SUMMARIES OF CANMET ENERGY RESEARCH CONTRACTS 1984-1985

COMPILED BY T.P. LANZER

RESEARCH PROGRAM OFFICE
CANMET REPORT 86-1E

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FOREWORD

This report summarizes energy-related R & D contracts that were sponsored by CANMET and completed in the years 1984 and 1985. The summaries were prepared to assist in transferring to industry the new technology created through CANMET's extensive contracting-out program. The value of energy-related R & D that was contracted-out in 1984 and 1985 exceeded $22.0 million. Energy contracts completed prior to 1984 were summarized previously in CANMET Reports 78-1, 79-26, 82-11, and 83-11.

Final reports for the contracts outlined in these summaries are available through the Technology Information Division, Canada Centre for Mineral and Energy Technology (CANMET), Department of Energy, Mines and Resources, 562 Booth Street, Ottawa, Ontario, K1A 0G1. Telephone: (613) 995-4029, Telex: 053-3395.

The CANMET Research Program Office is grateful to Tom Lanzer for diligently assembling this report.

I.C.G. Ogle
Director
Research Program Office

AVANT-PROPOS

Le présent rapport présente le bilan des contrats de R-D dans le domaine de l'énergie qui ont été parrainés par CANMET et menés à terme en 1984 et 1985. Les résumés ont été préparés dans le but de favoriser le transfert à l'industrie des nouvelles techniques qui ont été mises au point dans le cadre du vaste programme d'impartition du CANMET. La valeur des contrats de R-D accordés en 1984 et 1985 a dépassé 22 millions de dollars. Les contrats ayant trait à l'énergie achevés avant 1984 sont résumés dans les rapports du CANMET suivants 78-1, 79-26, 82-11, et 83-11.

Les rapports finals concernant les contrats mentionnés dans les résumés peuvent être obtenus à l'adresse suivante: Division de l'information technologique, Centre canadien de la technologie des minéraux et de l'énergie (CANMET), ministère de l'Énergie, des mines et des Ressources, 562, rue Booth, Ottawa (Ontario) K1A 0G1. Téléphone: (613) 995-4029; TÉLEX: 053-3395.

Le Bureau du programme de recherche du CANMET tient à remercier Tom Lanzer qui a fait diligence pour rassembler les éléments de ce rapport.

I.C.G. Ogle
Directeur
Bureau du programme de recherche

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ENERGY TECHNOLOGY

CONSERVATION

TITLE: HIGH EFFICIENCY RESIDENTIAL GAS FURNACE

CONTRACTOR:	Hiram Walker - Consumers' Gas Company Ltd.	FILE NUMBER:	0-9148	FUNDING	
		BEGIN/END:	March 81/Oct. 81		
				CANMET:	$ 32 323
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.S.C. Hayden	TECHNOLOGY:	Residential Heating Systems	TOTAL:	$ 32 323

OBJECTIVES

Examine potential new designs to achieve efficiency gains in residential gas furnaces.

PROCEDURE

Model potential techniques for achieving high efficiency and propose designs that appear most likely to achieve gains at minimum cost.

RESULTS

Two new designs for high-efficiency furnaces are presented:

1. Air-based; using a low-temperature counterflow plastic heat exchanger with recirculation, which offers high efficiency of condensation at minimal cost.
2. Hydronic combination unit; giving both space and service water heating in the same appliance. The space-heating system can be either used directly in a hydronic system or, with the addition of a fin coil, in a warm air system.

APPLICATION AND ONGOING WORK

As a result of this project, two subsequent contracts have been issued to Spider Engineering and to Consumers' Gas to produce working prototypes of the air-based and water-based designs. Both units are now undergoing experimentation at CCRL.

SUPPORTING DOCUMENTS

Final Report: "Conceptual Designs of High Efficiency Residential Gas Furnaces", by Spider Engineering, November 1981.

TITLE: FURNACE SYSTEM DESIGN OPTIONS TO IMPROVE OPERATIONAL EFFICIENCY OF RESIDENTIAL GAS FURNACES - PHASE 2

CONTRACTOR:	Consumers' Gas Company	FILE NUMBER:	I-9108	FUNDING	
		BEGIN/END:	March 82/Oct 82		
				CANMET:	$ 90 580
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	Dr. A.C.S. Hayden	TECHNOLOGY:	Residential Heating Systems	TOTAL:	$ 90 580

OBJECTIVES

Design and produce a high efficiency residential gas furnace, using plastics for the condensing section.

PROCEDURE

Using existing manufactured plastics (coroplast), in the form of a cross-flow sandwich-type heat exchanger and a novel flue gas recirculation loop to control the incoming temperature to the plastic condensing section, produce three working prototypes of this furnace, for detailed testing by the scientific authority.

RESULTS

Three prototype furnaces have been produced and delivered to the scientific authority where they are undergoing cycling tests to determine potential longevity problems. An additional contract has been issued to examine the optimum plastic materials for such an arrangement on a commercial basis.

APPLICATION AND ONGOING WORK

Potential use for this material is high for two reasons:

1. Plastic is much cheaper than the stainless steel now being used in condensing furnaces.

2. The plastic is more resistant to corrosion attack than the 300 series stainless, particularly to the emerging issue of chlorides.

SUPPORTING DOCUMENTS

Final Report: "Prototype High Efficiency Furnace Development", by Spider Engineering Associates, February 1983.

TITLE: RETROFIT PACKAGE FOR GAS-FIRED FURNACES - PHASE 2

CONTRACTOR: Clare Brothers Ltd.	FILE NUMBER: I-9109	FUNDING	
	BEGIN/END: Aug. 82/March 84		
		CANMET:	$ 80 785
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: A.C.S. Hayden	TECHNOLOGY: Residential Heating Systems	TOTAL:	$ 80 785

OBJECTIVES

Carry out a field demonstration of retrofit condensing heat exchangers fitted to conventional gas furnaces in lived-in homes.

Carry out modifications to specific components of the retrofit condensing heat exchangers developed under Phase I.

Carry out specific furnace measurements on-site.

PROCEDURE

1. Obtain approvals for specific field installations.
2. Carry out the installations and monitor the performance on same.
3. Carry out modifications of specific components developed in Phase I, in particular, the induced draft fan.
4. Carry out efficiency and condensate measurements on-site.
5. Fabricate and monitor two additional units with the improved design feature.

RESULTS

The field trial has resulted in equipment that can be retrofitted to existing domestic gas furnaces to improve the seasonal efficiency from 60% to nearly 90%, with a fuel saving of 25-35%. The reliability of the equipment has been demonstrated to the extent that the American Gas Association has approved sale of the equipment in the United States.

APPLICATION AND ONGOING WORK

The potential for efficiency improvement of existing residential gas furnaces is high using this technology. The contractor is now in the process of marketing same in the United States. In order to demonstrate to the more cautious Canadian regulatory authorities that the equipment is reliable and indeed, safer than the existing furnace on its own, a further field trial is being carried on during the 1984-85 heating season.

TITLE: THERMAL PERFORMANCE CHARACTERISTICS OF COMMERCIAL PREFABRICATED METAL CHIMNEYS FOR USE WITH OIL, WOOD AND GAS FURNACES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	2-9116	FUNDING	
		BEGIN/END:	Sept. 82/Oct. 83		
				CANMET:	$ 61 064
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	R.W. Braaten	TECHNOLOGY:	Residential Heating Systems	TOTAL:	$ 61 064

OBJECTIVES

Characterize temperature profiles of a range of prefabricated chimneys of various types under simulated typical operating conditions. This would provide basic information on chimney performance to assist in solving problems with chimneys that appear to be increasing with the use of higher efficiency equipment and alternate energy forms.

PROCEDURE

Chimney sections representing a range of chimney types - A, B, L, and 650 - and a variety of manufacturers were installed in an insulated outer shell that allowed cooled air to be passed over the outside of the chimney. Temperature profiles were obtained at various elevations along the chimney for flue gas, inner skin, and outer skin temperature.

RESULTS

Performance profiles for various chimneys are presented in the final report. In general, they verify that the chimneys perform as expected for each type, though there was one chimney model shown to have a performance that would be unacceptable under some operating conditions.

APPLICATION AND ONGOING WORK

Serves as basic information in deciding how to solve specific chimney problems as they arise.

TITLE: STUDY OF THERMAL STORAGE SYSTEMS

CONTRACTOR: University of Toronto	FILE NUMBER: I-9050	FUNDING	
	BEGIN/END: Nov. 81/March 82		
		CANMET:	$ 4 510
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: V.V. Mirkovich	TECHNOLOGY: Residential Heating Systems	TOTAL:	$ 4 510

OBJECTIVES

Provide an overview of thermal energy storage activities in Canada against the background of current world levels of thermal storage use.

PROCEDURE

Literature survey and interviews with scientists involved in this field at the National Research Council in Ottawa, Sandia Laboratories in Albuquerque, New Mexico, and at other institutes.

RESULTS

The required overview was obtained.

TITLE: ENERGY CONSERVATION IN INDUSTRIAL MINERALS PROCESSING

CONTRACTOR:	Canada Cement Lafarge Ltd.	FILE NUMBER:	2-9016	FUNDING	
		BEGIN/END:	Jan. 83/Dec. 84		
				CANMET:	$ 662 166
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	E. Joe	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 662 166

OBJECTIVES

1. Determine electrical energy consumption in comminution of industrial minerals in Canada for cement, asbestos, potash, silicon, nepheline syenite, lime, limestone, talc, mica, and gypsum.

2. Investigate on-line analysis method for fine particle sizing.

3. Develop a plan for pilot-scale testing for energy savings in comminution.

PROCEDURE

1. Measure actual power consumed in 10 operating plants and sample products to measure grinding efficiency.

2. Investigate Sedigraph, Microtrac, and other sizing apparatus for use in on-line testing.

3. Visit industrial pilot plants in Canada and U.S.A. that have comminution testing facilities.

RESULTS

1. Cement, asbestos, and limestone are the highest total energy consumers. Very finely ground products consumed the greatest amount of electrical energy and have the greatest potential for energy savings. Work on screening may aid energy efficiency in comminution. New grinding mills should be tested, i.e., Tower Mill, Attrition Mills.

2. Microtrac provided rapid on-line size analysis but more work is required to adapt to dry mode.

3. Pilot-scale test work should be carried out at several locations for the sake of economic effectiveness.

TITLE: ENERGY CONSERVATION BY CHEMICAL COMMINUTION OF ASBESTOS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9009	FUNDING	
		BEGIN/END:	April 83/Aug. 83	CANMET:	$ 35 532
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	G.W. Riley	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 35 532

OBJECTIVES

Assess the energy conservation potential of the chemical comminution technique for the beneficiation and recovery of fibre from Canadian asbestos mineral deposits.

PROCEDURE

Investigations were carried out to compare only the comminution steps of the conventional dry and wet processes with regard to energy consumption, fibre yield, and quality by processing a Canadian ore on a small batch pilot-plant scale. Operational parameters such as concentration and type of surfactant, as well as different comminution or separation techniques, have also been examined. The fibres produced by these processing methods were evaluated by conventional test methods used by the asbestos industry, as well as by a variety of analytical techniques.

RESULTS

Results of the investigations indicated:

1. Significant energy savings are observed for wet comminution of asbestos as compared to dry comminution.
2. Fibre yield is increased significantly by employing ballmilling with a surfactant.
3. Ballmilling tends to shorten the fibre (i.e., reduce the length).
4. The use of surface active agents may have a detrimental effect on fibre properties.
5. Multiple fibre grades may be produced by wet screening or classification.

APPLICATION AND ONGOING WORK

Work is continuing to include fibre separation steps.

Cassiar Asbestos Mines has indicated interest in the wet process to treat their tailings.

TITLE: ENERGY CONSERVATION IN CERAMIC GIFTWARE USING CANADIAN MINERALS AND RAW MATERIALS

				FUNDING	
CONTRACTOR:	Blue Mountain Pottery Limited	FILE NUMBER:	3-9012		
		BEGIN/END:	April 83/Aug. 83		
				CANMET:	$ 30 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	K.E. Bell	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 30 000

OBJECTIVES

On a laboratory scale, modify existing earthenware bodies for artware and dinnerware through additions/substitutions of Canadian mineral raw materials to obtain formulations suited for decoration by low-temperature decalcomania and once-firing. (Desired maturation temperature 750-850°C, single-fire vs current 2-fire practice.)

PROCEDURE

A variety of body fluxes were examined, singly and in combination - including fly ash, silica fume, nepheline syenite, spodumene, petalite, iron oxide, glass cullet, a commercial glass frit, and zinc and titanium oxides. Bodies with poor plastic properties were rejected, and the others were examined by temperature gradient method to establish the optimum firing temperatures for single firing. Fired strengths and absorptions were determined.

Decals were applied to the more promising bodies and single-fired. A plant trial was performed, in which decals were applied to slip-cast pieces and single-fired.

RESULTS

Additions of 20 wt % successfully reduced maturation temperatures for once-fired ware below 850°C. Additions of TiO_2 and/or ZnO altered the fired colour from red to light buff. Blue Mountain sees this serendipitous development as the basis for a complete new line of "terra cotta" products - unglazed ware decorated solely by decalcomania.

Adherence of some of the decals was not satisfactory - the supplier can provide decals with a higher glass content, which should solve the problem. Decals applied over a thin sprayed clear glaze and single-fired gave acceptable adhesion and appearance.

APPLICATION AND ONGOING WORK

Blue Mountain sees the results as the basis for a new and unique product line. They anticipate markets in Southwest U.S.A. and Japan, where the natural appearance of the ware complements the existing lifestyle, and markets have been identified. They plan to seek further government assistance in aid of implementing plant-scale production.

TITLE: STUDY OF THE OPTIMUM CONTROL AND CONSERVATION OF ENERGY IN THE CRYSTALLIZATION, DRYING AND COOLING OF POTASH

CONTRACTOR: Kilborn (Saskatchewan) Ltd.	FILE NUMBER: 2-9172	FUNDING	
	BEGIN/END: Dec. 82/June 83		
		CANMET:	$ 25 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: G.W. Riley	TECHNOLOGY: Energy Conservation in Industrial Processes	TOTAL:	$ 25 000

OBJECTIVES

1. Survey the problems of crystallizer control throughout the Saskatchewan potash industry in order to determine the development objectives of the industry.
2. Select an appropriate circuit for demonstration of the technology to improve operation of this circuit.
3. Develop a general control strategy in conceptual/analytical form.
4. Outline a program for further work.

PROCEDURE

The first stage of the study was to research the experience of crystallizer operations throughout the Saskatchewan potash industry. Based upon these findings, attempts were made to improve the operational performance of one producing plant.

Central Canada Potash was selected as the target for the study because their circuit topology was the least complex and they had on-stream KCl analysis.

A control methodology was then to be developed that would lead to a computer-based on-line energy optimization model for general application to potash crystallization.

RESULTS

1. A method of mass energy balancing for a potash circuit was developed called Coherent Mass Energy Balancing (COMEBAL).
2. Coherent mass balancing provides a means for estimating the nucleation, growth rate, and supersaturation levels in a potash crystallizer, and hence a means of modelling and controlling the crystal growth process.
3. Indications are that the practice of introducing water to prevent NaCl precipitation may be excessive under current practice.
4. Crystallizer circuits require additional instrumentation in order to provide a clearer picture of "what is going on in the process".
5. The system needs to be refined and made more efficient computationally.
6. The application of this control methodology should be extended to other potash circuits such as dryer/cooler systems and to other industrial minerals other than potash.

TITLE: COMPUTER AIDED DATA ACQUISITION AND ANALYSIS SYSTEM FOR A CONDUCTION CALORIMETER

CONTRACTOR:	3rd Wave Engineering	FILE NUMBER:	4-9033	FUNDING	
		BEGIN/END:	April 84/May 84	CANMET:	$ 7 992
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	Dr. E. Douglas	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 7 992

OBJECTIVES

Automation of data acquisition and analysis for a conduction calorimeter measuring total heat developed and the rate of heat of hydration of portland cement/slag/fly ash/silica fume binders.

PROCEDURE

The experiment to measure the heat evolved during the hydration of hydraulic binders is programmed and controlled by a stand-alone device called Auto-Graph II. The data collected is transferred to an Apple II disk file. The designed software calculates the total heat of hydration by integration, the heat evolution rate by differentiation, and the rate of change in heat evolution by second differentiation. The results of these calculations as well as the experimental output, which are displayed on the screen in the form of graphs, can be printed on the Epson plotter.

RESULTS

An experiment was run with ordinary portland cement. The performance of the equipment as well as the software was satisfactory, yielding the required results and graphs.

TITLE: REVIEW OF THE INFLUENCE OF FLUORIDE-EMISSION CONTROL SYSTEMS ON THE ENERGY EFFICIENCY OF TUNNEL KILNS MANUFACTURING STRUCTURAL CLAY PRODUCTS

CONTRACTOR:	Clay Brick Association of Canada	FILE NUMBER:	2-9056	FUNDING	
		BEGIN/END:	Aug. 82/Jan. 83		
				CANMET:	$ 35 500
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	K.E. Bell	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 35 500

OBJECTIVES

The objective of this project is to address two aspects of the preliminary work required for the design of a co-ordinated industry-wide research effort on the subject of the relationship between fluoride emission control and the energy efficiency of brick tunnel kilns, namely:

1. Prepare a complete critical review and updated literature survey of the current state-of-the-art with respect to the following items:
   a) brick kiln energy efficiency;
   b) fluoride emission control technology;
   c) basic research on the thermochemistry of fluoride evolution from typical raw materials.
2. Based upon the above review, prepare a detailed research program in the form of work statements and cost estimates.

PROCEDURE

1. Computer search of relevant literature; abstract pertinent articles.
2. Visit known centres of expertise in Europe and North America; view and discuss current applications (scrubbers).
3. Prepare phased workplan for further contracting out.

RESULTS

1. Indicated potential methodologies of fluorine control via additives to inhibit fluorine emissions.
2. Delineated unique source (Germany) for dynamic evaluation of fluoride emissions' behaviour; gained agreement for subcontracting studies on Canadian materials.
3. Summary report includes 5-phase workplan with estimated costs.

APPLICATION AND ONGOING WORK

Contract for Phase 2 is currently under negotiation by DSS.

SUPPORTING DOCUMENTS

Final report:

1. Fluoride Emission Control Systems and the Energy Efficiency of Tunnel Kilns; Volume 1: A Critical Review and Proposed Research Program; Volume 2: Appendix Consisting of Visitation Notes and Observations of the Clay Brick Association of Canada Industrial Task Force.
2. A Review of the Influence of Fluoride-Emission Control Systems on the Energy Efficiency of Tunnel Kilns Manufacturing Structural Clay Products - Literature Review.

Contract Report No. OSQ82-00090.

TITLE: EFFECT ON THE ENERGY EFFICIENCY OF TUNNEL KILNS MANUFACTURING STRUCTURAL CLAY PRODUCTS OF FLUORIDE EMISSION CONTROL SYSTEMS - PHASE 2

CONTRACTOR:	Pollutech Ltd.	FILE NUMBER:	3-9079	FUNDING	
		BEGIN/END:	Dec. 83/May 85		
				CANMET:	$ 144 475
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	K. Bell	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 144 475

OBJECTIVES

Based on the results of Phase I, examine the potential of: modified firing schedules and additives to reduce fluoride emissions from tunnel kilns producing structural clay products.

PROCEDURE

1. Thirty representative materials from across Canada were measured for fluoride content (Milestone 1).

2. Fluoride emission studies were conducted under subcontract by an expert German laboratory. Facilities required and procedures employed were recorded for potential technology transfer to Canada (Milestone 2).

3. Modelling studies were conducted to evaluate the effect on energy balances of kiln-firing schedule changes.

4. A literature survey of fluoride chemistry and previous work on emissions' inhibition identified several fluorides stable at brick-firing temperatures. Mixed success was reported for additions of metal oxides intended to produce such products.

   Twenty tests were performed on four selected clays and shales with additions of metal oxides and deflocculants: fluoride loss was evaluated by before and after analysis.

RESULTS

1. Measured fluoride contents varied from 202 to 1163 ppm. The highest values were found in the most used materials (Ontario and Quebec).

2. For the ten selected samples, fluoride emissions were concentrated in the 800° to 1000°C range. Rates of emission varied widely, from 15 ppm/h to 149 ppm/h. In most cases, emission rates are too high to enable inhibition of fluoride release without reducing soak time and maximum firing temperature, which would adversely affect brick quality.

3. Application of the above measures would have a positive effect on energy consumption, if they could be shown to be acceptable.

4. One shale (highest fluoride of the 30 measured) showed fluoride loss reduced by 30-60% for four additives evaluated. The other three materials showed mixed response to the same and alternative additives - minor reductions or actual increases in fluoride loss.

APPLICATION AND ONGOING WORK

Further laboratory investigation is desirable to verify and expand upon the work with additives; limited to 20 tests under this fixed-price contract. Discussions have been implemented with industry to determine the future course of action.

SUPPORTING DOCUMENTS

Final Reports entitled:

"Effect on the Energy Efficiency of Tunnel Kilns Manufacturing Structural Clay Products of Fluoride Emission Control Systems - Phase 2".

Progress Report: Phase A - Milestone 1
Progress Report: Phase A - Milestone 2
Final Report: Phase A
Final Report: Phase B

[Contract Report No. OSQ83-00230 for all four reports.]

TITLE: ASSESSMENT OF PROSPECTS FOR THERMAL PLASMA FURNACE TECHNOLOGY

				FUNDING	
CONTRACTOR:	Battelle, Geneva Research Centres	FILE NUMBER:	4-9051		
		BEGIN/END:	Aug. 84/Nov. 84		
				CANMET:	$ 24 015
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	J. Skeaff	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 24 015

OBJECTIVES

Identify the individual applications of plasma furnace technology that are the most likely candidates for industrial development, and evaluate their prospects on the basis of technical and economic criteria.

PROCEDURE

Discussions with scientists, suppliers, economists, potential and actual industrial users, and review of the literature.

RESULTS

A five-volume report concludes that plasma technology yields a broad spectrum of conventional products and offers definite advantages with respect to product purity.

