp. Ltd.	J. Gransden	Completed

Contract title	Contractor	Scientific authority	Status
Potassium vapour impregnation of metallurgical coals	McMaster University	J. Price	In progress
Prediction of flow and temperature conditions in the CCRL drop furnace	University of Ottawa	P.M.J. Hughes	Completed
Performance prediction of the CCRL tunnel furnace for coal combustion	Imperial College of Science & Technology	H. Whaley	Completed
Scanning and transmission electron microscope studies of macerals and pore structure in coals of different rank	Ontario Research Foundation	K. Thambimuthu	Completed
Correlation of mineral, maceral and petrophysical characteristics of coal to beneficiation technology	Atlantic Coal Institute	C. Adams	In progress
Design and construction and commissioning of an apparatus for determination of sintering characteristics of coal ashes	PTL Research Ltd.	K. Thambimuthu	In progress
Evaluation of combustion options for anthracite utilization	Gulf Canada Ltd.	J. Wong	Completed
Mineral matter spatial distribution in coal as related to the suitability of micronizing techniques in coal combustion	Atlantic Coal Institute	J.A. MacPhee	Completed
Continued study on the characterization of coals using photoacoustic infrared Fourier transform spectroscopy and chemical transformation and derivation	St. Francis Xavier University	J.A. MacPhee	In progress
Develop a simulation model of the CFB Summerside fluidized bed combustor (FBC) steam heating plant	Queen's University	E.J. Anthony	Completed

Contract title	Contractor	Scientific authority	Status
Combustion testing of ceramic coal-water fuel (CWF) atomizers in unit No. 1, Chatham, N.B. generating station	N.B. Electric Power Commission	H. Whaley	In progress
Testing ceramic nozzles at Chatham, N.B. generating station	FE to NRC	C. Adams	Completed
Combustion tests of dense coal CWF in a small tunnel furnace	Technical University of N.S.	K. Thambimuthu	In progress
Coal water fuel conversion and combustion testing in an industrial iron ore pelletizing furnace	Iron Ore Company of Canada	K. Thambimuthu	In progress
To monitor performance testing for low nitrogen and sulphur oxides retrofit burners at Canadian Forces Base, Gagetown, New Brunswick	G.A. Robb Associates	G.K. Lee	Completed
Stage combustion parameters for Atlantic coals	N.B. Electric Power Commission	G.K. Lee	In progress
Trace constituents program	FE to Environment Canada	C. Adams	Completed
IEA Coal combustion science, Annex II	ECN, Holland	H. Whaley	In progress
Demonstration for in-furnace reduction of SO_x and NO_x in tangential-fired boilers	Canadian Electrical Association	G.K. Lee	In progress
Study to investigate furnace system design options to improve operational efficiency of residential gas furnaces, Phase IV, Plastic heat exchanger	Consumers Gas Co.	A.C.S. Hayden	Completed
Development of a high efficiency oil-fired warm air furnace and domestic water heater	Clare Brothers Ltd.	A.C.S. Hayden	In progress

Contract title	Contractor	Scientific authority	Status
To update, produce and publish combustion handbook for Canadian fuels	Canadian Institute of Energy	A.C.S. Hayden	Completed
Study proposal for ENERSOLVE demonstration project	Neill and Gunter Ltd.	A.C.S. Hayden	Completed
Pre-engineering assessment of ENERSOLVE demonstration project in a foundry	Kent Engineering Ltd.	A.C.S. Hayden	Completed
Pre-engineering assessment of ENERSOLVE demonstration project in a foundry	Hatch Associates Ltd.	A.C.S. Hayden	Completed
Pre-engineering assessment of ENERSOLVE demonstration project - IPSCO	Keen Engineering Co. Ltd.	A.C.S. Hayden	Completed
Pre-engineering assessment of ENERSOLVE demonstration project	SNC Inc.	A.C.S. Hayden	Completed
A retrofit package for gas-fired furnaces, Phase III	Clare Brothers Ltd.	A.C.S. Hayden	Completed
Evaluation of the potential for the application of flue gas condensing systems to industrial boilers	Kent Engineering Ltd.	A.C.S. Hayden	Completed
Evaluation of the potential for the application of flue gas condensing systems to industrial boilers	SNC Inc.	A.C.S. Hayden	Completed
Development of method suitable for petroleum refinery use to determine aromatics in heating oils and diesel fuels	Chemex Labs Alberta (1984) Ltd.	S.W. Lee	In progress
Development of gas-fired domestic water heater	Eneroil Research Ltd.	F. Preto	In progress
Prototyping and testing the retrofit of residential gas-fired furnaces with induced draft fans	The Conserver Group Inc.	F. Preto	In progress