APPLICATION AND ONGOING WORK

Related to SNC Inc. study on plasma opportunities in Canada.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Simon-Carves of Canada Limited	FILE NUMBER:	2-9055-1	FUNDING	
		BEGIN/END:	Sept. 82/Dec. 82	CANMET:	$ 9 945
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 9 945

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site specific oil or gas-burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of the operation of an oil-fired boiler at Rio Algom's Panel Mine was undertaken. The efficiency of the unit was established and a number of possible ways to increase it were determined. A cost/benefit analysis was used to determine which modification would be best. It was concluded that the recovery of heat from the flue gases by means of an economizer would provide the shortest payback of less than two years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study. However, Simon-Carves (now Fenco Engineers) were invited to bid on, and were successful in being awarded, a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Kent Engineering Limited	FILE NUMBER:	2-9055-2	FUNDING	
		BEGIN/END:	Sept. 82/Jan. 83		
				CANMET:	$ 10 475
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 10 475

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site specific oil or gas-burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study was carried out on a natural gas fired boiler at Erco Industries plant at Vancouver, B.C. Tests were carried out to determine the operating efficiency and a series of retrofit options were proposed to increase the boiler efficiency. These were then rated against a cost effectiveness index that took costs and benefits into account. The best alternative was shown to have a payback period of about 15 months.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study. However, Kent Engineering were invited to bid on, and were successful in being awarded, a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

				FUNDING	
CONTRACTOR:	Interprovincial Engineering Limited	FILE NUMBER:	2-9055-3		
		BEGIN/END:	Sept. 82/Dec. 82		
				CANMET:	$ 11 990
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation Technology	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 11 990

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site specific oil or gas-burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of a brick kiln, fired with oil, was undertaken by Interprovincial Engineering. The study looked at the operation and control of the kiln as well as ways to apply state-of-the-art control and monitoring technology.

The study concluded that significant savings could be made that would result in a payback of less than two years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR: SNC Inc.	FILE NUMBER: 2-9055-4	FUNDING	
	BEGIN/END: Sept. 82/Feb. 83		
		CANMET:	$ 11 925
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: A.C.S. Hayden	TECHNOLOGY: Energy Conservation in Industrial Processes	TOTAL:	$ 11 925

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site specific oil or gas-burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of a cement kiln at the Miron cement plant in Montreal was undertaken. Testing was carried out to establish data on combustion and heat efficiencies of the kiln.

Conceptual equipment upgrading and retrofit procedures were prepared. Estimates of costs and potential fuel savings indicated that a return on investment of over 40% was possible.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study. However, SNC were invited to bid on, and were successful in being awarded, a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR: Shawinigan Energy	FILE NUMBER: 2-9055-5	FUNDING	
	BEGIN/END: Sept. 82/March 83	CANMET:	$ 13 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: A.C.S. Hayden	TECHNOLOGY: Energy Conservation in Industrial Processes	TOTAL:	$ 13 000

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site specific oil or gas-burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study was carried out on a converted waste fuel boiler at the Chesterville plant of Nestlé Canada. Improvements to the boiler systems were suggested which were estimated to result in fuel savings that would pay for the retrofit costs in slightly over one year.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study. However, BFH/Shawinigan were invited to bid on, and were successful in being awarded, a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Sandwell and Company Ltd.	FILE NUMBER:	3-9106-1	FUNDING	
		BEGIN/END:	Jan. 84/Aug. 84		
				CANMET:	$ 15 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 15 000

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

The subject of this study was a lime kiln in a pulp mill at Prince Rupert, B.C. Investigation showed that the present operation was very efficient, comparing favourably with similar sized Scandinavian lime kilns. It was also shown that further efficiency gains could be achieved by increasing the lime kiln retention time, by reducing the kiln radiation and convection losses, and by utilizing hog fuel in place of fossil fuel. This requires the installation of a hog fuel dryer.

The costs of the proposed modifications amounted to approximately $3.3 million, and produced annual savings of around $1.5 million or $5.60/air dry ton of pulp.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, Sandwell were invited to bid on a further study.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	SNC Inc.	FILE NUMBER:	3-9106-2	FUNDING	
		BEGIN/END:	Jan. 84/May 84		
				CANMET:	$ 14 931
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 14 931

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study was carried out on an oil and bark fired boiler at Trois Rivières, Québec. Recommendations included modifications to the hog fuel supply system to provide a more uniform distribution to the furnace; modifications to furnace over fire air supply; the addition of refractory to the lower furnace walls; and installation of gas burners to raise combustion air temperatures.

Estimated savings of $165 000 per annum should be possible at a cost of $770 000. The payback was estimated at less than five years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, SNC have been invited to bid on a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	BFH/Shawinigan	FILE NUMBER:	3-9106-3	FUNDING	
		BEGIN/END:	Jan. 84/April 84		
				CANMET:	$ 15 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 15 000

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of the operation of a natural gas and waste fuel gas fired-boiler at the Green Creek Pollution Control Centre in Ottawa was undertaken. Tests were carried out to establish the efficiency of the unit, and possible methods of improvement were studied. Cost/benefit analyses were carried out to determine which modifications would be best. It was recommended that new boiler controls and an economizer be installed, which would result in efficiency gains up to 7% and pay back the costs of installation in nine years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, BFH/Shawinigan were invited to bid on a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Kent Engineering Limited	FILE NUMBER:	3-9106-4	FUNDING	
		BEGIN/END:	Jan. 84/Aug. 84		
				CANMET:	$ 14 695
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 14 695

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of natural gas usage at a fiberglass insulation manufacturing facility was carried out. Analysis indicated that significant energy savings would be possible by recovering heat from the flue gases, diluting them with air, and injecting the hot air directly into the curing oven. Annual fuel savings were calculated at $150 000 per annum, giving a simple payback on the capital invested of 1.4 years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, Kent Engineering have been invited to bid on a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Keen Engineering Co. Ltd.	FILE NUMBER:	3-9106-5	FUNDING	
		BEGIN/END:	Jan. 84/May 84		
				CANMET:	$ 12 300
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 12 300

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

This study looked at the operation of a group of boilers providing a district heating service in Vancouver, B.C. The units ranged in size from 9.45 to 24.7 kg/s of steam at 1585 kPa, using natural gas as a fuel. Operating conditions were investigated and tests were carried out to determine operating efficiency. It was determined that economizers could be installed on two of the units, and that oxygen trim systems could be installed on all units, leading to annual fuel savings of over $150 000, which would pay back the capital costs of improvements in approximately two years.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, Keen Engineering were invited to bid on a further study.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR: Fenco Engineers Inc.	FILE NUMBER: 3-9106-6	FUNDING	
	BEGIN/END: Jan. 84/March 84		
		CANMET:	$ 14 965
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Conservation	OTHER:	--
AUTHORITY: A.C.S. Hayden	TECHNOLOGY: Energy Conservation in Industrial Processes	TOTAL:	$ 14 965

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study of an acid plant pre-heater at Belledune, New Brunswick was carried out. Tests indicated that an overall efficiency of less than 50% was being achieved. Modifications using recycled stack gases, pre-heating combustion air, and recovering heat from spent warm-up gases showed an annual fuel saving of $650 000, which resulted in a 3.5 year payback on investment.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, Fenco Engineers were invited to bid on a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Monenco Consultants Ltd.	FILE NUMBER:	3-9106-7	FUNDING	
		BEGIN/END:	Jan. 84/June 84		
				CANMET:	$ 14 945
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 14 945

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study was carried out on the operation of two boilers at a rapeseed oil production plant. The study included efficiency testing and an evaluation of the potential for efficiency improvement.

Because the boilers were fairly old, only improvements offering paybacks of two to five years were considered. Installing an economizer on one unit was estimated to provide an efficiency increase of over 7% and a payback on capital cost of approximately three years. Further improvements can be made to the control system.

Limited scope existed on the other unit for significant improvements.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study. However, Monenco Consultants were invited to bid on a further study at a separate site.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Hatch Associates Ltd.	FILE NUMBER:	4-9283-3	FUNDING	
		BEGIN/END:	Feb. 85/April 85		
				CANMET:	$ 16 400
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 16 400

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct size investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

A study was carried out on a gas-fired annealing furnace used in the manufacture of ductile cast iron piping. The furnace accounted for 60% of the total plant fuel consumption.

Investigation of the furnace operation showed that 60% of the losses were accounted for by the flue gases. Methods of reducing these losses were surveyed and showed that the use of recuperation and improved controls could pay back costs in two years.

Regenerating burners were also considered and although they could provide significant savings, the payback was three years.

A survey of the potential for application of conservation measures to other Canadian foundries showed that at present only a few recover waste heat from the existing operations.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of this study.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Fenco Engineers Inc.	FILE NUMBER:	4-9283-4	FUNDING	
		BEGIN/END:	Feb. 85/Nov. 85		
				CANMET:	$ 15 830
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 15 830

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

An investigation into the operational efficiencies of steel heat treatment furnaces at Algoma Steel's complex at Sault Ste. Marie was carried out. Energy balances were calculated, indicating an efficiency of 35%, with excess air of over 600%. Sealing furnace shells and installing a draft control system could save $10K with a 1.5-year payback. Recycling flue gas would give a 4.5-year payback. A comprehensive furnace management system would give savings of about 10% with a 4-year payback.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time as a result of the study. However, some of the information is being incorporated into a combustion handbook being produced by CCRL, and the information is also being passed on to the steel industry through the Industrial Energy Conservation Task Forces.

TITLE: PRE-ENGINEERING ASSESSMENT OF AN ENERSOLVE DEMONSTRATION PROJECT

CONTRACTOR:	Keen Engineering Co. Ltd.	FILE NUMBER:	4-9283-5	FUNDING	
		BEGIN/END:	March 85/April 85		
				CANMET:	$ 15 200
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation	OTHER:	--
AUTHORITY:	A.C.S. Hayden	TECHNOLOGY:	Energy Conservation in Industrial Processes	TOTAL:	$ 15 200

OBJECTIVES

Study the efficiency of oil and gas use in industrial process heating equipment such as boilers, kilns, and furnaces.

Carry out conceptual engineering for equipment upgrading, estimate costs for implementation of the work, and develop cost/benefit analyses.

PROCEDURE

1. Identify site-specific oil or gas burning industrial equipment that shows potential for energy conservation by effecting improvements in operational efficiency, and that is available for testing and upgrading.

2. Conduct site investigations and tests to establish data on fuel use, combustion efficiencies, and process load characteristics with time.

3. Carry out conceptual engineering to improve plant efficiencies and estimate cost/benefit impact. Estimate the project costs for detailed engineering, procurement and retrofit, and monitoring and maintenance of the upgraded plant.

4. Provide a final report describing the work done, the suggested improvements, and the costs and benefits of the proposed work.

RESULTS

This study examined energy use during ingot soaking in a steel manufacturing plant (IPSCO). The ingots are reheated in gas-fired soaking pits. Of the 13 plants in this mill, four used recuperators.

Performance measurements were carried out in two pits, with and without recuperators.

Use of recuperators throughout would save $350 000 per annum. Oxygen trim equipment could reduce high excess air levels and save another $150 000 per annum. Designing a pit cover to reduce heat loss during unloading, using improved wall insulation, and optimizing operating practices had potential for further savings.

It was determined that the energy-saving measures had wide application to other Canadian steel-making plants.

APPLICATION AND ONGOING WORK

No contracts for further work have been awarded at this time.

ENERGY TECHNOLOGY

PETROLEUM SUPPLY

TITLE: BITUMEN CONTENT ANALYSIS

CONTRACTOR:	University of Alberta	FILE NUMBER:	7-9118	FUNDING	
		BEGIN/END:	July 78/March 79		
				CANMET:	$ 2 262
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	V. Srajer	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 2 262

OBJECTIVES

Analyze oil sand samples for bitumen content.

PROCEDURE

To determine the bitumen content of the samples, about 350 g of oil sand was placed in a soxhlet extractor. Bitumen was extracted with toluene for 24 hours. Toluene was then separated from bitumen by using a rotary evaporator at 70°C and a reduced pressure of 30 mm Hg. Bitumen was recovered from silt by centrifuge and weighed for the percentage determination.

RESULTS

Twenty-nine oil sand samples were analyzed for bitumen content. The results are in the form of a one-page report.

APPLICATION AND ONGOING WORK

To support in-house research.

TITLE: EFFECT OF STIRRING ON ENHANCED SEPARATION OF PARTICULATES FROM LIQUIDS

CONTRACTOR:	University of Alberta	FILE NUMBER:	0-9173	FUNDING	
		BEGIN/END:	June 81/Sept. 82		
				CANMET:	$ 32 725
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D.K. Faurschou	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 32 725

OBJECTIVES

Investigate the influence of swirling flow on hindered settling/flotation of particulates in liquids with special reference to design of the Magna Rotary Turbulent Gravity Separation Unit (RTGS) for extraction of bitumen from oil sand by the Magna Cold Water/Solvent Process.

PROCEDURE

1. Develop and operate a physical model.
2. Extend the Masliyah hindered settling/flotation numerical model to account for the influence of flow rate and media density.
3. Conduct numerical simulations, based on experimental data, to predict the behaviour of fine mineral particulates and condensed hydrocarbon phases in aqueous processes for the extraction of bitumen.

RESULTS

Within a wide range of operating conditions, it was found that stirring action contracts a fluidized bed. Mathematical simulation of a gravity separation vessel where sand/bitumen droplets are separated indicates that stirring only slightly enhances separation.

APPLICATION AND ONGOING WORK

It was concluded that improved bitumen recovery may be better achieved by devising processes where large bitumen drops are produced.

SUPPORTING DOCUMENTS

1. Final Report: "The Effect of Stirring on Enhanced Separation of Particulates from Liquids".
2. "Effect of Stirring on a Liquid Fluidized Bed", by J.H. Masliyah and S. Mohamed, 32nd CSChE Conference, Vancouver, October 3-6, 1982.

TITLE: DEVELOPMENT OF TECHNIQUES TO STUDY SURFACE PROPERTIES RELEVANT TO COAL PROCESSING AND OIL RECOVERY - PHASE 4

CONTRACTOR: University of Toronto	FILE NUMBER: 2-9003	FUNDING	
	BEGIN/END: April 82/March 83	CANMET:	$ 95 500
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: Dr. H.A. Hamza	TECHNOLOGY: Recovery of Bitumen and Heavy Oil	TOTAL:	$ 95 500

OBJECTIVES

The overall objective of this work is to develop reliable methodology for the evaluation of surface properties of energy resource systems such as coal and heavy oils.

The determination of surface tensions and contact angles of coal particles is of great interest for coal beneficiation processes such as froth flotation and oil agglomeration, and for the inclusion of coal particles into oil droplets as a means of enriching the fuel. Knowledge of surface tensions and contact angles of sand, clay particles, and oil droplets will improve understanding of the adhesion of oil and sand, and therefore give better ideas for separation processes.

Methods for contact-angle measurements on small, irregularly shaped solid particles have not been available in the past, so this novel technique is of great interest in the evaluation of surface properties of coals and heavy oils.

PROCEDURE

New, independent techniques of determining the surface tension and contact angles of solid particles as well as liquid droplets (e.g., in emulsions) were explored.

The particle surface tension was determined by means of the freezing front technique and by sedimentation volume. Some preliminary particle adhesion measurements and direct contact angle measurements were performed on polished coal segments. A study of coal aging as related to temperature and storage, particularly the oxidation effects, was carried out.

Some preliminary experiments on polymer adsorption on coal and on the use of freezing front for emulsions were also conducted.

Liquid/liquid interfacial tension was measured using the new method of shapes of axisymmetric menisci.

The temperature dependence of the surface tension of different industrial oils was determined.

The density and specific heat of the different solid particles was also measured.

RESULTS

The sedimentation volume measurements provided good results for polymer and coal samples in comparison with the results obtained from the freezing front.

The adhesion of coal particles and direct contact angle measurements on polished coal segments gave very promising results.

Aging the coal particles under different circumstances showed that at low temperature and in N_2 atmosphere, the oxidation of coal slows down.

The freezing front technique, used in determining liquid/liquid interfacial tensions for oil/water emulsions, works well.

The new technique of shapes of axisymmetric menisci to evaluate the liquid/liquid interfacial tensions of liquid pairs is suitable for a wide range of interfacial tensions, including extremely low interfacial tensions.

APPLICATION AND ONGOING WORK

The results obtained from this study are mainly used in flotation and flocculation studies. Some of the results on emulsions are used for emulsion stability and breaking studies.

SUPPORTING DOCUMENTS

Final report.

Two manuscripts were accepted for publication (Chemical Eng Communication and Colloids and Surfaces).

One paper was published (Canadian Journal of Chemistry 60, 1982).

TITLE: ENHANCED HEAVY OIL RECOVERY PROBLEMS, INCENTIVES AND PRIORITIES

CONTRACTOR:	Winestock Petroleum Consulting Ltd.	FILE NUMBER:	2-9169	FUNDING	
		BEGIN/END:	Dec. 82/Jan. 84		
				CANMET:	$ 44 300
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D.K. Faurschou	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 44 300

OBJECTIVES

The study was commissioned in response to an unsolicited proposal to:

1. Provide an authoritative assessment of the relative importance of enhancing heavy oil recovery by increasing flushing and sweep efficiencies.
2. To provide a state-of-the-art assessment of laboratory and field studies for improving conformance, i.e., sweep efficiency.
3. Make recommendations regarding the priorities of specific avenues and projects that should be considered for federal energy R&D funding.

PROCEDURE

Based on the evaluation of the literature, field visits, personal contacts, experience, and numerical modelling, a report was prepared covering:

1. Major Recovery Problems.
2. EOR Recovery Technology.
3. Recent Efforts to Improve Conformance.
4. Future R&D Effort and Priorities.
5. Conclusion and Recommendations.
6. References.

RESULTS

Unresolved problems, in order of priority, with special reference to conformance are:

1. Flow fundamentals - divertents.
2. Effectiveness of divertents.
3. Timing of EOR.
4. Well configuration and operation.
5. Vertical transmissibility.
6. Flow fundamentals - emulsion.
7. Flow fundamentals - polymers.
8. Clays/fines.
9. Selective mobilization.

APPLICATION AND ONGOING WORK

The study will influence the application of R&D contract funds, particularly the 50:50 funding with industry, to improve the efficiency of processes for recovery of heavy oil.

TITLE: WET OXIDATION FOR IN SITU OIL RECOVERY - PHASE I

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9166	FUNDING	
		BEGIN/END:	Nov. 83/Sept. 85		
				CANMET:	$ 197 134
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D.K. Faurschou	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 197 134

OBJECTIVES

1. Develop wet oxidation kinetics and an understanding of operating parameters for the treatment of solid or residual fuels and of produced water slurries for direct energy recovery suitable to oilfield requirements.

2. Develop design parameters and concepts for the wet oxidation process, and any necessary ancillary equipment, to treat produced water and ancillary fuels for recovery of bitumen and heavy oil.

3. Conduct a preliminary assessment of the comparative economics of selected options for application of wet oxidation.

4. Prepare a targeted, justified program for development of high-thermal flux wet oxidation processes for oilfield use.

PROCEDURE

An extensive experimental program was undertaken to examine the application of wet air oxidation, specifically the Wetox® process, to oil sand recovery operations. Batch-scale experiments were conducted on the following:

a) produced waters
b) delayed coke
c) fluid coke
d) Eureka Process pitch
e) asphaltenes.

Continuous flow batch-scale tests were attempted using produced water and fluid coke. Although limitations in operating temperature and pressure in the unit precluded obtaining acceptable kinetic data, a number of potential practical problems with the operability of the system were identified.

RESULTS

The oxidation reaction kinetics were modelled assuming first-order reactions. The oxidation reactions of the produced waters tested were analogous to those of many organic materials, in that the oxidation rate inflected from a fast regime of about 50-75% conversion to a slow regime. With the solid fuels, however, rapid reaction proceeded until greater than 90% of the initial organic material was oxidized. Solid fuels are, therefore, particularly attractive candidates for wet oxidation.

A modification of the wet oxidation reactor, conceptualized during the research, allows for extremely high energy output per unit reactor volume. This now-patented modification results in versatility of application with lower capital and operating costs as compared to the unmodified systems.

A computer-aided technical and economic assessment validated a considerable number of options for the application of wet air oxidation in oil sand recovery operations. The cost of high-pressure steam was calculated to be $6,14/GJ (air-based system with no credit for CO_2).

For thermal energy, in the form of high-temperature water or process steam, with a credit given to relatively pure carbon dioxide as by-product, the cost was determined to be $2.79/GJ (pure oxygen-based system).

APPLICATION AND ONGOING WORK

Recommendations for future development of the process are discussed. The major step would be to construct and operate a suitable pilot-scale facility designed for the application.

SUPPORTING DOCUMENTS

Final Report: "Wet Oxidation of Produced Water and Ancillary Fuels for Oilfield Applications - Phase I, Kinetics, Conceptual Designs and Economics".

TITLE: STEAM INJECTION EXPERIMENTS IN A SCALED PHYSICAL MODEL

CONTRACTOR: University of Alberta	FILE NUMBER: 3-9167	FUNDING	
	BEGIN/END: Nov. 83/Nov. 85	CANMET:	$ 300 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: D. Faurschou	TECHNOLOGY: Recovery of Bitumen and Heavy Oil	TOTAL:	$ 300 000

OBJECTIVES

1. Design and fabricate a low-pressure, scaled steamflood model to simulate a selected field (Aberfeldy) in Saskatchewan with provision of the following:
   a) injection and production equipment, and material to simulate adjacent formations;
   b) facility for steam generation and steam quality control;
   c) equipment for rapid cooling of the model for establishing the initial conditions in accordance with the scaling criteria;
   d) facility for data acquisition, processing, and plotting.

2. Conduct a series of steamflood experiments to examine model performance under a wide variety of operating conditions, in particular the following:
   a) base steamflood in a model saturated with 100% water to observe temperature distributions and to refine operational procedures;
   b) waterflood at room temperature and at low temperature to establish the base oil recovery;
   c) continuous steamfloods in the Aberfeldy model;
   d) light oil steamflood;
   e) heavy oil steamflood;
   f) effect of production interval;
   g) effect of bottom water on steamflood recovery;
   h) steam slug driven by cold water.

The purpose of the above runs was to judge the model capability for a variety of experiments, and also to examine a broad range of steamfloods to determine the processes that merit a closer look in the near future.

PROCEDURE

Experiments were conducted in a scaled physical model, under a wide variety of conditions. A large part of the work was devoted to the design and construction of the scaled model apparatus used to conduct the steam injection experiments. The apparatus was designed to represent one-quarter of an eight hectare (20 acre) 5-spot pattern and was scaled based upon low-pressure scaling criteria.

A number of steamflood experiments were carried out to show the use of the apparatus and the efficacy of the process under investigation. To examine the recovery potential of the Aberfeldy heavy oil reservoir several types of runs were conducted, including steamfloods in a homogeneous pack, a continuous steamflood in a bottom water pack, slug runs on a homogeneous pack, and a steamflood following a water flood.

RESULTS

1. A low-pressure, scaled steamflood model was designed and constructed, then tested for a variety of steamflood runs, and found to be satisfactory for all purposes.

2. Oil viscosity has a considerable influence on the type of steam drive developed.

3. Based upon one run, it was concluded that bottom water has a considerable influence on the type of steam drive developed.

4. The steam slug process appears to be an efficient, practical, and viable recovery technique, with oil recovery of 30.9% of the original oil in place.

5. Among the techniques tested thus far, the steam slug process appears to be best suited for the Aberfeldy crude, with a recovery of at least 31% depending on the volume of the injected slugs.

6. The oil recovery observed for a light oil steamflood was higher than that of the Aberfeldy model. Thus, steamflooding may be a viable recovery method for light oils as well.