Contract title	Contractor	Scientific authority	Status
Development of vertical heat exchanges for ground source heat pumps	NRC/Division of Building Research	M. Wiggin	In progress
Development of design data for mixed, non-azeotropic refrigerants	Centre de research industrielle du Québec	M. Wiggin	In progress
Development of heat pump controls and design data for industrial high temperature heat pumps	NRC/Division of Mechanical Engineering	M. Wiggin	In progress
Realistic potential of district heating in Canada	Monenco Consultants Ltd.	M. Wiggin	Completed
Comparative analysis of hot water and steam for district heating distribution systems	RFP	M. Wiggin	Under negotiation
Technical feasibility study for a steam generating heat pump	J.H. Lock & Sons	M. Wiggin	Completed
Evaluation of a chemical heat pump for application in the petro-chemical industry	Stearns Catalytic Ltd.	M. Wiggin	In progress
Heat pump evaluation for heat recovery from sewage effluents and raw sewage	Boulianne, Dauphinais Desgagné Assoc.	M. Wiggin	Under negotiation
Evaluation of low-cost distibution system technology for Canada (on behalf of AECL)	CDHC	M. Wiggin	Completed
Feasibility study for industrial ventilation air heat recovery using heat pumps	Enermodal Engineering	M. Wiggin	In progress
To evaluate and improve the accuracy and efficiency of emission ratings of central chunk wood fired warm air heating systems	Centre de research industrielle du Québec	R. Braaten	Completed

Contract title	Contractor	Scientific authority	Status
Measurement of burning rate of Suncor coke in a circulating fluidized bed combustor	Technical University of N.S.	E.J. Anthony	Terminated
Combustion, sulphur neutralization and vanadium balance tests with syncrude coke and Fort McMurray limestone in a pilot scale atmospheric recirculating fluidized bed combustor	Polymath Energy Consultants Ltd.	D. Desai	In progress
A program of pilot plant-scale R&D on bubbling bed atmospheric fluidized bed combustion	Queen's University	E.J. Anthony	In progress
Gas sampling at Tupper AFBC facility	University of New Brunswick	E.J. Anthony	Completed
Engineering evaluation of fluidized bed boiler demonstration plant at CFB Summerside, P.E.I.	RFP	F. Friedrich	Under negotiation
Coal-water fuel derating assessment for the front wall-fired oil design boiler No. 10 Maritime Electric Company, Charlottetown, P.E.I.	Babcock and Wilcox Canada Ltd.	H. Whaley	Completed
An assessment of potential coal-water slurry atomizers and burners	Ralph Grossman, Consultant	H. Whaley	In progress
Industrial scale testing of coal/water slurries in Canada Cement Lafarge's Richmond wet process cement kiln	Canada Cement Lafarge Ltd.	H. Whaley	In progress
Combustion and performance testing of coal/water fuel at the Chatham, N.B. generating station	N.B. Electric Power Commission	H. Whaley	Completed

RESEARCH AGREEMENTS

University	Title	Funds awarded ($)	Contact officer
British Columbia	Coke texture and properties	12 000	J.T. Price
British Columbia	Heat transfer from circulating beds	10 000	E.J. Anthony
Sherbrooke	Asphaltenes: Structure et réactivité	12 000	M.A. Poirier
St. Francis Xavier	Detection/quantitation by photoacoustic FTIR spectroscopy of changes in oxygen functions of coals under mild thermolysis	10 000	J.A. MacPhee
Alberta	Optimized microprocessor control of heat pump/heat storage systems	10 000	A.C.S. Hayden
Alberta	Pressurized core sampler for oil sands and heavy oil formations	7 500	D. Faurschou
Queen's	Microwave induced metal hydride catalytic hydrogenation and hydrocracking of bitumen	12 000	J.F. Kriz
École Polytechnique	Stockage de l'hydrogéne à l'aide d'hydrocarbures cycloparaffiniques	11 500	S. Coulombe
St. Mary's	Phase change salts for thermal storage	10 400	M. Wiggin

COST RECOVERY WORK - (NON-ROUTINE)

Job. No.	Company/Project	Cost ($K)	% Recovery
024330	New Brunswick Electric Power Commission Fuels Evaluation for province of New Brunswick	18	100%
025401	Cape Breton Development Corporation Combustion Evaluation of Raw and Clean CBDC Donkin Coal: Harbour Seam	52.2	67%
025402	Quinsam Coal Ltd. Evaluation of combustion, slagging and fouling properties of raw and washed coal from Quinsam Coal Property on Vancouver Island, B.C.	40.5	67%

COST RECOVERY WORK - (ROUTINE - INCLUDES EXCHANGE ANALYSES)

AMAX Coal Co.

Bioshell Plants:
- Lac Mégantic
- Hearst, Ont.
- Iroquois Falls

Canadian Interlaboratory Round Robin
Commercia Testing and Engineering
Department of National Defence - Coal evaluation; petroleum fuels analysis
Environment Canada - Wastewater Technology Centre
Fuels Engineering of New York
New Brunswick Electric Power Commission
National Research Council - Fuels and Lubricants Laboratory
Ontario Ministry of Natural Resources - Petroleum
Ontario Ministry of Transportation
Others (DPW, Univ. of Ottawa, CCA, DVA, Private Companies)
Standard Laboratories

TOTAL VALUE = $66K

APPENDIX E

CONTACTS, MEETINGS, FIELD TRIPS, AND JOINT CONSULTATIONS

CONTACTS, MEETINGS AND FIELD TRIPS

ERL continued its leadership role in research into fossil fuel technology, energy conversion and energy conservation. As a leading research organization it is necessary to maintain external contacts with other research organizations for technology transfer and exchange of information related to its research programs. In this connection the first CANMET Oil and Gas Conversion Contractors' Review Meeting was held in Toronto, November 20-22, 1985. The meeting was organized to aid the transfer of technology and ideas generated within the contract R&D program, and to provide a forum of exchange among government, industry, para-public organizations and the university community interested in new and emerging technologies related to oil and gas conversion. The meeting was attended by 158 delegates from Canada, U.S., France and Finland. Five sessions were held on: recovery of bitumen and heavy oil; processing of bitumen, heavy oil and oil shale; distillate processing; liquid fuels from natural gas; and combustion and utilization of petroleum residues.

ERL scientists were active in 46 conferences across the continent and in other parts of the world at a cost of approximately $63 000. A total of 89 technical papers were presented, 34 publications were contributed to learned journals as indicated in Appendix B and 30 confidential reports were prepared.

During 1985/86 ERL hosted visits by scientific and technical personnel from many parts of the world, as well as conducting numerous tours of its facilities.

The research agreements and contracts awarded to industry, private consultants, and universities continued to grow necessitating continued technical supervision and travel by staff. In addition to consultations related to the contracts in Appendix D of this report, many visits were made to discuss and evaluate new proposals or to make preliminary plans for contract work in the next fiscal year. The development of the CANMET shared-cost energy conversion program, for example, required extensive contact by ERL technical and scientific staff.

On an individual basis, ERL scientists engage in external consultations through their membership in technical committees as indicated in Appendix C. Substantial contributions were made to standardization organizations such as ISO, CSA, and ASTM. The committees of these organizations include representatives from public and private sectors as well as from academic institutions.

ERL remains in the forefront of energy research and cooperates with others through the exchange of information and granting programs to private industry and universities. The expenses incurred by staff members at the Bells Corners Complex in carrying out 417 field trips related to these activities approached $280 000.

JOINT PROVINCIAL/INDUSTRY/FEDERAL/INTERNATIONAL CONSULTATIONS

PROVINCIAL

Alberta Energy and Natural Resources
Alberta Office of Coal Research and Technology
Alberta Oil Sands Technology and Research Authority (AOSTRA)
Alberta Research Council
B.C. Hydro
Centre de recherche industrielle du Québec
New Brunswick Electric Power Commission
New Brunswick Research and Productivity Council
Nova Scotia Mines and Energy
Ontario Hydro, Toronto
Ontario Research Foundation
Ontario Ministry of Energy
Ontario Ministry of Natural Resources
Saskatchewan Commercial Affairs
Saskatchewan Energy and Mines
Saskatchewan Power Corporation
Saskatchewan Research Council
Technical University of Nova Scotia