APPLICATION AND ONGOING WORK

This work was devoted to setting up the steam injection apparatus and to carrying out selected experiments designed to examine the recovery of oil from marginal reservoirs. A low-pressure scaled model was designed and constructed. A duplicate model, as well as a smaller model, were also built. The ongoing work (Phase 2) employs the apparatus to study variations of steamflooding in thin, heavy oil formations, with bottom water present in most instances. Lloydminster-type reservoirs are primarily addressed. The research will also be applicable to Cold Lake heavy oil formations. A process is being developed utilizing steam injection with additives.

TITLE: APPLICATION OF CONVENTIONAL MINING TECHNIQUES TO UNDERGROUND OIL SANDS MINING

CONTRACTOR:	Cominco Engineering Services	FILE NUMBER:	4-9198	FUNDING	
		BEGIN/END:	Dec. 84/Aug. 85		
				CANMET:	$ 66 690
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G. Zahary	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 66 690

OBJECTIVES

Develop a proposal to evaluate the application of conventional mining techniques to underground oil sands mining in order to improve the characteristics of the reservoir and the in situ recovery of bitumen.

PROCEDURE

1. Review the technical and patent literature on underground mining of petroleum-bearing formations.

2. Review available information on the geological-geotechnical conditions at an underground site and specify the reference formation to be used for planning purposes.

3. Design experiments to determine caving characteristics and methods of increasing the permeability of the formation.

4. Assess the opportunities available and potential contributions that might be made by the underground sector of the Canadian mining industry.

RESULTS

Underground experience in oil sand formations is so limited that detailed planning is not possible at present. The study calls for an experimental mining program to develop objective information on environmental conditions in oil sand formations and their response to mining by:

1. Developing an isolated experimental site within the Underground Test Facility (UTF), including a drill site close to the formation from which holes can be drilled for the study.

2. Widening the drilled or caved zone by blasting and monitoring the resulting changes in formation porosity.

3. Developing access openings in the undisturbed oil sands and advancing toward the caved zone to examine blasting and caving effects.

Conceptually, this work is expected to take some 2.5 years at a cost of $4 million. The work would be approached with caution given the lack of underground experience and the high investment already made in the UTF. Prior to mining the oil sands, special studies aimed at finding methods of coping with its sticky and abrasive nature are considered necessary.

APPLICATION AND ONGOING WORK

A more detailed study of the effect mining would have on the characteristics of the reservoir and the release of bitumen is required.

SUPPORTING DOCUMENTS

Final Report: "Application of Conventional Mining Techniques to Underground Oil Sands Mining".

TITLE: APPLICATION OF GEOPHYSICAL TECHNIQUES IN OIL SANDS

CONTRACTOR:	Terracon Geotechnique Ltd.	FILE NUMBER:	4-9243	FUNDING	
		BEGIN/END:	Oct. 84/July 85		
				CANMET:	$ 59 663
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G. Zahary	TECHNOLOGY:	Recovery of Bitumen and Heavy Oil	TOTAL:	$ 59 663

OBJECTIVES

1. Evaluate development of shallow geophysical mapping technology and identify its potential for resolution of mining problems arising in surface-mining operations in oil sands.

2. Identify Canadian expertise with an interest in the technology.

3. Identify knowledge gaps and make recommendations for further work.

PROCEDURE

Assemble a multi-disciplinary team consisting of a geophysicist, geologist, geotechnician, and mining engineer with oil sands mining experience. Specify the problem of dragline security in oil sands mining, i.e., potential failure modes, critical formation characteristics, alternative approaches to risk reduction, etc. Review the state-of-development of short-range geophysical technology, and the available experience with applications or trials in oil sands. Discuss the potential of geophysical techniques for indirect prediction of geotechnical properties of overburden and oil sands, and the relationship of these properties to surface-mining practice. Conduct two seminars on the results for an audience of mine operators and an audience of researchers.

RESULTS

Security of the dragline is threatened by sudden block failures in the highwall. These failures have occurred with little advance warning in close proximity to the tub of an operating dragline. The key geological factors that contribute to this type of failure are the orientation, dip, and continuity of primary bedding planes and the presence of clay bands.

High-resolution reflection seismic profiling is the most useful geophysical method that can be brought to bear to delineate bedding features. It is expected that additional development work will be required because reflection coefficients are not satisfactory. A representative test area would be selected and a synthetic seismogram derived from borehole sonic and density data. On this basis an optimum frequency range would be selected and trials conducted to select receivers, ground coupling procedures, and receiver arrays. Data redundancy and processing would be carried out, and the indicated structural geology compared to the geological model derived from independent measurements.

APPLICATION AND ONGOING WORK

Results are being reviewed and may serve as a basis for joint work with the company or with another research group doing similar work on coal deposits.

TITLE: TREATMENT OF BITUMEN/OIL EMULSIONS AND EFFLUENT WATERS

CONTRACTOR:	University of Waterloo	FILE NUMBER:	3-9122	FUNDING	
		BEGIN/END:	Sept. 83/Nov. 84		
				CANMET:	$ 96 832
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	N.A. Mansour	TECHNOLOGY:	Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 96 832

OBJECTIVES

Develop a two-phase flow meter for oil/water emulsion system.

Perform rheological studies on mineral and heavy oil emulsions.

PROCEDURE

To achieve the objectives, the following steps were followed:

1. Construct a flow loop equipped with various pipe diameters.
2. Design and construct two-phase flow metering system consisting of a conductivity meter and magnetic/venturi/orifice flow meter.
3. Establish a data acquisition system consisting of a front end and an IBM PC for collection of the two-phase flow data.
4. Perform rheological studies on mineral and heavy types of oil using various viscometers.

RESULTS

The two-phase flow system developed under this contract works well for monitoring oil in water emulsions and gives unsatisfactory results for water in oil. Salt contents, aging effects, and temperature play an important role in the measurement accuracy of the meter.

Rheological studies on mineral oils have proved that flow data obtained using coaxial viscometers represent the actual behaviour of these emulsions, contrary to the case using the Weissenberg Rheogoniometer. The rheological studies also concluded that a heavy oil emulsion behaves like a Newtonian fluid, but its viscosity changes with aging.

APPLICATION AND ONGOING WORK

Problems encountered in measuring water in oil, due to changes in salt contents and inversion, must be solved.

SUPPORTING DOCUMENTS

Final report with an appendix that includes seven papers to be published.

TITLE: TREATMENT OF AQUEOUS EFFLUENTS FROM BITUMEN/HEAVY OIL RECOVERY OPERATIONS

				FUNDING	
CONTRACTOR:	Alberta Oil Sands Technology and Research Authority	FILE NUMBER:	0-9119		
		BEGIN/END:	March 81/Oct. 81	CANMET:	$ 36 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	H. Sawatzky	TECHNOLOGY:	Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 36 000

OBJECTIVES

Prepare a report on the state-of-the-art of recycling produced saline water for steam generation in heavy oil/oil sands recovery operations. This review was required by the participants in the Memorandum of Understanding between the United States and Canada for Cooperation in R&D of Oil Sands and Heavy Oil, as a preliminary step for establishing a project on treatment of produced water. It was intended that a work statement on water treatment be prepared based on the problems identified, and a background review also identified.

PROCEDURE

The information for this review was obtained from the following sources:

a) computer-assisted key-word searches from five appropriate databases;
b) the contractor's in-house literature and texts;
c) unpublished literature from personal contacts;
d) vendor-supplied literature;
e) contacts with vendors, operators, consultants, and researchers;
f) published regulations from various government agencies;
g) quarterly reports from research centers active in the enhanced oil recovery field;
h) miscellaneous other sources.

The information was compiled as considered appropriate by the contractor, and the review with comments was prepared to provide the required background and identification of problems. Both economic and environmental issues were addressed.

RESULTS

A satisfactory report was prepared and included only data that existed in the literature or in unclassified industry reports. The report included discussions of current practices in the heavy oil/oil sands industry, their limitations, problems, and areas of future work. Other possible uses of produced water such as cooling water and irrigation were briefly discussed. Also, problems of corrosion in water treatment and steam generation were mentioned. Progress on tailings recovery was summarized.

APPLICATION AND ONGOING WORK

Part of Canada/U.S. Memorandum of Understanding for Cooperation in the R&D of Oil Sands and Heavy Oil.

TITLE: CRITICAL REVIEW AND ASSESSMENT OF TECHNOLOGIES FOR THE SEPARATION OF STABLE OIL/WATER/MINERAL EMULSIONS WITH EMPHASIS ON BITUMEN AND HEAVY OIL APPLICATIONS

CONTRACTOR: SNC Inc.	FILE NUMBER: 3-9136	FUNDING	
	BEGIN/END: Oct. 83/Oct. 84	CANMET:	$ 88 837
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: Z. Potoczny	TECHNOLOGY: Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 88 837

OBJECTIVES

Carry out an authoritative review and critical assessment of the methods that can be used:

a) to improve recovery of bitumen or heavy oil from wellhead production fluids arising from commercial in situ thermal recovery projects; and
b) to scavenge oil and otherwise improve the quality of the water from in situ thermal recovery projects for reuse (i.e., steam generation) or disposal.

PROCEDURE

All information concerning separation of oil/water/mineral emulsions or tailings was collected and reviewed, and commercial and emerging methods for such separations were selected.

The selected commercial and emerging methods were assessed technically and economically. Selected commercial methods were tested by the suppliers and developers of the systems. Emerging methods were surveyed and ranked.

Two samples collected from Alberta oil producers were tested using chemical heating and electrostatic field treatment.

RESULTS

The commercial treating methods were separated into four groups: thermo-physico-chemical systems, thermo-electrostatic systems, dilution and combined methods, and high-temperature systems. A total of fourteen different flowsheet configurations of the existing pilot plants were compiled. From the tests performed on the two emulsions it was shown that separation efficiency increased with increasing temperature, pressure, and applied voltage. Different demulsifiers also gave different separation efficiencies.

Six different methods of separating emulsions were proposed by SNC.

Capital and operating costs were calculated for these systems.

APPLICATION AND ONGOING WORK

Some of the results from this study are being used in the design and construction of the heavy oil mini-plant at CRL.

TITLE: TECHNICAL AND ECONOMIC ASSESSMENT OF THE APPLICATION OF MEMBRANE TECHNOLOGY FOR TREATING OIL/WATER/MINERAL EMULSIONS

CONTRACTOR:	Zenon Environmental Inc.	FILE NUMBER:	3-9185	FUNDING	
		BEGIN/END:	Nov. 83/May 85		
				CANMET:	$ 168 719
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. B. Farnand	TECHNOLOGY:	Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 168 719

OBJECTIVES

1. Review available literature and establish contact with vendors and operators of existing treatment units.
2. Characterize field-generated samples of produced water in terms of ultrafiltration performance.
3. Perform membrane screening experiments with the characterized produced water and a series of membranes chosen for their various properties of porosity, permeation rate, resistance to fouling, etc.
4. Perform batch concentration tests to determine the effect of higher oil concentration on ultrafiltration performance.
5. Perform membrane stability tests by operation of the ultrafiltration system in total recycle for a long time.
6. Perform a gross ultrafiltration followed by a reverse osmosis experiment to determine the ability to obtain high-quality water.
7. Prepare a preliminary economic assessment of membrane separation for the production of boiler feed quality water for several configurations. Existing assessments of current technology shall be used for comparison.
8. Prepare a final report that describes the experimental results, and report the literature survey and the economic assessment.

PROCEDURE

1. Samples of produced water were obtained from Texaco Resources' Athabasca Steam Flood pilot plant. These were characterized in terms of bitumen content, total dissolved solids, hardness, etc.
2. Ultrafiltration membranes were fabricated or purchased and tested for performance in continuous flow ultrafiltration test units. Performance was monitored by characterization of the permeate samples.
3. The design bases for the economic assessment of the ultrafiltration process were obtained entirely from the results of these experiments. Book value estimates of the capital and operating costs were used, in combination with the contractor's own experience.

RESULTS

1. The emulsion characterization and the literature survey demonstrated the variability of produced water. The sample used in this work was 1700 mg/L bitumen, with approximately 800 mg/L of total dissolved solids.
2. The membrane screening tests have shown that the thin film composite membrane (thin polyamide on a polysulfone support), the CHP membrane (Zenon Environmental), and the polysulfone PS-E500 membrane were the most successful.

3. Operating conditions for bitumen removal were defined, but were not optimized. Further work will be required to investigate optimum conditions such as operating temperature, pH, and cleaning.

4. Contact with operators indicated a favourable response, along with suggestions of lower bitumen content produced waters (100 mg/L), and with a much larger total dissolved solids content (20 000-30 000 mg/L).

5. The economic assessment of the membrane process indicated that not all configurations would be viable. Several methods were found to be competitive with existing produced water treatments, although these used assumptions with regard to long-term performance.

APPLICATION AND ONGOING WORK

Additional work has been proposed that will address the problems of membrane cleaning, higher operating temperature, higher total dissolved solids, lower oil content, and configured membrane testing. This will include laboratory work and field testing, presumably at the sites of interested operators.

TITLE: EVALUATION OF ADSORBENTS FOR TREATING STABLE OIL/WATER/MINERAL EMULSIONS PRODUCED DURING IN SITU BITUMEN/HEAVY OIL RECOVERY OPERATIONS

CONTRACTOR: Zenon Environmental Inc.

FILE NUMBER: 3-9226
BEGIN/END: March 84/March 85

CANMET SCIENTIFIC AUTHORITY: M. Poirier

ENERGY TECHNOLOGY ACTIVITY
SUB-ACTIVITY: Petroleum Supply
TECHNOLOGY: Treatment of Bitumen/Oil Emulsions and Effluent Waters

FUNDING

CANMET:	$ 48 583
CONTRACTOR:	--
OTHER:	--
TOTAL:	$ 48 583

OBJECTIVES

Develop physical methods for processing effluent streams from bitumen and heavy oil in situ recovery operations to produce water of acceptable quality for boiler feed.

PROCEDURE

The procedure involved the use of inexpensive adsorbents and inorganic salts.

RESULTS

The most promising results were obtained using Minto coal and fly ash. Other materials such as ferric chloride and alum have given promising results as well.

APPLICATION AND ONGOING WORK

A new contract for the development of a laboratory scale process is in progress. The procedure has been proven efficient for separating oil from water.

TITLE: HYDRODYNAMICS OF POLYMERS IN SOLUTION

CONTRACTOR: S&J Engineering	FILE NUMBER: 3-9088	FUNDING	
	BEGIN/END: Nov. 83/March 85	CANMET:	$ 56 492
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: W. Friesen	TECHNOLOGY: Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 56 492

OBJECTIVES

1. Model the hydrodynamic resistance of a network of dissolved polymers at low flow rates.
2. Measure the hydrodynamic resistance of high molecular weight water-soluble polymers such as polyacrylamide (PAM) and polyethylene oxide (PEO).

PROCEDURE

1. The polymer network was treated as a fibrous porous medium in which the entangled fibers were modelled by randomly oriented rings positioned on a cubical lattice. The permeability of the medium was calculated by taking into account the hydrodynamic interactions between rings.
2. The permeability of the polymer networks was obtained by measuring flow rate through a test cell as a function of pressure drop across the cell. Salt concentrations and polymer charge densities were varied.

RESULTS

1. Permeability was calculated as a function of radius of curvature and volume fraction of the rings. The permeability was shown to have only a slight dependence on the radius of curvature.
2. Permeabilities of PAM and PEO networks were measured, and the effective hydrodynamic diameters of the polymer chains were calculated. The hydrodynamic properties of PEO and PAM were observed to be substantially different. PAM hydrodynamic diameter was only slightly dependent on salt concentration and degree of hydrolysis.

APPLICATION AND ONGOING WORK

Enhanced oil recovery - in polymer flooding applications' estimation of the flow resistance of polymers in porous oil-bearing rock formations.

TITLE: ANALYTICAL METHODS FOR DETERMINATIONS OF RESIDUAL POLYACRYLAMIDE POLYMER IN COAL AND OIL PROCESS WATERS

CONTRACTOR:	Guelph Chemical Laboratories Ltd.	FILE NUMBER:	3-9189	FUNDING	
		BEGIN/END:	Nov. 83/July 85		
				CANMET:	$ 91 985
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. W.M. Leung	TECHNOLOGY:	Treatment of Bitumen/Oil Emulsions and Effluent Waters	TOTAL:	$ 91 985

OBJECTIVES

Develop methods for trace analysis of polyacrylamide (PAM) in coal and oil process waters using ultrafiltration (UF) and size exclusion high-performance liquid chromatograph (SEHPLC) - UV detection techniques.

PROCEDURE

1. Water sample was flocculated by desired dosage of flocculant.
2. The solids were removed by filtration and/or centrifugation, and the filtrate was desalted and concentrated by ultrafiltration (UF).
3. The retentate was then evaporated to dryness at 30°C under reduced pressure.
4. The dried residue was re-dissolved in 5 mL of 0.05 M Na_2SO_4 for SEHPLC analysis of PAM.

RESULTS

1. TSK gel 5000 PW column is suitable for the analysis of both anionic and non-ionic PAM polymers.
2. Detection limits of PAM by UV detection are in the range of 1-2 ppm.
3. Good reproducibility is achieved by the SEHPLC-UV method.
4. An average loss of 25% of flocculant is observed during the UF concentration/desalting procedures.

APPLICATION AND ONGOING WORK

This work is a good piece of academic research. Because of the tedious and lengthy procedures, and the requirement of highly skilled chromatograph technologists, the immediate adoption of this method by the coal/oil industries in the determination of residue PAM in water is not apparent. However, the spectrophotometric method, which is considered simpler and more economical than UF/SEHPLC, has good potential in field application. A preliminary study of this method is reported in the appendix of the final report. Further work to improve this method is underway at CRL, Edmonton.

TITLE: INITIAL DEVELOPMENT OF A DISTILLATE TREATMENT RESEARCH AND DEVELOPMENT PROGRAM

CONTRACTOR:	R.F. Webb Corporation Ltd.	FILE NUMBER:	I-9060	FUNDING	
		BEGIN/END:	Aug. 81/Jan. 82		
				CANMET:	$ 25 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	H. Sawatzky	TECHNOLOGY:	Upgrading Synthetic Crude Distillates	TOTAL:	$ 25 000

OBJECTIVES

The major purpose of this study was to assist in providing direction for research on distillate treatment to CANMET. It was particularly important to obtain predictions on the future demand for transportation fuels that would be required from synthetic crudes obtained from the bitumen and heavy oils of western Canada. This required predictions of future acceptable qualities and the technologies needed to upgrade synthetic crudes to transportation fuels with these required qualities.

PROCEDURE

A consulting firm with considerable experience and that already possessed considerable data relevant to transportation fuels was engaged to carry out the study. The following broad aspects were examined.

1. Liquid petroleum product demand projections, including all forms of transportation fuels as well as non-fuel uses.
2. Crude oil availability and quality, including conventional supplies, heavier crudes and syncrudes, and their qualities as well as economic considerations.
3. Production of synthetic crudes from bitumen/heavy oils as well as from coal and the implications of these syncrudes for the Distillate Treatment Program.
4. Refining developments and efficiencies of upgrading.
5. Canadian government role in technology developments.

RESULTS

The consulting firm carried out the required study. The firm made predictions and recommendations that were based on their interpretations of the available data and information. Although there might be considerable controversy about the predictions and recommendations, much background information was compiled that will be useful for some time.

TITLE: HYDRODEOXYGENATION OF MODEL COMPOUNDS

CONTRACTOR: SNC Inc.	FILE NUMBER: 0-9178	FUNDING	
	BEGIN/END: Nov. 81/March 85	CANMET:	$ 119 637
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: Dr. E. Furimsky	TECHNOLOGY: Upgrading Synthetic Crude Distillates	TOTAL:	$ 119 637

OBJECTIVES

Construct the bench-scale unit for hydrotreating studies of distillate fractions.

Compare hydrodeoxygenation reactivities of ortho-substituted phenols with that of the unsubstituted phenol.

PROCEDURE

Hydrotreatment of the feedstock (0.1 molar solution of phenol in hexadecane) at 350°C and hydrogen pressure of 6.90 and 10.35 MPa in the presence of molybdate catalyst (both oxidized and sulphided forms). Product distribution determined by gas chromatography with peak's identification being performed by gas chromatography-mass spectroscopic technique.

RESULTS

The order of hydrodeoxygenation reactivities of phenols was established as follows: phenol, tert-butylphenol, methylphenol, ethylphenol, dimethylphenol.

APPLICATION AND ONGOING WORK

The expertise and experience in the operation of the high-pressure unit, developed by the contractor and subcontractor (Technitrol Ltd. of Montreal), may be utilized in future during hydrotreatment of synthetic liquids.

TITLE: DETERMINATION OF AROMATICS IN OIL SAND DISTILLATES BY CARBON 13 NUCLEAR MAGNETIC RESONANCE

CONTRACTOR:	Carleton University	FILE NUMBER:	2-9085	FUNDING	
		BEGIN/END:	July 82/Sept. 84		
				CANMET:	$ 55 899
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	M. Wilson	TECHNOLOGY:	Upgrading Synthetic Crude Distillates	TOTAL:	$ 55 899

OBJECTIVES

Determine the concentrations of aromatics in middle distillates from synthetic crudes from Athabasca oil sands. The objective of this was to elucidate the kinetics of aromatics hydrogenation, determine the activity of the catalysts used, and establish correlations between fuel ignition and combustion properties and aromatic carbon content.

PROCEDURE

Middle distillate fractions were distilled from synthetic crudes obtained by coking of Athabasca bitumen. The feedstocks were catalytically refined with a variety of catalyst types and the conversion of aromatics to naphthenes was determined by C-13 NMR. The hydroprocessing experimental conditions such as temperature, pressure, and liquid hourly space velocity were varied. Cetane numbers of the fuel products were determined by engine tests, and combustion properties by a standard smoke point test.

RESULTS

The kinetic parameters measured revealed new information regarding the behaviour of different catalyst types for aromatics saturation in oil sand distillates. The effects on thermodynamic equilibrium and cracking of hydrocarbons were observed in hydroprocessing, and optimum conditions for fuel production were determined. The resultant products were evaluated as potential jet and diesel fuels, and interrelations were established between fuel cetane number, smoke point, and aromatic carbon content.

APPLICATION AND ONGOING WORK

There is no final report from this contract since it involved chemical analysis of products from in-house hydroprocessing. Ongoing in-house work is concerned with new catalyst development for these processes.

SUPPORTING DOCUMENTS

Published Reports: M.F. Wilson and J.F. Kriz, Fuel 63:190; 1984.

M.F. Wilson, J.F. Kriz, and I.P. Fisher, ACS Preprints 29:1:284; St. Louis, Miss.; April 8-13, 1984.

Two further reports in preparation.

TITLE: INCORPORATING HEAVY OIL AND SYNTHETIC CRUDE RESIDUA INTO FLUID CATALYTIC CRACKING FEEDSTOCKS

CONTRACTOR: Gulf Canada Limited	FILE NUMBER: 3-9027	FUNDING	
	BEGIN/END: July 83/Jan. 85		
		CANMET:	$ 110 920
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: Dr. S.H. Ng	TECHNOLOGY: Upgrading Synthetic Crude Distillates	TOTAL:	$ 110 920

OBJECTIVES

Evaluate the viability of producing transportation fuels from heavy oil and synthetic crude residua by incorporating these materials into fluid catalytic cracking feedstocks. Yield data obtained by microactivity testing, along with established modelling procedures, will allow an assessment of these feedstocks in the FCCU operation.

PROCEDURE

1. Characterization of three vacuum gas oils (IPL, Syncrude, and Lloydminster), three heavy oil-residua (Athabasca bitumen, IPL vacuum tower bottoms, Lloydminster atmospheric tower bottoms), and three special MAT feeds that are compositionally different.

2. Characterization of three equilibrium FCC catalysts that are aluminosilicates composed of crystalline zeolites and binders.

3. Impregnation of equilibrium FCC catalysts with metal salts (Ni, V, Sb) to study the effect of a metals passivator on MAT yield.

4. Microactivity tests with different feedstocks and catalysts.

5. Calculation of MAT product yields and verification of the reliability of the data by doing a mass balance for each run.

6. Statistical analysis to obtain predictive models for coke and conversion from temperature and catalyst/oil ratio, and to establish correlations between individual product yields and conversions at different temperatures.

RESULTS

1. IPL VGO was the superior feedstock, producing much more gasoline than Lloydminster VGO, which in turn was only marginally better than Syncrude VGO.

2. Relative to their respective vacuum gas oils, residua produced more coke, light ends, LPG's, and light cycle oil, and less gasoline and decant oil per unit weight of feed at similar conversions.

3. Residua, like gas oils, have shown variable quality as FCCU feedstocks. Quality is dependent on composition and on detrimental catalyst contaminants such as nickel and vanadium compounds.

4. Metal (Ni and V) contamination of catalysts adversely affected catalyst activities and increased the level of coke laid down on the catalysts.

5. Coimpregnation of catalysts with antimony, as well as nickel and vanadium soaps, showed that antimony compounds prevented losses in catalyst activity. However, the result was not conclusive on coke reduction by the passivator.

6. A comparison of gas oil feedstocks, ranging in composition from aromatic Syncrude vacuum gas oil to cycloparaffinic and paraffinic materials, shows that all saturate feeds produced similar large yields of liquid products. As a result, the saturation of Syncrude vacuum gas oil would be sufficient to produce an excellent FCCU feed.

APPLICATION AND ONGOING WORK

This contract studied non-conventional vacuum gas oils, bitumen, and residua as FCC feedstocks. Advanced metals-tolerant catalysts and a metals passivator have been evaluated by determining MAT yields experimentally with both conventional and synthetic crude atmospheric tower bottoms. These data, along with those for conventional gas oils, provide an experimental basis for estimating commercial yields of transportation fuels from non-conventional FCCU feeds.

SUPPORTING DOCUMENTS

Final Report: "A Study of Incorporating Heavy Oil and Synthetic Crude Residua into Fluid Catalytic Cracking Feedstocks".

TITLE: DEVELOPMENT OF IMPROVED SYNTHETIC CRUDE PROCESSES

CONTRACTOR: Gulf Canada Limited	FILE NUMBER: 3-9057	FUNDING	
	BEGIN/END: July 83/Feb. 85		
		CANMET:	$ 185 587
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	$ 185 587
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: M.F. Wilson	TECHNOLOGY: Upgrading Synthetic Crude Distillates	TOTAL:	$ 371 174

OBJECTIVES

1. Selection of a typical commercial synthetic crude oil.
2. Feedstock preparation and characterization.
3. Performance screening of a series of commercial catalysts in hydrotreating middle distillate and hydrocracking gas oil.
4. Performance optimization of the best hydrotreating and hydrocracking catalysts.
5. Hydrotreating and hydrocracking production runs.
6. Evaluation of the gains in product quality.

PROCEDURE

1. Distillation of typical Athabasca syncrude into three factions - naphtha, middle distillate, and gas oil.
2. Preliminary screening of eight hydrotreating catalysts was carried out in a microreactor. The catalysts were evaluated based on conversion of nitrogen, sulphur, and aromatics.
3. Using the most suitable catalysts, optimum operating conditions were established by doing runs at three different temperatures and pressures.
4. Using the above optimum operating conditions, production runs on middle distillate and gas oil were carried out.
5. The evaluation and testing of products was for motor gasoline, aviation Jet A and B, and diesel fuels.

RESULTS

The typical synthetic crude oil yielded 15.7, 60.4, and 20.4 vol % naphtha, middle distillate, and gas oil, respectively.

A highly active nickel/molybdenum on alumina catalyst was chosen for hydrotreating. An equally active nickel/tungsten on silica/alumina catalyst was selected for hydrocracking of gas oil.

High-severity operating conditions were required to produce suitable quality fuels. These involved pressures of 17.2 MPa(g) for hydrotreating.

Production runs were carried out successfully. In all cases, quality fuels were generated. Details of specification problems are reported.

APPLICATION AND ONGOING WORK

This work is closely related to new refinery operations recently installed in Alberta. The operations are devoted exclusively to upgrading synthetic crude oil to transportation fuels.

SUPPORTING DOCUMENTS

Final Report: "Development of Improved Synthetic Crude Processes and their Impact on Distillate and Other Product Qualities".

TITLE: IMPACT OF PROBLEMATIC COMPONENTS ON SYNTHETIC CRUDE PROCESSING

CONTRACTOR:	Gulf Canada Limited	FILE NUMBER:	3-9059	FUNDING	
		BEGIN/END:	July 83/Feb. 85		
				CANMET:	$ 52 988
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	52 988
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. H. Sawatzky	TECHNOLOGY:	Upgrading Synthetic Crude Distillates	TOTAL:	$ 105 976

OBJECTIVES

The primary objective of this project is to obtain background information on the nature of problematic components and their roles in processing heavy and synthetic feedstocks. A secondary objective is to define a possible new pretreatment process appropriate for facilitating upgrading residual oils.

Samples

1. Athabasca Bitumen - both atmospheric and vacuum distillation bottoms.
2. Lloydminster Heavy Oil - both atmospheric and vacuum distillation bottoms.
3. IPPL Crude - both atmospheric and vacuum distillation bottoms.
4. Suncor Untreated Crude - coker gas oil.
5. Syncrude Synthetic Crude gas oil.

PROCEDURE

Static extractions of the samples were made with dimethyl sulphoxide-water mixtures (DMSO-H_2O), nitromethane, and acetone at slightly below the solvent boiling point with sonication. Later the DMSO-H_2O mixture was optimized for water content and a second extraction was made using DMSO with 6% sulphuric acid.

Supercritical extractions were made with acetone, acetic acid methanol, water, and sulphur dioxide.

All extracts and raffinates were characterized.

In the case of successful extraction of nitrogenous compounds, the raffinates of the extracted samples were subjected to microactivity tests to determine if removal of nitrogenous compounds improved catalytic cracking properties.

RESULTS

Dimethyl sulphoxide with 6% wastes for the first extraction stage, followed by extraction using DMSO with 6% sulphuric acid, was the only promising solvent. The static extractions were successful only with the lighter samples, namely the Syncrude and Suncor gas oils and the IPPL atmospheric distillation bottoms. Extracts accounting for about 4% of the samples, with about 75% of their nitrogen contents, were obtained.

The microactivity tests of the raffinates from successful extraction consistently showed a greater than 5% improved conversion to gasoline over those from the unextracted samples. Addition of the nitrogenous extract decreased conversion. This illustrates the undesirability of these nitrogenous components in catalytic cracking feedstocks.

APPLICATION AND ONGOING WORK

The extractions have also been applied to hydroprocessing feedstocks with marked improvement in processibility. The utilization of the extracts of nitrogenous compounds in asphalts is being studied.

TITLE: DEVELOPMENT AND EVALUATION OF CATALYSTS FOR PRODUCTION OF LIQUID FUELS FROM LOW GRADE HYDROCARBON SOURCES

CONTRACTOR: B.C. Research Council	FILE NUMBER: 0-9174	FUNDING	
	BEGIN/END: Jan. 82/Feb. 83	CANMET:	$ 37 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: J.F. Kriz	TECHNOLOGY: Catalytic Processes for Hydrocarbon Conversion	TOTAL:	$ 37 000

OBJECTIVES

1. Determine the performance of commercial cobalt-molybdenum and nickel-molybdenum based catalysts on refinery pitch and crude liquids derived from Canadian coals.
2. Prepare reduced molybdenum oxide.
3. Determine performance of the prepared catalysts on the crude liquids tested previously.
4. Evaluate and compare technical and economic aspects of the different catalyst systems.

PROCEDURE

Materials were pitch (vacuum residue) from IOCO B.C. Refinery, an anthracene oil supplied by the Nova Scotia Research Foundation, and liquids prepared from coals from B.C. Coal Ltd. Greenhills Mine, Devco No. 26 Harbour Seam, and Hat Creek. The liquids were prepared by hydrotreating the coals in a 2-L autoclave for one hour at 420°C and about 8 MPa hydrogen using a tetralin solvent (3:1 ratio to coal). The crude liquids were separated by extraction with tetrahydrofuran.

The catalyst tests were performed using small (batch) "tubing bomb" reactors pressurized with about 8 MPa hydrogen. The effects of catalysts were characterized by product analysis including extractions, thermogravimetric analyses, and GC gas analyses.

RESULTS

A number of conclusions addressed specific effects of the individual catalysts tested. These were not always consistent for the entire range of operating conditions used. The extent of experimental error could often not be established, making some of the experimental evidence less reliable.

Sulphided commercial catalysts were found to be more efficient than reduced molybdenum in preventing product degradation for refinery pitch and anthracene oil, but the efficiency was comparable in the case of the coal-derived liquids. The commercial catalysts caused greater hydrogen consumption and higher yield of a low-boiling product.

After the final report was issued, the work done under this contract was regarded as leading to a more successful development. Experiments involving feedstocks of wide boiling range indicated that products of higher quality can be obtained and effects of processing conditions can be characterized with much improved confidence.

APPLICATION AND ONGOING WORK

Extension or continuation of this work was not recommended at the time of contract completion.

TITLE: HYDRODESULPHURIZATION OF HYDROCRACKED PITCH FROM ATHABASKA BITUMEN

CONTRACTOR: SNC Inc.	FILE NUMBER: O-9117	FUNDING	
	BEGIN/END: Jan. 81/March 82		
		CANMET:	$ 32 362
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: J. Kriz	TECHNOLOGY: Catalytic Processes for Hydrocarbon Conversion	TOTAL:	$ 32 362

OBJECTIVES

Perform a preliminary investigation of desulphurization of hydrocracked pitch using phosphorus and phosphine at atmospheric pressure. Use a batch autoclave experimental system for performing the tests.

PROCEDURE

Phosphine was generated in a flask according to:

$$2P_4 + 3KOH + 9H_2O \rightarrow 5PH_3 + 3KH_2PO_4$$

The pitch sample was dissolved in toluene. Phosphorus and phosphine are expected to react with organic sulphur to form phosphorus polysulphide and hydrogen sulphide (R.A. Meyers, "Coal Desulphurization", Chapter 3, Marcel Dekker, New York, 1977). Experiments were performed with phosphine and toluene-dissolved pitch at atmospheric pressure and 100°C and 250°C.

RESULTS

The planned experiments were completed. Sulphur removal between 10 to 18% was observed. The formation of polysulphides was not observed, thus it was assumed that the sulphur removal proceeded via formation of volatile sulphur compounds. Phosphorus was found in the product.

APPLICATION AND ONGOING WORK

Although a small amount of desulphurization was observed, the method was not found to be effective enough to warrant further development.

TITLE: HYDRODESULPHURIZATION OF HYDROCRACKED PITCH FROM ATHABASCA BITUMEN

CONTRACTOR:	W & Y Consultants Kingston Limited	FILE NUMBER:	2-9002	FUNDING	
		BEGIN/END:	May 82/May 83		
				CANMET:	$ 63 452
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	J.F. Kriz	TECHNOLOGY:	Catalytic Processes for Hydrocarbon Conversion	TOTAL:	$ 63 452

OBJECTIVES

Continue with method development for removal of sulphur from hydrocracked pitch using microwave-enhanced catalytic hydrodesulphurization.

Confirm and extend previously obtained experimental data which were subject to a patent application.

PROCEDURE

The method is based on the use of metal-metal hydride catalysts that cause hydrodesulphurization of solid materials such as pitch. This reaction was found to take place at atmospheric conditions (ambient temperature and pressure) when facilitated by microwave irradiation. An experimental system consisted of a source of microwave irradiation and a glass reaction vessel equipped with lines for hydrogen inlet and product gas outlet. A number of catalysts have been tested and analyses were performed on the product sulphur content.

RESULTS

The results indicated that certain metal hydrides are more efficient in the microwave catalytic desulphurization of pitch than metal powders. Up to 70% sulphur removal was achieved (at ambient conditions) and hydrogasification of the original material to a small extent was also observed. Power requirements were estimated and the need for a more suitable design was identified.

APPLICATION AND ONGOING WORK

Continuation of this work and work on related aspects was made possible through R.A.P. funding. Other projects using the same technique, but applied to different processes, are supported by AOSTRA.

SUPPORTING DOCUMENTS

Final Report: "Study on Hydrodesulphurization of Hydrocracked Pitch from Athabasca Bitumen - Further Test of the Microwave Process".

TITLE: APPLICATION OF PHOTOMETRIC TECHNIQUES TO THE STUDY OF THREE-PHASE FLUIDIZED BED REACTORS USED IN THE HYDROCRACKING OF HEAVY OILS

CONTRACTOR:	University of Western Ontario	FILE NUMBER:	I-9057	FUNDING	
		BEGIN/END:	Nov. 81/Oct. 83	CANMET:	$ 128 565
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D.D.S. Liu	TECHNOLOGY:	Catalytic Processes for Hydrocarbon Conversion	TOTAL:	$ 128 565

OBJECTIVES

1. Engineer and test photometric probes based on the use of fibre optics for measurements of hydrodynamic properties such as voidage, bubble sizes, and velocities in gas-liquid three-phase flows.
2. Estimate the holdups of different phases (gas-liquid-solid) based on results of photometric and pressure measurements.
3. Perform feasibility tests for industrial applications of fibre optical probes selected in multiphase flow systems.

PROCEDURE

1. Develop a data acquisition system.
2. Construct a multi-beam laser absorption photometric system.
3. Construct a bidimensional (2D) column for generating gas-liquid-solid three-phase flows.
4. Carry out absorption photometric measurements of three-phase flows in the 2D column.
5. Construct the U-shape fibre optical detectors according to the suggestion of the Scientific Authority and install them on the 2D column.
6. Carry out bubble measurements in three-phase flows using the U-shape fibre probes.
7. Install pressure taps on the column.
8. Carry out optical and pressure measurements simultaneously.
9. Estimate holdups of different phases from optical and pressure measurements.
10. Construct a cylindrical three-phase column, and equip the column with U-shape fibre probes and pressure taps.
11. Carry out measurements similar to those for the 2D column.

RESULTS

1. The use of multiple laser beam absorption technique allows the measurements of bubble velocities in a 2D column. Applications are limited to a small beam path, especially in strongly absorbing material, due to excessive beam attenuation at longer path lengths.
2. The U-shape fibre probes allow a very sensitive detection of bubbles across each probe.
3. A significant achievement in the development of multi-probe systems was made. They were successfully applied to measurements of bubble sizes and velocities in both two-phase or three-phase flows.
4. The demonstration of industrial applications was carried out in a simulating cylindrical column.

APPLICATION AND ONGOING WORK

Potential applications of the U-shape fibre probes can be judged by the following factors:

1. High melting point.
2. High hardness.

3. Reasonable range of refractive index to be chosen.
4. Physical size can be very small.
5. High inertness to chemicals.

TITLE: OPTIMIZATION OF BENCH SCALE HYDROGENATION UNIT

CONTRACTOR:	Stearns Catalytic Ltd.	FILE NUMBER:	3-9183	FUNDING	
		BEGIN/END:	Oct. 83/March 84		
				CANMET:	$ 30 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	M. Ikura	TECHNOLOGY:	Catalytic Processes for Hydrocarbon Conversion	TOTAL:	$ 30 000

OBJECTIVES

Optimize the operation and performance of the bench-scale hydrogenation unit by processing coal/bitumen mixtures under high temperature and pressure.

PROCEDURE

1. Introduce and run slurry feeds.
   Check - slurry circulation pump
   - high-pressure piston pump
   - product collection system
   - slurry feed rate.

2. Provide a test run for a mass balance.

3. Modify system components as required.

RESULTS

1. Slurry circulation and high-pressure piston pumps function properly as designed.

2. Product collection system is functional.

3. Slurry feed tank system was modified to reduce pipe stress loadings.

4. A proportional controller was added to the feed tank, resulting in a constant stress loading due to pipe expansion.

5. Installation of a gas recirculation loop including gas condenser, gas compressor, and gas flow control loop to simulate a scaled-up plant.

6. Test runs at various feed rates were carried out.

TITLE: INVESTIGATION OF DIRECT CONVERSION OF CH_4 TO CH_3OH BY CONTROLLED OXIDATION

CONTRACTOR: University of Manitoba	FILE NUMBER: 2-9106	FUNDING	
	BEGIN/END: Oct. 82/March 84		
		CANMET:	$ 44 850
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: D. Fung	TECHNOLOGY: Conversion of Natural Gas to Liquid Fuels	TOTAL:	$ 44 850

OBJECTIVES

Investigate the chemical conversion process of methane to methanol under controlled oxidation conditions at various temperatures, pressures, and oxygen levels.

PROCEDURE

The controlled oxidation reaction of methane to methanol was investigated at 450°C at pressures of 5.06 and 12.66 MPa (50 and 125 atmospheres) and at oxygen levels of 5, 10, and 20%.

The experiments were carried out in a 316 stainless steel reactor tube (75 cm x 0.4 cm ID). Two reaction systems were devised:

1. Monoflow system: where the reactants (CH_4, O_2, N_2) were premixed in a single cylinder before going into the reactor.
2. Dual flow system: where the reactants were delivered from separate supply cylinders to a small mixing chamber.

RESULTS

Yields of methanol of 80% can be obtained at 450°C and 5.06 MPa (50 atm) at the 50% oxygen level. Material balances for the reactants and products are within 5-10% for carbon. The methanol yield depends on the degree of mixing of the reactant gases in the dual flow system. The more they can be mixed, the better is the yield of the product.

APPLICATION AND ONGOING WORK

This project will be continued in fiscal year 1984-85.

TITLE: DEVELOPMENT AND PERFORMANCE TESTS OF A NEW CATALYST FOR THE CONVERSION OF SIMPLE ALCOHOLS INTO SYNTHETIC GASOLINE

CONTRACTOR:	Centre de Recherche Industrielle du Quebec	FILE NUMBER:	2-9156	FUNDING	
		BEGIN/END:	Nov. 82/Sept. 84	CANMET:	$ 336 831
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G. Jean	TECHNOLOGY:	Conversion of Natural Gas to Liquid Fuels	TOTAL:	$ 336 831

OBJECTIVES

1. Optimize the catalyst formulation and perfect the development of a new zeolite catalyst that can produce gasoline from methanol.

2. Measure the catalyst stability and acquire process data for optimum operating conditions and future economic feasibility study.

PROCEDURE

1a) Prepare a series of catalysts having different compositions (metal content).
 b) Test these catalysts in a microreactor in order to obtain sufficient data to determine the catalyst activities.
 c) Complete analysis of gasoline produced.

2a) Test the best formulation identified in Phase 1, under continuous operation.
 b) Vary process conditions to determine optimum operating conditions.

RESULTS

1. Several catalysts of different compositions.

2. Process data on various catalysts.

3. Choice of the best catalyst formulation.

4. Determination of catalyst's lifespan.

5. Determination of optimum operating conditions.

APPLICATION AND ONGOING WORK

1. CRIQ is seeking support from the private sector to pursue the development of this process.

2. The process does not appear economical at present, but this could change with a substantial increase in oil prices.

TITLE: PREPARATION AND CHARACTERIZATION OF ZEOLITES

CONTRACTOR: University of Laval	FILE NUMBER: 4-9123	FUNDING	
	BEGIN/END: June 84/Sept. 84		
		CANMET:	$ 2 900
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: V.M. Allenger	TECHNOLOGY: Conversion of Natural Gas to Liquid Fuels	TOTAL:	$ 2 900

OBJECTIVES

Synthesize zeolites having four different silica/alumina ratios from the Pentasil family.

Carry out ion-exchange of prepared zeolites to obtain H-form. Activate zeolites by calcination.

Carry out characterization of the prepared catalysts.

PROCEDURE

The contractor purchased necessary equipment (Teflon flasks, autoclave, etc.) and chemicals, and developed a procedure for synthesis from known or new art.

The contractor ion-exchanged the zeolites with NH_4+ and proceeded to calcine the batches at an appropriate temperature.

PIXE-PIGE, X-ray diffraction, and electron microscopy were used to characterize the samples.

RESULTS

Four lots of catalysts were prepared having Si/Al ratios in the order of 30, 60, 90, and 200, respectively.

The catalysts in their final form were received on September 30, 1984. Roughly 100 g of each batch was received.

The analyses performed showed good crystalline structure and the required unit cell size.

APPLICATION AND ONGOING WORK

Design and evaluation of catalysts and processes for the conversion of natural gas into hydrocarbon fuels.

TITLE: DIRECT PRODUCTION OF AROMATIC HYDROCARBONS/GASOLINE FROM SYNTHESIS GAS

CONTRACTOR:	University of Saskatchewan	FILE NUMBER:	2-9137	FUNDING	
		BEGIN/END:	Nov. 82/Nov. 84		
				CANMET:	$ 117 218
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. S.H. Ng	TECHNOLOGY:	Conversion of Natural Gas to Liquid Fuels	TOTAL:	$ 117 218

OBJECTIVES

Produce aromatic-rich, high-octane number gasoline from synthesis gas in one step at rather mild conditions (101.3 kPa and 250-300°C) using Fischer-Tropsch catalysts in combination with zeolite catalysts.

PROCEDURE

1. Review of the current literature on the subject.
2. Preparation and characterization of HZSM-5.
3. Preparation and screening of six Fischer-Tropsch (FT) catalysts using a microreactor.
4. Testing of FT-HZSM-5 catalyst combination in a microreactor.
5. Design and construction of a 12.7 mm I.D. packed bed reactor.
6. Testing of FT-HZSM-5 combined catalyst in a 12.7 mm I.D. packed bed reactor.
7. Testing of FT-HZSM-5 and FT-ZMQ combined catalysts in a dual-bed microreactor.