INDUSTRY

Alberta Energy Company, Calgary
Alcan, Kingston
Algoma Steel Corp.
Babcock and Wilcox Canada, Cambridge, Ontario
Bantrel Group
B.C. Research, Vancouver
Bomen Construction Company, Calgary
B.P. Canada Inc., Calgary
Canadian Boiler Society
Canadian Carbonization Research Association
Canadian Coal Liquefaction Corporation
Canadian Electrical Association
Canadian Gas Association
Canadian Occidental Petroleum Limited
Canadian Utilities Ltd.
CANSTAR Oil Sands Ltd., Calgary
Canterra Energy Ltd.
Cape Breton Development Corporation
Catco, Montreal
Crows Nest Resources, Calgary
Denison Mines, Vancouver
Domtar
Ensyn Engineering Associates, Ottawa
Esso Resources, Calgary
Foster Wheeler Canada
Gemini Biochemical Research Ltd., Calgary

INDUSTRY (cont'd)

Global Thermo Electric, Calgary
G.T. Page Consulting Ltd.
Gulf Canada Ltd.
Haider Mirza Catalyst Services, Point Edward, Ontario
Harrison Saturn Joint Venture (SMC) Ltd., Edmonton
Heuristic Engineering Incorporated, Vancouver
Idea Corporation
INCO Metals, Toronto
Industrial Membrane Research Corporation, Nepean
Luscar Ltd., Edmonton
Luscar-Sterco Coal Company
Manalta Coal Ltd., Calgary
Memteck, Nepean
McIntyre Mines, Calgary
McTarr Petroleum, Vancouver
Murphy Oil, Calgary
Nickel Development Institute, Toronto
Northern Reactor Gasification, Calgary
Norwest Consultants, Calgary
Obed Mining Company, Alberta
Ontario Natural Gas Association
Pentum Company, Springhill, Nova Scotia
Petro Canada
Resorption Canada Ltd., Ottawa
Sandwell Beak Research Group, Mississauga, Ontario
Shawinigan Integ, Vancouver
SNC Inc., Montreal
Stelco Inc., Toronto
Stone Webster Canada
Suncor Ltd., Alberta
Syncrude, Edmonton
TransAlta Utilities Corporation, Alberta
Transyt Canada Inc., Toronto
UMATAC
Volcano Inc., St. Hyacinthe, Québec
Westar Resources
Zenon Environmental Inc., Burlington

FEDERAL

Canadian General Standards Board
Consumer and Corporate Affairs
Department of National Defence
Department of Regional Industrial Expansion
Environment Canada
External Affairs
International Development and Research Centre
Ministry of State for Science and Technology

FEDERAL (cont'd)

National Research Council
Parks Canada
Revenue Canada
Supply and Services Canada

INTERNATIONAL

UNITED STATES

Air Products and Chemicals, Inc., Allentown, PA.
Amax Coal Co. Ltd., Evansville, Indiana
American Society for Testing and Materials
Argonne National Laboratory, Illinois
Atlantic Richfield, California
Battelle Columbus Laboratories, Columbus, Ohio
Coalition of Northeast Governors
Core Laboratories, Denver, Colorado
Ebon Research Systems, Washington, D.C.
Foster Wheeler
Institute of Gas Technology, Chicago, Illinois
Rockwell Corporation, Los Angeles, California
Southern Research Institute, Birmingham, Alabama
Standard Laboratories, West Virginia
Steven Winter Associates, New York
Sun Oil Company, Philadelphia
U.S. Army Corps of Engineers
U.S. Department of Energy
U.S. Environmental Protection Agency
Wyoming Analytical Laboratories, Denver, Colorado
ZN Inc., Sharon, Connecticut

OTHERS

Babcock Power, London, England
Beijing Research Institute of Coal Chemistry, China
EBARA Corporation, Tokyo, Japan
Elkraft Power Co., Copenhagen, Denmark
Essence et Lubrifiant Française (ELF), France
Gaz de France
Hunan Coal Preparation Research Institute, China
International Energy Agency
ISO Central Secretariat, Geneva, Switzerland
Japan Iron and Steel (NKK), Kawasaki, Japan
Japan Organo Co. Ltd., Japan
Ministry of Coal Industry, China
National Research Institute for Pollution Resources, Japan
Nippon Steel Corporation, Japan
Technical Research Centre, Finland