RESULTS

1. Microreactor study indicates that:
   a) The presence of HZSM-5 results in the formation of aromatics that are not formed when FT catalyst is used alone. In addition, the presence of HZSM-5 causes a substantial decrease in methane selectivity, lowers the olefin/paraffin ratio, and markedly increases the selectivity of C_4 fraction.
   b) It is believed that the olefins and oxygenates produced from the zirconia-based Co-Ni FT catalysts are the precursors for the aromatization reaction over HZSM-5. The formation of aromatics is favoured at high HZSM-5/FT catalyst ratios, low space velocities, and high reaction temperatures.
2. In the 12.7 mm I.D. reactor:
   a) Over the FT catalyst alone, the CO conversion declines with time-on-stream, with most of the decline occurring during the initial period of operation.
   b) The initial deactivation of the FT catalyst promotes the formation of methane and olefins, while the C_5+ selectivity exhibits almost no variation with time-on-stream.
   c) Over the mixed FT-HZSM-5 system, the CO conversion declines with time-on-stream, showing a trend similar to that observed over the FT catalysts alone. However, the presence of HZSM-5 causes a slight increase in CO conversion and CO_2 yield at all times of operation.
   d) For the FT-HZSM-5 system, a dramatic variation in the product distribution takes place during the first 24 h of operation. A sharp increase in the selectivity of C_5+ fraction, with a simultaneous drop in the selectivities of C_1 to C_4 fractions, is observed during this period.
   e) For the FT-HZSM-5 system, the presence of HZSM-5 results in significant reduction in olefinic content of the products. In addition, isobutane increases significantly in the presence of HZSM-5.
3. In the dual-bed microreactor system, increasing the HZSM-5/FT or ZMQ/FT ratios while keeping both reactors at 250°C results in:
   a) A decrease in the selectivity of the C_5+ aliphatics fraction, with a corresponding increase in the production of aromatics.

b) An increase in the selectivity of isobutane.
c) A decrease in the olefinicity of the C_2 and C_3 fractions with a corresponding increase in the production of aromatics.

4. In the dual-bed microreactor system, the production of aromatics is maximized at a HZSM-5/FT ratio of 4 and HZSM-5 reactor temperature of 300°C.

5. In the dual-bed microreactor system, under the same reference conditions:
   a) Catalyst HZSM-5 is found to produce greater amounts of aromatics than the catalyst ZMQ.
   b) Catalyst ZMQ produces substantially greater amounts of C_5+ aliphatics than HZSM-5.
   c) The C_3 fraction is much larger, while the $i\text{-}C_4$ fraction is much smaller, when using catalyst ZMQ as compared to that when HZSM-5 is used.

APPLICATION AND ONGOING WORK

Further work is ongoing. The selected zirconia-based Co-Ni FT catalyst is used in combination with HZSM-5 and ZMQ in a dual-bed 12.7 mm I.D. reactor system under high pressure.

SUPPORTING DOCUMENTS

Final Report: "Direct Production of Aromatic Hydrocarbons/Gasoline from Synthesis Gas".

TITLE: CARBON DEPOSIT MORPHOLOGY ON METAL SURFACES DURING HYDROCARBON SYNTHESIS

CONTRACTOR:	University of Ottawa	FILE NUMBER:	3-9161	FUNDING	
		BEGIN/END:	Nov. 83/May 85		
				CANMET:	$ 52 300
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. J. Galuszka	TECHNOLOGY:	Conversion of Natural Gas to Liquid Fuels	TOTAL:	$ 52 300

OBJECTIVES

Carbon has long been recognized as an important intermediate in the hydrogenation of carbon monoxide. It is generally believed to form by dissociative adsorption of carbon monoxide on the metal, but the subsequent steps whereby carbon either accumulates or reacts are not well understood.

A research program has been established that addresses the question of the possible effectiveness of the various forms of surface carbon in the synthesis of hydrocarbons. The proper conditions for creation of various forms of carbon, i.e., metal surface morphology, temperature, and CO/H_2 mixture composition have been investigated. Nickel and iron surfaces were compared in this respect to find out more about the different performance of these two metals in relation to the hydrocarbon synthesis reaction.

PROCEDURE

A closed circulation system incorporating a gas chromatograph was used for the present study. A thin layer of metal sputtered on a quartz plate acted as a catalyst. The Edward Sputter Coater, Model S150A, was used to prepare metal films on quartz plates. The total amount of metal on a quartz plate was quantitatively analyzed by the use of Direct Current Plasma Spectroscopy. The SEMCO NANOLAB #7 SEM was used to examine the metal films.

RESULTS

Oxidation-reduction treatment altered both iron and nickel surface morphology, however, final appearance and catalytic activity were different. The nickel surface was very much affected by hydrogenation and carbon monoxide disproportionation reaction. No reactive surface carbon was detected by SEM for either surface.

Surface carbon formation was the slowest step during hydrocarbon formation on nickel, whereas hydrogenation of the surface carbon seems to be the rate-determining step in the case of the iron catalyst.

APPLICATION AND ONGOING WORK

The data obtained have been presented at the 17th Biennial Conference on Carbon, Lexington, Kentucky and a journal publication is pending. Also, the data have been utilized as a base for establishing an in-house research program. Continuation of contract work in the same direction is being considered.

TITLE: EVALUATION OF OIL SHALES FROM EASTERN CANADA AND CONCENTRATION OF KEROGEN-RICH OIL SHALE COMPONENTS

CONTRACTOR:	Research and Productivity Council of New Brunswick	FILE NUMBER:	0-9068	FUNDING	
		BEGIN/END:	Nov. 80/July 82		
				CANMET:	$ 45 970
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. H. Sawatzky	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 45 970

OBJECTIVES

The major objective was to determine whether the yield of some of the Albert oil shales in New Brunswick could be significantly increased by retorting under hydrogen pressure rather than in the conventional Fischer retorting. This required the establishing of facilities for retorting under hydrogen pressure as well as for conventional retorting.

A second objective concerned the production of concentrate with standard beneficiation methods.

The overall goal of these studies was to promote the development of technology for economic exploitation of oil shales, as well as establishing a new source of liquid fuels in eastern Canada.

PROCEDURE

Facilities for retorting the oil shale at pressures up to 3.45 MPa of hydrogen and temperatures as high as 700°C were established, as well as for standard Fischer retorting tests. The conditions for obtaining optimum yields were determined for both types of retorting.

Six samples of Albert shale varying in oil content from less than 50 to 250 L/t, obtainable by the conventional Fischer retorting, were then retorted under hydrogen and the liquid yields determined.

The concentration of kerogen in oil shale was studied for size separation, spherical agglomeration, gravity methods, and in flotation.

RESULTS

The retorting under hydrogen pressure did not increase the liquid yields from the oil shale samples that were studied. However, the Fischer retorting produced yields that corresponded to carbon conversions up to 88%. This was considerably higher than expected because eastern U.S. shales yielded only 25% conversions. This can be explained by the fact that the oil shales studied are considerably less mature and contain more hydrogen than their older U.S. counterparts.

This facility can be used to determine whether hydrogen pressure can increase the retorting yields of other Canadian oil shales.

Only gravity separations showed promise for concentrating kerogen for viable industrial operations. Five grinding and gravity separations gave concentrations that could produce 350 L/t, but yields were low.

TITLE: EVALUATION OF CANADIAN OIL SHALES

CONTRACTOR:	New Brunswick Research and Productivity Council	FILE NUMBER:	2-9015	FUNDING	
		BEGIN/END:	June 82/March 83		
				CANMET:	$ 75 500
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	E. Furimsky	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 75 500

OBJECTIVES

Assess oil shales from Eastern Canada with respect to their liquid production potential.

Determine oil yields during retorting in an inert atmosphere and in the presence of hydrogen.

PROCEDURE

The experimental work was based on the use of the Pyrochem retort for high-temperature and high-pressure tests. The low-temperature retorting was performed in a modified Fischer assay retort.

RESULTS

Results confirmed the high response of oil shales from Eastern Canada to retorting in the presence of hydrogen, i.e., the yields of liquids were increased substantially.

It was further confirmed that oil shales from New Brunswick are comparable, in their oil yields, to the U.S. shales selected for commercialization.

APPLICATION AND ONGOING WORK

Further testing is anticipated to determine the optimal conditions of retorting. The experimental results will be used for technical and economic assessment of oil shale reserves as a potential source of liquid fuels.

TITLE: EFFECT OF TEMPERATURE AND HYDROGEN PRESSURE ON LIQUID YIELDS FROM SELECTED OIL SHALES

CONTRACTOR:	New Brunswick Research and Productivity Council	FILE NUMBER:	4-9066	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 58 388
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. E. Furimsky	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 58 388

OBJECTIVES

Optimize hydrogen retorting of eastern Canadian oil shales to achieve high yields of liquid products.

Determine the optimal hydrogen pressure and temperature.

Five samples of shales were evaluated (two from New Brunswick, two from Ontario, and one from Newfoundland).

PROCEDURE

Hydrogen retorting experiments were performed in the pyrochem retort with a fixed bed of shale. The hydrogen pressure was varied from 0.69 to 5.52 MPa (100 to 800 psi) with temperatures in the range of 450 to 700°C. The liquid products were trapped in an ice-cooled calibrated receiver and their amount determined.

RESULTS

Results show that for New Brunswick oil shales, hydrogen pressure of about 0.69 MPa (100 psi) is sufficient to achieve improved yields. For Ontario and Newfoundland oil shales, hydrogen pressure of about 3.45 MPa (500 psi) is required to achieve better yields.

APPLICATION AND ONGOING WORK

The results of this work will be used to compare the production yields of liquid fuels from thermal retorting and from rapid pyrolysis. The aim is to select a suitable process for converting eastern Canadian oil shales to transportation fuels.

TITLE: RAPID PYROLYSIS OF NEW BRUNSWICK OIL SHALES

CONTRACTOR:	University of British Columbia	FILE NUMBER:	4-9000	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 32 970
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. E. Furimsky	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 32 970

OBJECTIVES

Evaluate liquid production potential of New Brunswick oil shales using rapid pyrolysis in a spouted bed reactor.

PROCEDURE

Most of the experiments were performed in a single-stage electrically heated spouted bed. A few experiments were conducted in a two-stage unit with an upper pyrolysis stage and a lower combustion stage.

RESULTS

Effects of temperature and particle size have been evaluated. In the temperature range of 450° to 550°C, using three particle size fractions in the range of 0.5 to 4 mm, the 2- to 4-mm fraction gave the highest yields of liquid products. For this fraction, the yield of liquids was more than 90% of that obtained by Fischer assay.

APPLICATION AND ONGOING WORK

This work will be used to compare the costs of liquid production by different technologies, i.e., hydrogen retorting and thermal retorting. Also, some additional research will be conducted at CANMET as a result of this contract.

TITLE: DEMONSTRATION OF AN INTEGRATED OIL SHALE RETORT SYSTEM

CONTRACTOR:	Research and Productivity Council	FILE NUMBER:	3-9086	FUNDING	
		BEGIN/END:	Oct. 83/Dec. 84		
				CANMET:	$ 126 671
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	126 671
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	E. Furimsky	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 253 342

OBJECTIVES

1. Development of a new process for an integrated utilization of New Brunswick oil shales and Minto coal.

2. Decrease in sulphur emissions via co-combustion of oil shales with the high-sulphur coal.

PROCEDURE

The two-stage process includes the following:

1. Retorting of oil shale in a vertical retort to produce transportation fuels.

2. Co-combustion of spent shale from the retort with a high-sulphur coal to supply heat for the retorting and for other needs in the plant.

RESULTS

Experimental results, such as yields of liquid products, properties of liquid products, data on the operability of the units, sulphur emissions from the combustor, etc. are summarized and interpreted in the final report.

APPLICATION AND ONGOING WORK

The continuation of this program (Phase 2) follows the completion of Phase 1. The work statement for the work in Phase 2 will include some modification of combustor and hot gas distributor, to ensure continuous operation in the integrated mode.

TITLE: EVALUATION OF PROCESSING OPTIONS FOR THE OIL SHALES OF ONTARIO

CONTRACTOR:	Watts, Griffis and McQuat Limited	FILE NUMBER:	4-9311	FUNDING	
		BEGIN/END:	Jan. 85/June 85	CANMET:	$ 45 267
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	M. Skubnik	TECHNOLOGY:	Conversion of Oil Shale to Liquid Fuels	TOTAL:	$ 45 267

OBJECTIVES

Identify the most appropriate mining and processing routes for each of four oil shales from Ontario, specifically Kettle Point, Whitby, Marcellus, and Long Rapids.

Assess the economic viability and environmental impact, and develop a technical base for further R&D.

PROCEDURE

1. Data compilation.
2. Mining review.
3. Beneficiation review.
4. Processing review.
5. Economic assessment.
6. Environmental and energy supply review.

RESULTS

1. The total resource of the Kettle Point formation (near Sarnia) representing 4160 million m^3 oil shale (26 L/t Fischer Assay) appears to have the best potential for development.
2. Open pit mining would be the most likely method of exploitation.
3. Beneficiation of raw shale prior to retorting appears technically feasible.
4. Retorting in the presence of hydrogen, by HYTORT or other processes, can more than double Fischer Assay oil yields and significantly improve the quality of the product.
5. Capital costs (mid-1982 U.S. dollars) for a 30 000 ton/day (27 215 tonne/day) oil shale retorting complex, using the HYTORT retort process to produce 2225 m^3 oil/day, would be $820 million and annual operating costs of the plant would be $106.4 million. The crude shale oil should sell at $40.63 and $49.54 (1982 U.S. dollars) per bbl to generate a 15% ROR at 100% and 25% equity financing, respectively.

APPLICATION AND ONGOING WORK

The contractor is willing to continue with the experimental program on beneficiation, hydrogen retorting, oil product characterization, and spent shale utilization including extraction of V, Ni, Cr, Ag, and Mo.

TITLE: MARKET SURVEY OF PRESSURE VESSELS FOR SYNTHETIC FUEL PRODUCTION SYSTEMS

CONTRACTOR:	Chinook Fuel Innovations Ltd.	FILE NUMBER:	0-9168	FUNDING	
		BEGIN/END:	July 81/Dec. 81		
				CANMET:	$ 38 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	J.T. McGrath	TECHNOLOGY:	Materials for Hydrocarbon Processing	TOTAL:	$ 38 000

OBJECTIVES

Provide a Canadian market assessment of the pressure vessels required for energy conversion processes including tar sands and heavy oil upgrading, coal liquefaction, and gasification.

PROCEDURE

Surveyed the Canadian needs for heavy wall reactor vessels.

RESULTS

1. Identified specific energy conversion projects and likely number of pressure vessels to year 2000.
2. Identified materials and fabrication techniques required to make Canadian fabricators competitive with foreign suppliers of heavy wall reactor vessels.

APPLICATION AND ONGOING WORK

This survey provided a complete picture of the major energy conversion projects and the number, size, and specifications of the large reactor vessels required for these projects as anticipated in 1982. Unfortunately, the market has declined since then and future predictions are difficult in 1984.

TITLE: DEVELOPMENT OF AN ON-LINE ACOUSTIC EMISSION MONITORING SYSTEM FOR WELDING THICK-WALLED VESSELS

CONTRACTOR:	Tektrend International Inc.	FILE NUMBER:	I-9038	FUNDING	
		BEGIN/END:	Aug. 81/Oct. 84		
				CANMET:	$ 169 648
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	V. Caron	TECHNOLOGY:	Materials for Hydrocarbon Processing	TOTAL:	$ 169 648

OBJECTIVES

The project was to develop a self-contained intelligent welding monitoring station based upon the use of advanced pattern-recognition and signal classification techniques to provide real-time process and quality control during the welding of thick-walled pressure vessels.

PROCEDURE

The project comprised three main phases:

1. Phase I included preliminary data acquisition using laboratory specimens and data analysis to establish feasibility and design criteria for the next two phases.

2. Phase 2 involved design and construction of the prototype unit (hardware), identification and development of better features to use with AE signal classification using advanced signal analysis package (software).

3. Phase 3 included development of the interactive data acquisition software package and laboratory demonstration in the CANMET welding equipment facilities.

RESULTS

The main results were the design and construction of a prototype unit and the development of a complex software in order to achieve, by means of acoustic emission, the location and identification of defects in the course of a welding operation. Welding tests were done at CANMET to check on the suitability of both hardware and software under those test conditions. Although the results obtained were satisfactory, they were limited to major weld cracking. It should be explained that the projected tests were not expected to provide a final assessment but rather to demonstrate that the system developed was operational. Further tests will be needed to determine its reliable and effective capability to industrial applications.

SUPPORTING DOCUMENTS

Final Report and Technical Appendix: "Acoustic Emission Monitoring System for Welding Thick-Walled Vessels", March 1985.

TITLE: DEVELOPMENT AND IMPLEMENTATION OF A GENERAL PURPOSE SIGNAL ANALYSIS SYSTEM FOR NONDESTRUCTIVE TESTING BASED UPON PATTERN RECOGNITION

CONTRACTOR:	Tektrend International Inc.	FILE NUMBER:	3-9007	FUNDING	
		BEGIN/END:	May 83/Dec. 84		
				CANMET:	$ 113 691
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	J.P. Monchalin	TECHNOLOGY:	Materials for Hydrocarbon Processing	TOTAL:	$ 113 691

OBJECTIVES

By analysis of the signal, obtain a better recognition and characterization of the flaw.

PROCEDURE

Use pattern recognition algorithms.

RESULTS

A software program for ultrasonic NDT that includes a preprocessor and classification software has been developed. It has been applied to classification by size of weld defects.

Two reports were prepared for publication:

1. Ultrasonic Welding Defect Sizing by Advanced Pattern Recognition Techniques.

2. Defect Characterization and Sizing in Pipeline Weldments by Analysis of Ultrasonic Echo Features.

APPLICATION AND ONGOING WORK

Identification and sizing of flaws for all kinds of ultrasonic NDT.

SUPPORTING DOCUMENTS

1. Final report including a theory of operation, user's guide, and two scientific reports (published papers).

2. Software for VAX and LSI-11 computers.

TITLE: DESIGN, DEVELOPMENT, ASSEMBLY AND TESTING OF AN AUTOMATED ULTRASONIC TESTING SYSTEM FOR THE CHARACTERIZATION OF DEFECTS IN WELDMENTS

CONTRACTOR: Techno Scientific Inc.	FILE NUMBER: 2-9127	FUNDING	
	BEGIN/END: Feb. 83/Nov. 85		
		CANMET:	$ 245 332
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: D. Mak	TECHNOLOGY: Materials for Hydrocarbon Processing	TOTAL:	$ 245 332

OBJECTIVES

Display a three-dimensional image of an object by collecting and analyzing ultrasonic data.

PROCEDURE

Using either a rotating transducer or putting an object on a rotating turntable, a three-dimensional image can be constructed.

RESULTS

Images are displayed in final report.

APPLICATION AND ONGOING WORK

System can be applied to imaging defects in metal.

TITLE: SCANNING TRANSMISSION ELECTRON MICROSCOPY STUDIES OF HIGH-STRENGTH LOW-ALLOY STEELS

CONTRACTOR: McMaster University	FILE NUMBER: O-9133	FUNDING	
	BEGIN/END: Aug. 81/March 84	CANMET:	$ 108 880
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: J.D. Boyd	TECHNOLOGY: Materials for Oil and Gas Pipelines	TOTAL:	$ 108 880

OBJECTIVES

Utilize the unique capabilities of a dedicated scanning transmission electron microscope (STEM) to produce fundamental knowledge and data on the structure of HSLA steels relevant to several PMRL projects, and carry out pioneering work in the development of techniques for applying the STEM to metallurgical problems.

PROCEDURE

Preparation of suitable thin foils and replicas from various PMRL-supplied materials, followed by extensive microstructural characterization, both visually and chemically, in a high-resolution dedicated STEM.

RESULTS

1. Internationally recognized study on the complex nature of mixed carbonitrides in both as-cast and as-rolled HSLA steels.

2. Development of a thermodynamic microsegregation model to aid in the understanding of carbonitride formation.

3. Detailed characterization of the evolution of carbonitride morphology.

4. A comparison of elemental detection via STEM and Scanning Auger Microscope regarding P segregation in Cr-Mo-V steel.

5. The use of STEM microdiffraction, assisted by a custom computer program, to study the strain distribution in shear bands.

6. Preparation of experimental standards for X-ray and electron energy loss analysis.

7. Special metallographic techniques for the examination of large areas of microalloyed steels, especially the as-cast state.

8. Several conference presentations, six publications, plus PMRL deliverables (experimental standards, computer program).

APPLICATION AND ONGOING WORK

Produced metallurgical data directly relevant to several current PMRL projects that, either wholly or partially, are continuing from where this contract stopped.

TITLE: EFFECTS OF MOLYBDENUM, TITANIUM, AND NIOBIUM ON THE HOT WORKING (CONTROLLED ROLLING) OF LINE-PIPE STEELS - PHASE 3

CONTRACTOR: McGill University	FILE NUMBER: 0-9171-2	FUNDING	
	BEGIN/END: April 84/March 85		
		CANMET:	$ 67 498
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: G.E. Ruddle	TECHNOLOGY: Materials for Oil and Gas Pipelines	TOTAL:	$ 67 498

OBJECTIVES

Conduct experimental research to determine the effects of the microalloying elements Mo, Nb, and Ti on the rates of recrystallization, grain growth, and precipitation in terms of controlled-rolling practice of high-strength line-pipe grade steels, with a view to enabling reduction of microalloying costs and improvement of steel properties.

1. Examine grain-coarsening behaviour during initial reheat of the steels, and choose a reheat treatment that will produce consistent, uniform starting grain sizes.

2. Determine the effects of Mo, Nb, and Ti in solution on the retardation of dynamic recrystallization, and relate these effects to roll-separating forces in controlled rolling. Steels microalloyed with Mo, Nb, and Ti, singly and in combination, are to be tested using hot compression and/or hot torsion methods.

3. Determine the precipitation kinetics of Nb(CN) and TiC, and the effects of precipitation on dynamic and static recrystallization and grain growth in austenite.

4. Establish guidelines for composition and thermomechanical treatment of Nb- and Ti-microalloyed steels in controlled-rolling practice.

PROCEDURE

The investigation was divided into sub-projects as follows:

1. Dynamic recrystallization and precipitation behaviour in singly alloyed Nb and V steels.

2. Coarsening of Nb(CN) precipitates under rolling conditions.

3. Effects of microalloying elements in solution on retardation of recrystallization.

4. Controlled-rolling behaviour of Mo-microalloyed steels.

5. Static recrystallization behaviour of singly and multiply alloyed Mo, Nb, and V steels.

6. Effect of multiple microalloying additions on recrystallization and precipitation behaviour.

7. Effect of Mn addition on the controlled-rolling behaviour of Ti-microalloyed steels.

8. Solute hardening in Ti-microalloyed steels.

9. Effect of Ti concentration on the precipitation of TiC.

10. Grain-coarsening behaviour of Ti- and Nb-microalloyed steels.

RESULTS

Following are some of the principal results of the investigation that the contractors have discussed in terms of controlled-rolling practice in the supporting documents.

1. While addition of V led to very little solute retardation of static recrystallization of deformed austenite, Mo addition was much more effective, and Nb addition had the strongest retardation effect. The effects were observed prior to the start of appreciable precipitation.

2. The increases in yield strength of austenite per 0.1 wt % addition of Nb, Ti, Al, V, Mo, Mn, and Si are 44, 42, 25, 8, 5, 2, and 1%, respectively. The effectiveness of these addition elements on solute retardation of recrystallization is in the same rank order. The strengthening effectiveness of the addition elements is related to the combined effects of atom size differences and electronic modulus differences with Fe.

3. Multiple additions of Mn, Mo, Nb, Ti, and V, when present in solution, retard recovery and recrystallization to a greater extent than the sum of their individual effects. Multiple additions also delay precipitation, leading to increased precipitation strengthening of the ferrite.

4. Nb(CN) and TiC precipitation are retarded by an increase of Mn. This is associated with decreased C activity and increased carbide solubility.

5. The addition of Mo retards precipitation of both Nb(CN) and VN such that the proportion of precipitation in austenite is decreased, and in ferrite is increased, which leads to increased precipitation strengthening of the ferrite.

6. Nb(CN) precipitates coarsen at a greatly increased rate, during and following deformation, to a size that renders them ineffective in retarding austenite recrystallization; and recrystallization itself further accelerates precipitate coarsening.

APPLICATION AND ONGOING WORK

For CANMET and Canadian industrial development of thermomechanical processes using Nb- and Ti-bearing steels, e.g., strip for light gauge tubing, conventional gauge plate for line-pipe, and marine applications.

SUPPORTING DOCUMENTS

Final Report: "The Effects of Molybdenum, Titanium and Niobium on the Hot Working (Controlled Rolling) Behaviour of Line-Pipe Steels", (Phases 1-3), by J.J. Jonas and M.G. Akben, March 1984. (This report includes a bibliography of publications that also document the research results.)

TITLE: EFFECT OF NIOBIUM ON HEAT AFFECTED ZONE TOUGHNESS OF ARCTIC GRADE LINEPIPE

CONTRACTOR: Stelco Inc.	FILE NUMBER: 3-9025	FUNDING	
	BEGIN/END: April 83/Dec. 84		
		CANMET:	$ 20 600
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	DSS:	30 500
AUTHORITY: M. Godden	TECHNOLOGY: Materials for Oil and Gas Pipelines	TOTAL:	$ 51 100

OBJECTIVES

1. Investigate the decreased HAZ toughness caused by Nb in linepipe steels by:
   a) Characterizing the ductile and cleavage fracture resistance of steels with different Nb contents.
   b) Relating the fracture parameters to microstructure.
   c) Studying the effect of Nb on hardenability and microstructure.
2. Develop EELS standards.
3. Develop replication techniques to identify HAZ location with respect to thermal cycle experienced.

PROCEDURE

Three steels of varying Nb content were thermally heat treated to simulate a weld thermal cycle. Mechanical properties were characterizated by:

1. Tensile tests.
2. Charpy V-notch tests.
3. CTOD tests.

Microstructure was characterized by:

1. SEM.
2. Optical metallography.
3. Dilatometry.

Various techniques were tried to accurately trace HAZ location in carbon replicas.

SiO replicas were developed for EELS analysis of C and N.

RESULTS

1. HAZ microstructures have lower critical cleavage stress (therefore higher ductile/brittle transition temperature) than base material.
2. Nb-containing HAZ's have lower critical cleavage stress than those without Nb because they have higher yield stress.
3. A technique to directly observe cleavage fracture initiation was developed in the SEM.
4. A technique was developed to accurately locate regions of HAZ in replicas.
5. EELS standards were developed and delivered to PMRL.

APPLICATION AND ONGOING WORK

The major part of the work developed fundamental explanations of the poor fracture resistance of HAZ microstructures, and will aid in the design of steels with better HAZ toughness.

The techniques developed assist the ongoing PMRL work in developing light/element analysis by EELS, as well as assisting with an investigation of multipass HAZ that is to commence shortly.

SUPPORTING DOCUMENTS

Interim Report: The Effect of Niobium on the Heat-Affected-Zone Toughness of Arctic Grade Line Pipe.

Final Report: "Evaluation of Replication Methods for the Study of HAZ Structures in Multipass Weldments and the Preparation of EELS Standards".

TITLE: DURABILITY OF CONCRETE IN ACIDIC NORTHERN WATERS

CONTRACTOR:	Laboratoire de Beton Ltée	FILE NUMBER:	O-9022	FUNDING	
		BEGIN/END:	Feb. 81/Feb. 82		
				CANMET:	$ 18 920
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 18 920

OBJECTIVES

1. Recovery of concrete test specimens from Lake Sakami.
2. Examination of the specimens with evaluation of any deterioration.
3. Relocation of the specimens to a more accessible site.

PROCEDURE

With the help of divers and sonar equipment, attempts were made to recover the specimens installed in Lake Sakami in 1976. Such attempts eventually proved unsuccessful; however, it was possible to locate the companion samples installed in 1977. These were recovered and transported to La Grande 2 by means of helicopter and trucks. The specimens were then examined for any deterioration and photographed before being reinstalled at a new exposure site near the main LG2 dam.

RESULTS

No significant deterioration observed to this date; however, the project is mostly concerned with long-term effects. Monitoring of the specimens is intended to continue up to 10 years.

TITLE: PERFORMANCE OF PORTLAND CEMENT/SLAG/FLY ASH CONCRETES IN MARINE ENVIRONMENTS - PHASE 2

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	8-9126	FUNDING	
		BEGIN/END:	June 79/Aug. 79	CANMET:	$ 16 994
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 16 994

OBJECTIVES

Study the long-term durability of concrete incorporating blast-furnace slag and fly ash under extreme exposure to sea water including freezing-and-thawing, wetting-and-drying, and salt water attack.

PROCEDURE

Fifty-one concrete mixes were prepared with mix proportions covering a wide strength range, three types of cement, and different percentages of fly ash and slag. A total of 33 prisms and 420 cylinders were cast for field and laboratory studies. The field test specimens, after curing, were transported by trucks to Treat Island, Maine, for long-term exposure to sea water attack. The laboratory test specimens were shipped to CANMET for strength studies.

RESULTS

The work is intended for long-term studies and no results are available yet.

The final report describes the preparation of the concrete mixes.

SUPPORTING DOCUMENTS

Final report: "Preparation of Specimens for Study of Performance of Portland Cement/Slag/Fly Ash Concrete in Marine Environment - Phase 2".

TITLE: DURABILITY OF PORTLAND CEMENT/FLY ASH CONCRETE IN MARINE ENVIRONMENT - PHASE 4

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	0-9156	FUNDING	
		BEGIN/END:	May 81/Jan. 82		
				CANMET:	$ 15 624
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 15 624

OBJECTIVES

Study the long-term durability of fly ash concrete under extreme exposure to sea water including freezing-and-thawing, wetting-and-drying, and salt water attack. A fly ash from Nova Scotia was to be used in the studies.

PROCEDURE

Twenty-four air-entrained concrete mixes, with W/C ratios ranging from 0.40 to 0.60, were prepared using two types of cement and incorporating fly ash as a 25% replacement for cement.

A total of 15 large prisms, 305 x 305 x 915-mm in size, and 205 cylinders, 152 x 305-mm in size, were cast for field and laboratory studies. The large prisms, after curing, were transported to Treat Island, Maine for long-term exposure to sea water attack. The cylinders were either tested at UNB or shipped to CANMET for long-term strength studies.

RESULTS

The work covered by the contract was satisfactorily completed.

Concrete test prisms were cast and shipped to Eastport, Maine for long-term durability studies. Compression tests were made on companion test cylinders for reference purposes.

SUPPORTING DOCUMENTS

Final report: "Preparation of Specimens for Durability of Portland Cement/Fly Ash Concrete - Phase 4". This report consists primarily of a work statement.

TITLE: YEARLY INSPECTION OF FLY ASH/SLAG CONCRETE TEST SPECIMENS EXPOSED AT TREAT ISLAND - PHASE I

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	2-9111	FUNDING	
		BEGIN/END:	Aug. 82/Feb. 83		
				CANMET:	$ 9 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 9 000

OBJECTIVES

Carry out periodical inspection and testing of concrete specimens installed at Treat Island, Maine. This is part of a project to study the long-term performance of various types of concrete exposed to severe environmental conditions such as a combination of freezing-and-thawing, wetting-and-drying, and sea water attack.

PROCEDURE

The contractor was requested to travel to Treat Island to inspect and test more than 100 fly ash/slag concrete test blocks that had been installed on the island during the last four years. The following was carried out:

1. Visual inspection of each block with proper identification of the block.
2. Pulse velocity determinations on each block.
3. Photographic record of deteriorated blocks, and determination of nature and degree of deterioration.
4. Rearrangement of the test specimens after inspection.
5. Detailed report of testing and inspection.

RESULTS

From inspection and testing, only two blocks were found to exhibit extensive deterioration, these being non-air-entrained specimens containing superplasticizers.

A general trend toward increasing surface deterioration was noted in all specimens with increasing replacement of cement by fly ash or slag. However, at this stage there was no evidence of internal deterioration of any of these specimens, regardless of their composition.

(It was found necessary to re-label each block in such a way as to ensure permanent identification.)

TITLE: YEARLY INSPECTION OF FLY ASH/SLAG CONCRETE TEST SPECIMENS EXPOSED AT TREAT ISLAND - PHASE 2

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	3-9056	FUNDING	
		BEGIN/END:	June 83/Oct. 83	CANMET:	$ 10 712
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 10 712

OBJECTIVES

Carry out periodical inspection and testing of concrete specimens installed at Treat Island, Maine. This is part of a project to study the long-term performance of various types of concrete exposed to severe environmental conditions such as a combination of freezing-and-thawing, wetting-and-drying, and sea water attack.

PROCEDURE

The contractor was requested to travel to Treat Island to inspect and test more than 138 fly ash/slag/silica fume concrete test blocks that had been installed on the island during the last five years. The following activities were carried out:

1. Visual inspection of each block with proper identification of the block.
2. Pulse velocity determinations on each block.
3. Photographic record of deteriorated blocks and determination of the nature and degree of deterioration.
4. Rearrangement of the test specimens after inspection.
5. Detailed report of testing and inspection.

RESULTS

In general, the inspection and testing did not reveal any drastic changes in the conditions of most specimens over the previous year; however, a general trend toward increasing surface deterioration in all specimens with increasing replacement of cement by fly ash or slag was clearly observed to continue; this was specially so for concretes with increasing water-to-cement ratios.

Of all specimens exposed, only three non-air-entrained concretes cast from the first phase were found to exhibit extensive deterioration.

TITLE: YEARLY INSPECTION OF FLY ASH/SLAG CONCRETE TEST SPECIMENS EXPOSED AT TREAT ISLAND - PHASE 3

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	4-9019	FUNDING	
		BEGIN/END:	April 84/Feb. 85		
				CANMET:	$ 9 935
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 9 935

OBJECTIVES

Carry out periodical inspection and testing of concrete specimens installed over the last six years at Treat Island, Maine. This is part of a project to study the long-term performance of various types of concrete exposed to severe environmental conditions such as a combination of freezing-and-thawing, wetting-and-drying, and sea water attack.

PROCEDURE

The contractor was requested to travel to Treat Island to inspect and test more than 138 fly ash/slag/silica fume concrete test blocks that had been installed on the island during the last six years. The following was carried out:

1. Visual inspection of each block with proper identification of the block.
2. Pulse velocity determinations on each block.
3. Photographic record of deteriorated blocks and determination of nature and degree of deterioration.
4. Rearrangement of the test specimens after inspection.
5. Detailed report of testing and inspection.

RESULTS

The replacement of cement by slag has no apparent effect on the durability of concrete with a water-to-cement ratio of 0.4. A slight loss in durability is noted with a water-to-cement ratio of 0.5 with 65% replacement. With a water-to-cement ratio of 0.6, a significant increase in deterioration takes place at a 65% replacement level. In this latter case, the deterioration is much more than just a surface phenomenon and involves loss of aggregate particles.

Replacement of cement with both slag and fly ash produces severe deterioration when used at a 60% slag and 20% fly ash replacement rate, even with water-to-cement ratios of 0.4.

APPLICATION AND ONGOING WORK

It would appear that in many cases deterioration is on the threshold of proceeding rapidly, so to obtain maximum information the specimens should be examined and studied closely over the next decade. During that time the effect of mix proportion, cement type, and the role of supplementary cementing materials should become apparent.

TITLE: ACCELERATED TESTING OF CONCRETE IN MARINE ENVIRONMENT

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	2-9136	FUNDING	
		BEGIN/END:	Jan. 83/Sept. 84		
				CANMET:	$ 17 019
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	DSS:	10 500
AUTHORITY:	B. Nebesar	TECHNOLOGY:	Materials for Offshore Structures	OTHER:	5 000
				TOTAL:	$ 32 519

OBJECTIVES

Develop a reliable method for accelerated testing of concrete containing various supplementary cementing materials, and intended for offshore and other uses in the marine environment.

Test results should ideally correlate with long-term exposure tests in natural (sea shore) setting. From the accelerated tests, more reliable and faster decisions about the suitability of various materials and mixes for general marine applications are expected.

Also, the method could possibly be useful for a proposal for a standard method, to be submitted to a standards writing organization.

PROCEDURE

Concrete test specimens were exposed in a specially designed, automated marine environment simulation system to intermittent action of hot air (∿70°C) and reconstituted sea water (at room temperature). The system provides for four cycles per day.

Two types of specimens from three series of concrete mixes were measured; either in the form of cylinders with a central rebar, permitting monitoring of the corrosion potential, or in the form of prisms, particularly for reference specimens.

The following parameters were measured (where applicable): mass in air and water, density, volume, corrosion potential, flexural and compressive strength, dynamic modulus of elasticity from transit time and resonant frequency, and visual appearance.

The results for test and reference specimens were plotted versus the number of cycles (975), thus providing an immediate, direct picture of mix performance that was correlated as well with the long-term tests in natural marine environment.

RESULTS

The accelerated durability test was successful. The apparatus performed well with only an occasional minor malfunction when new concepts were tested. The results obtained from the accelerated durability test compared favourably to those from long-term exposure tests, although they were not absolutely identical. The accelerated durability test and the long-term exposure study also show that similar trends exist between transit time measurements and visual inspection of the surface.

The monitored variables: mass in air, mass under water, volume, density, transit time of a sound pulse, and resonant frequency proved to be sufficient to evaluate the durability of the concrete mixes that were tested. With these measurements it was possible to distinguish a difference in durability between various concrete mixes. It was found that concrete with a W/C ratio of 0.4 showed the best durability, while concrete with a W/C ratio of 0.6 showed inferior durability.

The accelerated test illustrated that 65% slag replacement for cement, coupled with a W/C ratio of 0.6, had a detrimental effect on the durability of the concrete. However, this test does not prove that all slag types have the same detrimental effects on durability.

APPLICATION AND ONGOING WORK

The developed system will be used to further monitor the performance of various concrete mixes in the on-going long-term and the accelerated tests, thus providing a base for technological and standardization decisions. Several units are being assembled at CANMET to start testing concrete mixes containing various cementing materials. The information obtained and disseminated will affect the use of concrete in the marine environment.

SUPPORTING DOCUMENTS

The final report (177 pp.), a literature survey, and an undergraduate thesis describing the electronic design and automation of the system, are filed with the scientific authority. They are, at present, confidential. A paper is being prepared for presentation at the Second International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, April 21 to 25, 1986, Madrid, Spain, and for publication.

TITLE: EVALUATION AND REFINEMENT OF A NEW TECHNIQUE FOR MEASURING THE PERMEABILITY OF CONCRETE - PHASE 2

CONTRACTOR:	Laboratoire de Béton Ltée.	FILE NUMBER:	3-9199	FUNDING	
		BEGIN/END:	Feb. 84/Sept. 84		
				CANMET:	$ 26 080
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 26 080

OBJECTIVES

Develop standard test procedures for the use of a new permeability technique for concrete.

PROCEDURE

Part 1 of the work consisted of proof-testing and modification of five permeability cells previously developed for CANMET, and the fabrication of 10 additional cells of similar design. Part 2 consisted of mounting and testing each component of the 15-cell assembly and carrying out a complete test sequence on 150-mm diameter concrete specimens. For the latter, three types of non-air-entrained concrete with w/c ratios of 0.50, 0.65, and 0.80 were used.

RESULTS

The development of standardized test procedures for the new technique required a series of modifications to the original equipment, most of which were made through this contract work. One remaining problem area is the pressure membrane (leaking tendency), for which a solution has been proposed.

APPLICATION AND ONGOING WORK

Reproducibility of the new technique needs to be determined.

TITLE: ROLE OF SILICA FUME AND SLAG IN DEVELOPING HIGH-STRENGTH, LOW-PERMEABLE CONCRETE FOR OFFSHORE STRUCTURES

CONTRACTOR:	University of Sherbrooke	FILE NUMBER:	3-9061	FUNDING	
		BEGIN/END:	June 83/Aug. 84		
				CANMET:	$ 39 800
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 39 800

OBJECTIVES

1. Determine the mechanical properties of pelletized blast-furnace slag concrete incorporating various percentages of condensed silica fume.

2. Determine the efficiency of silica fume in relieving the problem of low early-age strength of blast furnace slag concrete.

PROCEDURE

The investigation included the preparation, by the contractor, of a total of eighteen 0.12 m^3 concrete mixtures. The water-to-(cement + BFS) ratios [W/(C + BFS)] investigated were 0.40, 0.50, and 0.65. The additions of condensed silica fume ranged from 5 to 20% by mass of cement plus BFS. Cylinder specimens were cast to determine both early- and later-age compressive strength; prisms were cast to determine 14- and 28-day flexural strength. The values of Young's modulus of elasticity "E" were determined at the age of 28 days, and the drying shrinkage at ages up to 180 days.

RESULTS

1. The low early-age strength of portland cement concrete incorporating blast furnace slag can be increased by the incorporation of condensed silica fume. At three days, the increase in strength is shown to be marginal; however, at the age of 14 days and beyond, the incorporation of BFS can be fully compensated for with a given percentage of condensed silica fume, regardless of the W/(C + BFS) ratio. This is also true of the flexural strength.

2. The continuing increase in strength at 91 and 180 days of the concrete incorporating BFS and condensed silica fume indicates that sufficient lime is still present at these ages for the cementitious reaction to continue.

3. The observed increase in drying shrinkage resulting from the incorporation of condensed silica fume in concrete containing BFS is generally marginal and of little practical consequence.

TITLE: DEVELOPMENT OF A CANADIAN SOURCED STEEL SUITABLE FOR THE HULL CONSTRUCTION OF A LARGE ICE BREAKING TANKER FOR SERVICE IN THE CANADIAN ARCTIC

				FUNDING	
CONTRACTOR:	Algoma Steel Corporation Limited	FILE NUMBER:	2-9027-2		
		BEGIN/END:	Jan. 83/March 85		
				CANMET:	$ 72 505
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	72 505
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	D. Boyd	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 145 010

OBJECTIVES

1. Design and manufacture a plate steel that meets the grade requirements described in Lloyd's Rules and Regulations for the Classification of Ships, Grade LT60.
2. Develop and qualify welding procedures, appropriate to Canadian shipyards, that produce adequate heat affected zone toughness in the experimental steel.

PROCEDURE

1. Preparation of one, 200 tonne heat of steel, production of plates of 25-75 mm thickness, and normalizing heat treatment of all plates.
2. Tensile, Charpy and metallographic evaluation of all plates.
3. Evaluation of heat-affected zone toughness and development of welding procedures (subcontract to the Welding Institute of Canada).
4. Supply of plate samples to CANMET and several other research laboratories for specific testing/research programs.

RESULTS

1. Experimental steel exceeded LT60 requirements in all thicknesses.
2. The sulphur content was relatively high (0.011 wt %) and it is expected that this will result in poor through-thickness ductility and a low resistance to lamellar testing.
3. A maximum heat input of 2-3 kJ/mm is indicated for adequate HAZ toughness, which is a low limit for current welding processes.
4. There was evidence of low toughness in the subcritical HAZ of the butt welds of 75-mm plate.
5. The report includes a comprehensive literature survey of the welding behaviour of steel plate used in ship construction and offshore structures.

APPLICATION AND ONGOING WORK

The data produced by this project should facilitate the acceptance of CSA-based steels for current international requirements for ship construction and offshore structures. Further work is recommended in:

1. Understanding the relationships between chemistry/microstructure and weld HAZ properties.
2. Using CTOD test for specifying the toughness of parent plate and weld HAZ.
3. Weldment corrosion.

TITLE: MATERIALS FOR OFFSHORE STRUCTURES AND ARCTIC VESSELS

CONTRACTOR:	AMCA International Ltd.	FILE NUMBER:	2-9027-3	FUNDING	
		BEGIN/END:	Dec. 82/Nov. 83		
				CANMET:	$ 148 100
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	148 100
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	A.F. Crawley	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 296 200

OBJECTIVES

Examine the suitability of two candidate steels (ASTM A710 Gr. A Cl.3 and Algoma LT60 steel) that can be produced in Canada, for use in the construction of offshore structures and arctic vessels. Characteristics examined were:

1. Formability
   Assess the deterioration in toughness at the tension surface of cold-rolled formed plates that may be subjected to strain aging and/or stress relieving cycles.

2. Weldability
   Investigate the hydrogen-induced susceptibility to cold cracking of the two candidate steels and compare them to a conventional structural steel. Ultimately, translate the anticipated lower susceptibility into lower welding preheat requirements.

PROCEDURE

Formability

1. Large plates were formed in a three roll forming machine to outer fibre strain levels of 3% and 6%.

2. Samples of each strain level were processed to stress-relieved, strain-aged, and strain-aged followed by stress-relieving conditions.

3. CVN toughness transition curves and tensile properties were determined.

4. CTOD specimens were tested for selected strain-heat treatment combinations.

Weldability

1. Hardening curves were obtained from mean-maximum HAZ hardness of six beads on a plate of 0.7-5.3 kJ/mm heat input.

2. Controlled Thermal Severity Tests were carried out and compared to an established steel (BS4360 Gr. 50E).

3. Tekken tests were carried out and compared to Controlled Thermal Severity (CTS) tests.

RESULTS

The candidate steels were suitable for offshore structures and marine applications. Both steels were comparable with, and in some aspects, certainly welding superior to the established steel. The conclusion is that Canada is quite capable of producing steels for offshore and arctic vessel applications.

APPLICATION AND ONGOING WORK

Confirmation of Canadian capability to produce suitable steels for offshore structures.

SUPPORTING DOCUMENTS

Final Report: "Weldability and Formability of Two Candidate Steels for Offshore Structures and Arctic Vessels".

TITLE: DEVELOPMENT AND EVALUATION OF AN ALL-POSITION MECHANIZED FLUX-CORED ARC WELDING SYSTEM FOR THE ON-SITE FABRICATION OF OFFSHORE OIL AND GAS STRUCTURES

CONTRACTOR: NOVA, An Alberta Corp.

FILE NUMBER: 2-9027-5
BEGIN/END: Feb. 83/March 84

FUNDING

CANMET:	$ 68 000
CONTRACTOR:	68 000
OTHER:	--
TOTAL:	$ 136 000

CANMET SCIENTIFIC AUTHORITY: J.E.M. Braid

ENERGY TECHNOLOGY ACTIVITY
SUB-ACTIVITY: Petroleum Supply
TECHNOLOGY: Materials for Offshore Structures

OBJECTIVES

Develop an all-position, mechanized flux-cored arc welding (FCAW) system for the on-site fabrication of offshore oil and gas installations.

PROCEDURE

1. Mechanize FCAW process with both rutile and basic FCAW consumables.
2. Extend capability of basic, low hydrogen, FCAW wires to all welding positions using pulsed welding techniques.
3. Develop welding procedures in 25-mm thick, large diameter pipe in all positions to maximize productivity with the mechanized FCAW system.
4. Develop and evaluate welding procedures in 25-mm thick LT60 plate steel in vertical-up position.

RESULTS

1. FCAW system successfully mechanized using CRC M-200 and M-1000 welding bugs with (1) Lincoln Idealarc DC-600; (2) OTC Transistarc MM-350; and (3) Miller Trailblazer 55D power sources. The OTC unit is a pulsed DC power supply and additional work was required to establish wire feed rates for the CRC units to match pulse frequency and burn-off rates of various wires. Only 3 rutile wires deposited acceptable beads using both the DC and pulsed power sources, and only one basic wire produced acceptable deposits using the pulsed mode only.
2. Welding procedures were developed for the three rutile wires for both the pipe girth welds and LT60 plate welds. In LT60 plate welds, CVN at -60°C were in the range 29-54 J while CTOD results at -45°C were marginal, with one rutile wire giving values between 0.1 and 0.2 mm in both DC and pulsed modes.

APPLICATION AND ONGOING WORK

Direct application to pipeline welding (both on- and off-shore) and welding of joints for offshore structures both in-shop and on-site. Results also indicate direction of further research work to improve automatic out-of-position FCAW weld metal toughness.

Ongoing Work

1. Results applicable to work on FCAW consumables being evaluated by AMCA International under CANMET Contract 4-9028.
2. New 50:50 contract with NOVA on Pulsed GMAW, Contract 4-9065.

SUPPORTING DOCUMENTS

Final Report: "Development of All-Position, Mechanized and Automatic FCAW Systems for the Fabrication of Offshore Structures and Arctic Vessels".

TITLE: OPTIMIZATION OF INJECTION TECHNOLOGY FOR HIGH QUALITY STEEL - PHASE I

CONTRACTOR: McMaster University	FILE NUMBER: 2-9186-I	FUNDING	
	BEGIN/END: April 83/March 85	CANMET:	$ 74 149
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: A.R. Palmer	TECHNOLOGY: Materials for Offshore Structures	TOTAL:	$ 74 149

OBJECTIVES

1. Optimization of current injection processes such as hot metal and steel desulphurization.

2. Development of Canadian expertise in injection technology.

PROCEDURE

1. Injected various powdered reagents into 3 tonne melts of carbon-rich iron (hot metal) - representing the high-carbon product of a blast furnace.

2. Investigated the effect of:
   a) prior deoxidation with aluminum
   b) type of reagent
   c) rate of supply of reagent
   d) ratio of solids to carrier gas
   e) quantity and composition of top slag.

RESULTS

Forty-eight successful injections of commercial-grade calcium (DSR) carbide into 2.5 tonne heats of hot metal were carried out. The most important conditions were the type of top slag, solid to gas loading, and oxygen activity. Four initial slag conditions were studied: no slag, a dry top slag (60% CaO, 40% SiO_2), a liquid slag (a commercial continuous casting powder, basicity 1.3), and the dry slag modified by pre-plunging of aluminum. The calcium carbide utilization, fraction of sulphur removed, and reaction rate increased in the above order. The solid to gas loadings ranged between 15 and 160 kg/Nm^3, and it was found that lower loadings were beneficial to calcium carbide utilization, sulphur removal, and reaction rate. Oxygen activity measurements showed that aluminum additions were associated with low oxygen activity and excellent desulphurization results. It was also shown that oxygen was detrimental to the plume reactions and to the top slag reactions.

APPLICATION AND ONGOING WORK

Removal of sulphur from blast furnace iron (i.e., prior to steelmaking processes) for improved internal quality of steel intended for line-pipe, marine and Arctic structures, and other severe applications.

Phase 2, now being planned, will elucidate further details and apply the findings to treatment of liquid steel.

SUPPORTING DOCUMENTS

Final report: "The Optimization of Injection Technology for High Quality Steel - Phase I".

TITLE: CORROSION-FATIGUE OF Mn-Ni-Al BRONZE PROPELLER ALLOYS

CONTRACTOR: University of Montreal	FILE NUMBER: 2-9107	FUNDING	
	BEGIN/END: Nov. 82/March 85		
		CANMET:	$ 72 098
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Petroleum Supply	OTHER:	--
AUTHORITY: M. Sahoo	TECHNOLOGY: Materials for Offshore Structures	TOTAL:	$ 72 098

OBJECTIVES

Ni-Al bronze (NAB) and Mn-Ni-Al bronze (MAB) alloys are widely used for large propellers for LNG tankers and icebreakers. Because of the prospects of shipping in heavy ice conditions in the Canadian Arctic to carry oil and gas, and because of a number of recent propeller failures in northern service, there is a need for extensive data on the mechanical behaviour of these alloys in severe service environments.

The Physical Metallurgy Research Laboratories of CANMET are investigating these alloys to (i) document their mechanical properties, (ii) identify failure mechanisms, and (iii) develop improved alloys and foundry practice. The corrosion-fatigue behaviour of Ni-Al bronze alloys has been determined. The present work considers the corrosion-fatigue behaviour of Mn-Ni-Al bronzes as functions of the environment (air vs 3.5% NaCl aqueous solution), the R- or load-ratio, the cyclic frequency, and the material condition.

PROCEDURE

Tests were carried out on:

1. Sand-cast plates, 295 x 148 x 25 mm, AC.

2. Plates normalized at 900°C for 2 h followed by slow-cooling (10°C/h to 230°C), NSC.

3. Slow-cooled plates annealed at 690°C for 2 h followed by water quenching, HT.

The tests were performed on either an MTS or an Instron servohydraulic machine, employing a sinusoidal wave form, a cycling frequency of either 1 or 20 Hz, and an R- or load-ratio ($R = K_{min}/K_{max}$) of either 0.1 or 0.5. A desk-top computer was employed for test control and data acquisition. The crack lengths were calculated from the sample compliance and were verified with optical crack length measurements using a travelling microscope.

The tests in the 3.5% NaCl solution were performed under freely corroding conditions by circulating this solution at a rate of 0.5 L/min from a 3.6-L reservoir into a plexiglass corrosion-fatigue cell, attached to the sample using electronic-grade silicone glue (i.e., glue not releasing acetic acid during setting). The salt solution in the reservoir was changed every 48 h.

RESULTS

1. Accelerated crack propagation occurred in the NaCl solution for the higher growth rates irrespective of the material condition.

2. At the lower rates, the fatigue crack propagation was slower in the salt solution than in air as a result of corrosion-product induced crack closure effects.

3. The HT alloys had the highest resistance to fatigue crack propagation as a result of their microstructure, which contained relatively large amounts of β-phase.

4. The HT condition generally gave the highest threshold values, followed by the NSC condition and the AC condition. In addition, the threshold values were higher in the NaCl solution than in air.

5. The threshold values decreased only in the AC and NSC materials on increasing the R-ratio, as a result of decreased crack closer component.

APPLICATION AND ONGOING WORK

This work has shown that the microstructure of existing propellers should be modified to increase the resistance to fatigue crack propagation. Additional studies will be made on alloys containing 8 and 10% Mn, which have relatively high CVN impact toughness even in the slow-cooled condition.

SUPPORTING DOCUMENTS

Final Report: "Corrosion-Fatigue of Mn-Ni-Al Bronze Propeller Alloys", by I. Dickson, L. Handfield, S. Lalonde, Y. Blanchette and J.P. Bailen, CDT P814, March 1985.

TITLE: DETERMINATION OF STRESS INTENSITY FACTORS FOR WELD DEFECTS

CONTRACTOR:	Carleton University	FILE NUMBER:	2-9083	FUNDING	
		BEGIN/END:	Sept. 82/April 84		
				CANMET:	$ 45 610
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	O. Vosikovsky	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 45 610

OBJECTIVES

Determine linear elastic stress intensity factors for surface weld toe cracks in welded plate T-joints, and investigate the effects of mode of loading, weld geometry, and crack shape on stress intensity factors.

PROCEDURE

Finite element analysis modelling.

RESULTS

Stress intensity factors are determined for straight fronted cracks with depth/thickness ratio a/t ranging from 0.05 to 0.7, and for semi-elliptical cracks with aspect ratios a/c of 1.0, 0.5, and 0.25 and a/t in the range of 0.05 to 0.4. Weld profiles of 30°, 45°, and 70° are investigated. Modes of loading are pure and three point bending.

APPLICATION AND ONGOING WORK

The determined stress intensity factors are used in ongoing work for prediction of fatigue lives of welded joints for offshore structures. The accuracy of fracture mechanics predictions is being experimentally verified by tests of welded plate T-joints at CANMET.

SUPPORTING DOCUMENTS

Final Report: "Determination of Stress Intensity Factors for Weld Toe Defects", by R. Bell and J. Kirkhope.

TITLE: FINITE ELEMENT ANALYSIS OF STRESS CONCENTRATION IN TUBULAR T-JOINTS

CONTRACTOR:	Memorial University of Newfoundland	FILE NUMBER:	3-9055	FUNDING	
		BEGIN/END:	May 83/March 84	CANMET:	$ 24 974
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	O. Vosikovsky	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 24 974

OBJECTIVES

Determine the distribution of stresses on the surface and through the wall thickness along the brace/chord intersection in welded tubular T-joints loaded axially and in plane bending.

PROCEDURE

Finite element analysis.

RESULTS

The maximum stress concentration factors for the two loading modes were determined, and they agreed well with other solutions from the literature. The distribution of stresses through the wall of chord and brace was determined for intact and cracked joints.

APPLICATION AND ONGOING WORK

The results are the first step for determination of stress intensity factors for cracked joints and prediction of fatigue life using fracture mechanics.

SUPPORTING DOCUMENTS

Final Report: "Finite Element Analysis of Stress Concentration in Tubular T-Joints", by M. Arockiasamy, G.S. Bhuyan, and K. Munaswamy.

TITLE: DESIGN OF A HEAVY-SECTION FRACTURE TESTING MACHINE - PHASE I AND 2

CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	I-9069	FUNDING	
		BEGIN/END:	March 82/Dec. 83	CANMET:	$ 79 323
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	W. Tyson, K.C. Wang	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 79 323

OBJECTIVES

Design a drop-weight impact-testing machine to test heavy-section offshore structural steels.

PROCEDURE

1. Investigate the high-energy impact-testing machines available in Canada and U.S.A.
2. Collect information on the required components and estimate the cost.
3. Design a heavy-section fracture-testing machine.

RESULTS

Based on the initial investigation, the original 150 kJ machine was downsized to 70 kJ. A heavy-section fracture-testing machine was designed.

APPLICATION AND ONGOING WORK

The design is complete. Proper funding is required to build this machine.

SUPPORTING DOCUMENTS

Three reports on "Design of a Heavy-Section Fracture Testing Machine".

1. Phase One Report.
2. Phase One Report - Supplemental Cost Considerations.
3. Phase Two Report.

TITLE: FACTURE RESISTANCE CHARACTERIZATION OF CANADIAN STEELS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	4-9113	FUNDING	
		BEGIN/END:	July 84/Sept. 84	CANMET:	$ 6 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	K.C. Wang	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 6 000

OBJECTIVES

1. Measure the dynamic tear (DT) energy of structural steels based on ASTM E-604 specifications.

2. Compare the test results of DT specimens at 16-mm and 19-mm thicknesses for 38 WT, 50 WT, and 100 QT steels.

PROCEDURE

1. DT specimens 16 mm thick in both longitudinal and transverse directions will be prepared from 19-mm plates according to ASTM E-604.

2. Test temperatures are 50°, 20°, 0°, -46°, and -80°C.

3. Tests will be performed in an instrumented impact test system. Initiation, propagation, and total energy will be measured and analyzed.

RESULTS

1. All tests and analyses were completed satisfactorily.

2. The reduction of impact energy cannot be simply accounted for by the reduction of thickness from 19 mm to 16 mm alone. The impact energy of 50 WT specimens was reduced by 50% in the longitudinal direction, but there was no reduction for 100 QT specimens.

3. All remaining materials have been shipped to CANMET for further analysis.

APPLICATION AND ONGOING WORK

Provide database for Canadian structural steels.

TITLE: ASSESSMENT OF FATIGUE DESIGN OF LARGE WELDED JOINTS IN OFFSHORE STRUCTURES

				FUNDING	
CONTRACTOR:	Det norske Veritas (Canada) Limited	FILE NUMBER:	3-9099		
		BEGIN/END:	Sept. 83/April 84		
				CANMET:	$ 40 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. R. Thomson	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 40 000

OBJECTIVES

Examine fatigue design rules and compare with documented fatigue failures of structures in the North Sea.

RESULTS

The body of this report gave an excellent summary of the approaches of the various regulatory authorities (Det norske Veritas, Lloyds Register, Department of Energy-U.K., American Bureau of Shipping, etc.) and presented and discussed a limited amount of data on field failures of secondary structural members. Large portions of the report were subsequently incorporated in the CSA Task Force working on a draft standard on "Fatigue Design for Offshore Structures".

TITLE: REVIEW OF DESIGN STANDARDS FOR OFFSHORE STEEL STRUCTURES

CONTRACTOR:	Centre for Frontier Engineering Research	FILE NUMBER:	4-9135	FUNDING	
		BEGIN/END:	Nov. 84/Nov. 84		
				CANMET:	$ 62 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. R. Thomson	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 62 000

OBJECTIVES

Prepare a review of standards for offshore structures, and propose a material selection methodology for steel plate.

PROCEDURE

Work performed by the contractor in conjunction with appropriate CSA committee personnel, in particular representatives of Det norske Veritas (Calgary).

RESULTS

Documents on:

a) review of standards for offshore steel structures, and
b) material selection methodology for fracture toughnesses,

have been published and delivered by the contractor.

APPLICATION AND ONGOING WORK

Contract reports are direct feed material into the materials group of the CSA Task Force on Offshore Structure Standards.

TITLE: DESIGN GUIDELINES FOR STEEL FIXED OFFSHORE STRUCTURES - PHASE 3

CONTRACTOR:	Centre for Frontier Engineering Research	FILE NUMBER:	4-9303	FUNDING	
		BEGIN/END:	Dec. 84/March 85		
				CANMET:	$ 8 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Petroleum Supply	OTHER:	--
AUTHORITY:	Dr. W.R. Tyson	TECHNOLOGY:	Materials for Offshore Structures	TOTAL:	$ 8 000

OBJECTIVES

Provide a review of material selection criteria for offshore assemblies in the post-weld heat-treated condition; refine the material selection charts from Phase 2 work; and present results at a meeting in Ottawa.

PROCEDURE

The work is an extension and refinement of that performed in Phase I and 2, which presented a survey of material selection requirements for input to writing a CSA standard for steel offshore structures. The contractor was required to draw on collected literature, contacts, and experience to present an authoritative review.

RESULTS

This report addresses steel plate requirements for fixed offshore structures for operation off the east coast of Canada. It documents a critical review of existing design codes and the relevant literature. The report also incorporates our response to the comments made by the CSA materials working group on the first draft of the report.

APPLICATION AND ONGOING WORK

The results have already been useful as background material for writing national standards for materials selection for offshore structures. Background work is now complete, although refinements will continue.

SUPPORTING DOCUMENTS

Final Report: "Development of Steel Plate Requirements for Fixed Offshore Structures - Part 2".

This supplement (Part 2) is not a self-contained document, but rather an extension of the original report.

ENERGY TECHNOLOGY

COAL

TITLE: LONGWALL MINING DEMONSTRATION WESTERN CANADA - PHASE I - FEASIBILITY STUDY

				FUNDING	
CONTRACTOR:	Montreal Engineering Co. Ltd.	FILE NUMBER:	I-9129		
		BEGIN/END:	May 82/June 82		
				CANMET:	$ 48 220
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G. Zahary	TECHNOLOGY:	Mining	TOTAL:	$ 48 220

OBJECTIVES

Review and evaluate documentation pertinent to a proposal for carrying out a demonstration of a longwall mining system in collaboration with CANMET at the Grande Cache property of McIntyre Mines Limited. The project is intended to generate key engineering and operational information for public use and thereby to encourage the wider use of this mining method in the mountain coal seams of western Canada.

PROCEDURE

The contractor examined potential mining sites for their suitability with respect to the application of longwall mining methods. The caving characteristics of the formation immediately overlying the seam and the strength of the floor were explicitly identified. A possible mining layout, description of equipment, manpower, services, cost estimates, production level, etc. were defined to a conceptual level of accuracy. The organizational structure to carry out the demonstration trial and maximize the transfer of technology to the regional industry was proposed; critical knowledge gaps, experimental work, and engineering data to be generated by the trial were broadly specified.

RESULTS

It was concluded that the time was right for such a trial in western Canada and the sites available were potentially suitable for longwall mining. A detailed engineering study would be needed to confirm this conclusion. The longwall experience under mountain conditions was considered to be more readily transferable to plains coal seams and hence the regional coal industry would gain from the demonstration. It was recommended that a working organization be set up with commitments from all parties and that CANMET should accept responsibility for all data collection.

Equipment costs would be of the order of $12 million, and the trial would take 4 to 5 years with operating costs of the order of $25 per clean long ton. The shales, mudstones, and siltstone in the immediate roof were considered to be cavable but there were reservations about the sandstones, especially where they approach the coal seam. The floor was considered to be weak and further testing was recommended.

APPLICATION AND ONGOING WORK

The report was used as a basis for negotiating an engineering and system design study (Contract No. 2-9036).

SUPPORTING DOCUMENTS

Final Report: "An Appraisal of the Proposal by McIntyre Mines for a Longwall Demonstration Project at their Grande Cache Property", Serial No. OSQ82-00029.

"Mining Demonstrations and Longwall Mining Systems", by G. Zahary and I.R. Muirhead, Report ERP/CRL 83-15(OP,J).

TITLE: ENGINEERING AND SYSTEM DESIGN FOR THE USE OF LONGWALL MINING IN WESTERN CANADA AT MCINTYRE MINES, GRANDE CACHE PROPERTY

CONTRACTOR: McIntyre Mines Limited	FILE NUMBER: 2-9036	FUNDING	
	BEGIN/END: Sept. 82/Feb. 83		
		CANMET:	$ 194 938
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: G. Zahary	TECHNOLOGY: Mining	TOTAL:	$ 194 938

OBJECTIVES

Perform a comprehensive feasibility study, including mine planning and detailed system engineering, for a site-specific retreating longwall installation at McIntyre's No. 9G mine at Smoky River. This will serve to evaluate the technical, operational, and economic viability for a longwall mining demonstration.

PROCEDURE

A planning team was organized to address the requirements outlined in the study "An Appraisal of the Proposal by McIntyre Mines for a Longwall Demonstration Project at their Grande Cache Property" [Contract No. 1-9129, Serial No. OSQ82-00029], and to develop a project plan including consideration of the following:

1. Geological and Geotechnical Evaluation.
2. Mine Layout.
3. Mining Support Systems.
4. Longwall Equipment Specification and Assessment of Bids.
5. Longwall Operations.
6. Capital/Operating Costs and Financing.
7. Demonstration Project Organization.

A number of subcontracts were undertaken in support of this work as follows:

1. Assessment of the geology.
2. Appraisal of the roof strata.
3. Geotechnical evaluation.
4. Pillar design for longwall mining.
5. Evaluation of the shearing of the No. 4 seam.

A comprehensive report and a complete set of drawings and maps were prepared, and the results displayed in two debriefing sessions.

RESULTS

A site suitable for a longwall mining demonstration was located in the No. 9G-4 Mine. Three panels could be extracted over a total period of some four and a half years. This would enable both the development and production phases of longwall mining to be evaluated in different mining conditions, including gradients up to 30°. The specification of a typical panel would be:

- Development system	2-entry
- Face length	550 ft (168 m)
- Extracted height	10 ft (3.0 m)
- Pillar width	120 ft (36.6 m)
- Direction of mining	Retreat/faces on-dip
- Panel run	4800 ft (1463 m)

As early as possible following a decision to proceed with the demonstration project, CANMET should form a Steering Committee and Project Management Group. The Steering Committee would confirm the objectives of the program, monitor the performance of the demonstration, and ensure that appropriate information is collected and properly disseminated. The Project Management Group would be responsible for the mining operations and research activities, receiving guidance from, and reporting to, the Steering Committee.

A demonstration longwall will produce large vol-

umes of coal and is likely to affect the production plans of any mining company involved. CANMET should be assured of the market for coal produced from the longwall for the demonstration period before undertaking any significant capital expenditure on equipment.

Present circumstances dictate that, unless markets can be found for the incremental production from longwall and risk capital can be procured, it is unlikely that the demonstration can proceed at the present time.

APPLICATION AND ONGOING WORK

Demonstration of the longwall mining system is to be held in abeyance for two years, when an effort will be made to locate another contractor.

SUPPORTING DOCUMENTS

Longwall Demonstration in Western Canadian Coals

Phase I - Mine Planning and Systems Engineering
- Executive Summary
- Technical Report Volume I
- Appendices
  McIntyre References Volume 2
  Consultants Reports Volume 3
  Longwall Equipment Volume 4.

TITLE: GEOLOGICAL EVALUATION OF THE TECHNICAL FEASIBILITY OF LONGWALL MINING IN THE GALT SEAM AT KIPP TRIAL MINE

CONTRACTOR:	Precambrian Shield Resources	FILE NUMBER:	2-9165	FUNDING	
		BEGIN/END:	Dec. 82/March 83		
				CANMET:	$ 156 250
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H.G. Naidu	TECHNOLOGY:	Mining	TOTAL:	$ 156 250

OBJECTIVES

Evaluate mining conditions of a site in the Lethbridge coalfield by conducting a mining trial and geotechnical study with particular reference to:

a) stability and support of U/G headings
b) optimum horizons for mining
c) caving characteristic of roof
d) suitability of shield support.

Transfer this information to another site in the same coalfield where only borehole data are available. Also, assess the technical feasibility of mining the Galt seam by longwall.

PROCEDURE

An underground roadway drivage operation was carried out for three months at Kipp Mine, Alberta. During this period, various kinds of supports were tried to establish the most suitable support system.

Strata behaviour was monitored by instrumentation.

Core drilling was carried out in the roof and floor, and the cores tested in the laboratory.

Later, at Picture Butte, exploratory holes were drilled, cored, and tested for geological/geotechnical correlation purposes.

Various data were processed and analyzed, as presented in the reports, with recommendations.

RESULTS

Extraction of the Galt seam appears to be technically feasible by longwall. Main roads driven in a north-south direction would possibly require arch support whereas rock bolts would be quite satisfactory for gateroads driven in an east-west direction. Mudstone when dry, as well as coal in the floor, have been found to be strong enough for shield supports used in longwall.

APPLICATION AND ONGOING WORK

This study provides us with a preliminary evaluation and can be used for further study with a view to introducing longwall mining in the Lethbridge coalfield, e.g.:

a) surface geophysical study for delineating faults; detailed geotechnical evaluation for support system, techno-economic analysis, equipment selection, and others.

SUPPORTING DOCUMENTS

Preliminary and final reports along with field data are available at CANMET in Ottawa and Calgary.

TITLE: SEMINAR ON LONGWALL MINING IN WESTERN CANADA

CONTRACTOR:	John P.L. Bacharach and Associates Limited	FILE NUMBER:	3-9157	FUNDING	
		BEGIN/END:	Sept. 83/Nov. 83	CANMET:	$ 16 700
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G. Zahary	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 16 700

OBJECTIVES

Make available to the coal-mining industry in western Canada information on longwall mining practice pertinent to regional mining conditions, and provide a forum for discussion of joint industry/government projects for demonstration of mining technology.

PROCEDURE

A two-day seminar was organized in cooperation with the University of Calgary. The speakers were drawn largely from the recently completed mine planning and systems engineering study undertaken to operate a longwall demonstration project at the Grande Cache property of McIntyre Mines Limited. Other speakers were drawn from the provincial government, local consultants, and a U.S. coal company where a mining demonstration is underway. Longwall mining practice was discussed in the context of resource recovery, safety, production and productivity, geological/geotechnical considerations, mine design and equipment, and two case studies. Interaction between speakers and participants was encouraged.

RESULTS

The seminar was attended by 35 people of whom about half were from industry (mine operators/developers) and the remainder from consulting firms, government, and all-other in that order. A handbook containing the presentations was issued that also serves as the contract report. The seminar allowed the knowledge gained in planning a longwall installation in western Canada in the current economic/technical climate to be displayed. Much of this benefit was realized in the discussion by the participants. This was not reported. The handbook material provides guidance by experts with local personal experience for setting priorities and identifying constraints in applying longwall mining systems in the region.

APPLICATION AND ONGOING WORK

Progress was made in establishing the necessary industrial consensus needed to undertake a demonstration project of the scale envisaged here.

SUPPORTING DOCUMENTS

Final report: "Longwall Mining in Western Canada - Handbook".

TITLE: RAPID TRANSPORT OF PERSONNEL AND MATERIALS IN UNDERGROUND COAL MINES

				FUNDING	
CONTRACTOR:	Norwest Resource Consultants Limited	FILE NUMBER:	4-9091		
		BEGIN/END:	Nov. 84/March 85		
				CANMET:	$ 63 105
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	R.K. Singhal	TECHNOLOGY:	Mining	TOTAL:	$ 63 105

OBJECTIVES

Review the existing and emerging technology relating to rapid transport of personnel and materials in underground coal mines, and identify appropriate technology for Canadian underground coal mines.

PROCEDURE

This review is based on published information and data available to the public. The following items identify the scope of the work:

1. Summarize developed concepts, approaches, techniques, and technologies being used as efficient underground rapid transport systems for personnel and materials in coal mines.

2. Discuss the strengths and weaknesses of each system considered under item (1) above.

3. Survey developments in other fields (metalliferous mining, urban transit, heavy industry, etc.).

4. Consider site visits to operating underground coal mines and centres of related expertise only with the prior written approval of the Scientific Authority.

RESULTS

Information for the study was acquired from published articles and from equipment manufacturers. A very large range of equipment is available from many manufacturers providing a wide choice of sizes, shapes, and special features in almost all categories. This diversity serves the mining industry's need for machines to work in specific and often unique environments.

A general review of the transportation systems in many mines identified that there is an increasing need for long-distance, rapid, underground movement of men and materials. Many operating systems at present tend to lack the speed, reliability, and safety that the industry will demand in the future.

Major innovations in underground mine transport are likely to occur as a result of the application of technology originally developed for other purposes. Technology now in use in urban transit systems, materials handling, and specialized applications in other industries may be expected to contribute to major changes. Rack and pinion or rubber-tired locomotives, linear induction motors, guided rail steering, and levitation systems are some of these emerging technologies.

Automation of control systems and materials handling are areas where improvements in efficiency and safety can be achieved. Often these improvements can be retrofitted to existing equipment with substantial benefits and acceptable costs.

The report includes a detailed review of each equipment category, presentation of typical specifications, and an evaluation of the applicability of each category within an overall transportation system.

The study is not site-specific and provides summary data that can be used as the basis for designing safe and cost-effective mine transport systems for existing or proposed mining projects.

The report includes more than 60 data sheets on transport systems and identifies locations at which equipment is currently in use.

TITLE: UNDERGROUND COAL MINE CONVEYOR SYSTEMS: A REVIEW OF AVAILABLE TECHNOLOGY AND INDUSTRY NEEDS FOR THE PREVENTION, DETECTION AND CONTROL OF FIRES

CONTRACTOR: Robinson, Dames and Moore	FILE NUMBER: 4-9095	FUNDING	
	BEGIN/END: Sept. 84/March 85		
		CANMET:	$ 35 444
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: G.A. Haslett	TECHNOLOGY: Mining	TOTAL:	$ 35 444

OBJECTIVES

Review available technology and industry needs for the prevention, detection, and control of fires in underground coal mine conveyor systems to achieve the following objectives:

1. A ranking, in terms of relative risk, of the various components of standard underground conveyor installations.

2. A summary of commercially available technology and recent research findings relevant to the prevention, detection, and control of conveyor fires and smouldering incidents.

3. An examination of monitoring with computer-based remotely operated systems, and a comparison of such systems with labor-intensive site monitoring and with combined approaches.

4. A summary of present and future Canadian industry needs.

PROCEDURE

A computer-assisted bibliography search for published literature, relevant to past experience with conveyor fires in underground coal mines and to available technology and recent research findings relating to the prevention, detection, and control of conveyor fires and smouldering incidents, was conducted. The databases that were searched comprised CANMET, IEA Coal Research, NTIS, COMPENDEX, ISMEC-Mechanical Engineering, and EI-Engineering Meetings. A bibliography of literature relevant to this study was compiled from 180 references and is included in Appendix 1. Copies of the relevant literature were obtained from libraries and other sources and, following a detailed review, have been extensively referenced in this report.

In addition to the bibliography search, extensive correspondence and telephone conversations were entered into with potential sources of information relevant to the objectives of this study. A complete list of those with whom Robinson, Dames and Moore corresponded or conversed by telephone is provided in Appendix 2.

RESULTS

The study concludes that idler rollers, mounted on the intermediate structure of the conveyor, constitute the greatest hazard and cause of fires and identifies the introduction of fire-resistant grease, self-locking idlers, and infrared scanning as the most recent technological developments to reduce the fire risks.

The study reviews the commercially available technology for fire protection, prevention, detection, and suppression in underground coal mines and identifies differences between Canada and other countries in the application of the technology. A summary of present and future Canadian needs identifies specific matters that appear to merit more detailed consideration either in Canadian regulations or codes or practice, or as topics for further research and development.

TITLE: CUTTING AND JOINING METALS IN CANADIAN UNDERGROUND COAL MINES: A REVIEW OF AVAILABLE TECHNOLOGY, INDUSTRY NEEDS AND RESEARCH OPPORTUNITIES

CONTRACTOR:	Robinson, Dames and Moore	FILE NUMBER:	4-9096	FUNDING	
		BEGIN/END:	Nov. 84/April 85		
				CANMET:	$ 32 658
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.A. Haslett	TECHNOLOGY:	Mining	TOTAL:	$ 32 658

OBJECTIVES

The objectives of this study of available technology, industry needs, and research opportunities, in relation to cutting and joining of metals in Canadian underground coal mines, are as follows:

1. Review available technology for cutting and joining metals that could find application in underground coal mines.
2. Rank the various available technologies based on consideration of their strengths and weaknesses.
3. Rank emerging techniques and technologies that could, with research and development, find application in underground coal mines, based on consideration of their strengths and weaknesses.
4. Propose a program of research, development, and demonstration to bring the most promising techniques/technologies to commercialization.
5. Summarize existing regulations governing flame cutting and arc welding in Canadian underground coal mines.
6. Review existing industry needs and frequency of flame cutting and arc welding in Canadian underground coal mines.
7. Identify future industry needs in relation to cutting and joining metals.
8. Compare current Canadian practices with those in selected foreign jurisdictions.

PROCEDURE

A computer-assisted bibliography search was conducted for published literature relevant to available techniques for cutting and joining metals in underground coal mines and to emerging techniques and technologies. The databases that were searched included NTIS, COMPENDEX, MINTEC, and Weldasearch. A bibliography of literature relevant to this study was compiled from 104 references and is included in Appendix A.

In addition to the bibliography search, extensive correspondence and telephone conversations were entered into with potential sources of information relevant to the objectives of this study. Robinson, Dames and Moore evaluated the applicability of the various cutting and joining technologies to underground coal mines based on data obtained by contacting officials in the Canadian coal industry, correspondence with Canadian underground coal mine regulatory authorities, review of relevant literature, and by reference to Robinson, Dames and Moore's experience with the requirements and constraints of underground coal mining.

RESULTS

1. The report questioned the need for cutting and joining underground.
2. Reviewed all available alternatives.
3. Proposed a research program that stated, as a major component, involvement with Government Regulatory Authority.
4. Recommended encouraging modular attachable/detachable component construction to obviate the need for cutting and joining. This report is considered to be satisfactory commensurate with an expenditure of $ 32 600.

TITLE: EXPLORATION BOREHOLE SEALING TECHNIQUES

CONTRACTOR:	Associates Mining Consultants	FILE NUMBER:	4-9098	FUNDING	
		BEGIN/END:	Sept. 84/May 85		
				CANMET:	$ 45 048
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. T.R.C. Aston	TECHNOLOGY:	Mining	TOTAL:	$ 45 048

OBJECTIVES

Identify, review, and evaluate current and potential sealing techniques with application to offshore exploration boreholes and/or those boreholes penetrating major aquifer horizons. Summarize and compare Canadian and foreign sealing regulations, and discuss the risks associated with longwall mining through offshore or major aquifer intersecting boreholes.

PROCEDURE

Literature review and contact with companies and individuals having state-of-the-art knowledge of borehole sealing techniques and regulations with respect to both the coal mining and oil industries.

RESULTS

The contract found that considerable expertise and technology exists within the oil industry, but that this needs to be transferred to the mining industry. The exact type and location of borehole seals should be governed by site-specific conditions. Finally, seals should be placed immediately below known aquifer horizons, but far enough for potential mining areas to lie in a zone of yielding deformation rather than brittle fracture during subsequent subsidence development.

APPLICATION AND ONGOING WORK

The contract forms a milestone in the long-term research program currently being undertaken in the Sydney coalfield to monitor and evaluate undersea subsidence criteria.

TITLE: IMPROVEMENTS AND EXTENDED APPLICATIONS OF THE SUBSIDENCE MONITORING AND TELEMETRY SYSTEM

CONTRACTOR:	Ecological and Resources Consultants Limited	FILE NUMBER:	1-9131	FUNDING	
		BEGIN/END:	July 82/Dec. 83		
				CANMET:	$ 139 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	M.Y. Fisekci	TECHNOLOGY:	Mining	TOTAL:	$ 139 000

OBJECTIVES

1. Maintenance and upgrading of the existing telemetry system.
2. Expansion of the system of five field stations.
3. Research on further improvements and interpretation.

PROCEDURE

1. Maintain the installed system over the hydraulic mine.
2. Exchange transceivers (from Motorolas to REPCO) to improve the reliability.
3. Investigate the expansion of the subsidence monitoring area beyond the mountain ridge in Sparwood with one of two alternatives:
   a) use a modified version of the present master station and a relay station on the ridge.
   b) use another master station to control the slaves beyond the ridge (with 5 slaves and 5 bi-axial tiltmeters).
4. Conduct research on the following:
   a) Additional testing of new types of tiltmeters in order to select the optimal model for future telemetry systems.
   b) Inclusion of extended data analysis capability at the master station.
   c) Development of a new mode of operation for the monitoring system where each slave itself could alarm the master about an unusual event concerning the data being sensed.
   d) Implementation and operation of access to the public telephone network for remote data acquisition purposes.
   e) Long-term in-house testing of individual units of the system for its enhanced reliability.
   f) Investigation of the interpretation and integration of the monitored ground movement, including a feasibility study on the prediction theory for the ground subsidence.

RESULTS

Contract work on the subsidence computerized telemetry system was successfully completed and presented at a seminar, December 1983.

The new telemetry system now consists of upgraded tiltmeters and transceivers together with a powerful computer for remote monitoring. The application of the system to pit slope monitoring, both in coal and tar sands, will expand its flexibility in different engineering applications.

APPLICATION AND ONGOING WORK

Last year, Westar Mining Ltd., Sparwood, B.C. proposed the expansion of telemetry installations to monitor mining subsidence beyond the Sparwood Ridge (remote and inaccessible areas). Accordingly, installation of such a monitoring network was programmed for this summer. Unfortunately, due to changes in mining priorities, the hydraulic mine is scheduled to terminate early in 1985. Therefore, steps are being taken to apply the computerized telemetry system in monitoring pit slopes both in coal and tar sands.

TITLE: REVIEW AND EVALUATION OF POTENTIAL DATA COLLECTION METHODS FOR MONITORING SUBSIDENCE OVER LONGWALL WORKINGS IN SUBMARINE COALFIELDS

CONTRACTOR:	Jacques, Whitford and Associates Limited	FILE NUMBER:	3-9031	FUNDING	
		BEGIN/END:	Feb. 84/Sept. 84		
				CANMET:	$ 60 095
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. T.R.C. Aston	TECHNOLOGY:	Mining	TOTAL:	$ 60 095

OBJECTIVES

Examine and evaluate current/potential subsidence monitoring technology that could be used to monitor seafloor subsidence profiles associated with the undersea coalfield workings in the Sydney coalfield.

PROCEDURE

Literature review and contact with companies and individuals having state-of-the-art knowledge of subsidence and offshore subsidence monitoring technology.

RESULTS

The contract identified four generic instrumentation schemes currently available for monitoring seafloor subsidence: Seafloor, Subsea, Geophysics, and Direct Monitoring. In addition, the surface-positioning systems required for the four schemes were also examined.

APPLICATION AND ONGOING WORK

The contract forms a milestone in the long-term research program currently being implemented in the Sydney coalfield to monitor seafloor subsidence.

TITLE: COMPUTER BASED SUBSIDENCE PREDICTION TECHNIQUES: A LITERATURE REVIEW AND EVALUATION OF THEIR APPLICATION TO CANADIAN UNDERGROUND COAL MINING

CONTRACTOR: RE/SPEC Ltd.	FILE NUMBER: 4-9101	FUNDING	
	BEGIN/END: Sept. 84/June 85		
		CANMET:	$ 63 800
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: Dr. T.R.C. Aston	TECHNOLOGY: Mining	TOTAL:	$ 63 800

OBJECTIVES

Identify, review, and evaluate available analytical/numerical modelling techniques that have been used for subsidence prediction, along with any methods that, although not tried, might find application with suitable research and development.

PROCEDURE

Literature review, contact with companies and individuals having state-of-the-art knowledge of subsidence prediction, and numerical/analytical modelling. A case history based on conditions in the Sydney Coalfield was used to evaluate a variety of the identified techniques.

RESULTS

The contract determined that existing prediction methods can be divided into two main types: empirical and analytical. Results obtained from the case history indicate that a major difference exists between subsidence values obtained by empirical methods and those produced by analytical means; the latter yield lower vertical displacements than the former.

APPLICATION AND ONGOING WORK

The contract forms a milestone in the long-term research program currently being implemented in the Sydney Coalfield to monitor seafloor subsidence.

TITLE: AN ANALYTICAL APPROACH TO THE DESIGN OF PILLARS IN COAL

CONTRACTOR:	Coal Mining Research Centre	FILE NUMBER:	0-9106	FUNDING	
		BEGIN/END:	Feb. 81/Oct. 82		
				CANMET:	$ 85 137
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. D.F.G. Hedley	TECHNOLOGY:	Mining	TOTAL:	$ 85 137

OBJECTIVES

1. Develop an analytical approach that will define coal pillar stability and lead to the evaluation of optimum pillar dimensions.

2. Evaluate the applicability of this analytical approach to pillar design by testing it, using experimental data extracted from the literature.

PROCEDURE

1. The concept is that a coal pillar under load is comprised of a solid core surrounded by a peripheral fractured zone. Failure occurs if the fractured zone extends to the centre of the pillar or if the solid core yields.

2. Analytical solutions for the stress distribution across elastic pillars were modified, taking into account the physical properties of solid, fractured, and yielding coal. The method used was to split the pillar into a number of equal slices and to analyze the stresses on each successive slice, then compare with appropriate fracture or yield criteria for coal.

3. This analytical technique was tested against 14 case histories taken from the literature.

RESULTS

1. A computer program was developed to calculate stress distribution across coal pillars, taking into account size and shape of the pillar as well as the properties of solid and broken coal. Stable, yielding, or fracture conditions are determined.

2. The analytical method gave a good fit to all except one of the 14 case histories considered, provided that appropriate choices are made for the properties of solid and broken coal.

3. Results indicate that:
   a) there is a minimum pillar stress below which fracture cannot initiate, hence there is a minimum pillar strength;
   b) in specific circumstances, once fracture initiates at the pillar edge, it propagates immediately to the centre and results in a pillar burst;
   c) in more normal circumstances a failure zone surrounds the elastic core. As pillar load is increased, the failure zone gradually extends to the centre.

SUPPORTING DOCUMENTS

Final Report: "An Analytical Approach to the Design of Coal Pillars".

Part 1: The Analytical Method.
Part 2: Application of the Model to Case Histories.

TITLE: ROOFS SUPPORTED BY NON-TENSION RESIN BOLTS

CONTRACTOR: University of Alberta	FILE NUMBER: 1-9055	FUNDING	
	BEGIN/END: Oct. 81/June 84		
		CANMET:	$ 26 413
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	DSS:	9 217
AUTHORITY: B. Das	TECHNOLOGY: Mining	TOTAL:	$ 35 630

OBJECTIVES

Systematic evaluation of resin bolts on physical models in the laboratory.

PROCEDURE

This includes: literature review, selection of model materials and development of physical models, laboratory study of effect of resin bolts on models, data analysis using suitable computer programs, conclusions and recommendations.

RESULTS

Study of the models has been completed. Analysis of the test data is in progress. This work is continued under a new contract: "The Behaviour and Design of Roofs Supported by Non-Tensioned Resin Bolts - Part 2", Requisition No. 4-9314.

APPLICATION AND ONGOING WORK

Will be evaluated after completion of Part 2 of the contract.

TITLE: ROCK CLASSIFICATION SYSTEM FOR APPLICATION IN UNDERGROUND COAL MINING

CONTRACTOR: SNC Inc.	FILE NUMBER: 2-9034	FUNDING
	BEGIN/END: Nov. 82/Oct. 83	
		CANMET: $ 51 718
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR: --
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER: --
AUTHORITY: Dr. B. Das	TECHNOLOGY: Mining	TOTAL: $ 51 718

OBJECTIVES

Develop a rock classification system suitable for underground coal-mining application in Canada. This system should serve the following purposes:

1. Should constitute the basis of a general classification framework for application in underground coal mining.

2. Should be able to deal with the specific problems related to underground coal mining in as many aspects as possible so that the system may expand into a more generalized form through additional studies.

3. Should be useful at the exploration stage as well as at the mining stage so that the results of these two different stages can be correlated.

4. If possible, it should provide a simple and less expensive testing method over and above the standard method, which could be more precise.

PROCEDURE

The following procedure was adopted to achieve the objectives:

1. Review and evaluate the previous work in this field in the world.

2. Collect and analyze the geotechnical characteristics of the Canadian coal fields.

3. Propose a classification system for application in underground coal mining in general and to Canadian conditions in particular.

4. Make recommendations on widening the scope of the system through further study in different areas.

5. Technology transfer through debriefing seminar, publication, and applications in the Canadian coal industry.

RESULTS

The following results have been achieved:

1. A rock classification system has been proposed to meet the required objectives.

2. A debriefing seminar with participation from the Canadian coal industry and others was organized as the first step of technology transfer. A paper is under preparation for publication. Many coal companies are showing interest in this work.

APPLICATION AND ONGOING WORK

Several coal operators/developers are interested in this work. Samples have been received from two coal companies for laboratory tests. Samples are also expected from some others. Laboratory is being equipped for carrying out this study. Negotiation is underway for mine sites for field study and also for procuring field equipment. Some laboratory tests already carried out.

Long-term plan being prepared for verification tests, standardization, technology modification, development of a rock properties data bank, and classification of the Canadian coal fields.

TITLE: DETERMINATION OF SLAKE DURABILITY INDICES OF LITHOLOGICAL UNITS SURROUNDING THE HARBOUR AND HUB SEAMS IN THE CAPE BRETON COALFIELD

CONTRACTOR:	University College of Cape Breton	FILE NUMBER:	4-9020	FUNDING	
		BEGIN/END:	April 84/Nov. 84		
				CANMET:	$ 9 497
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 9 497

OBJECTIVES

Determination of Slake Durability Indices of various lithologic units in the Sydney Coalfield.

PROCEDURE

One-hundred-seventeen samples tested with ASTM method.

RESULTS

Production and safety problems are associated with mechanized coal mining when the underlying rock is inherently weak and/or susceptible to water softening. The Slake Durability Index is one means of measuring this weakness. The determination of slake indices, and the equipment and procedures used, are described for over one hundred samples supplied by the Geology Department of the Cape Breton Development Corporation (CBDC). Sample sites are documented, data analyses performed, and a correlation between index and actual rock condition discussed.

On the basis of samples tested, Prince mine seat earths exhibited generally higher indices than those of the Lingan mine. CBDC should continue building up a database of indices for their properties, and attention should be paid to verifying low seat earth indices in the Lingan-Phelan project area.

TITLE: STABILITY ENHANCEMENT OF COAL MEASURES STRATA WITH AQUEOUS BASED CHEMICAL AGENT

				FUNDING	
CONTRACTOR:	Jacques, Whitford and Associates Limited	FILE NUMBER:	3-9034		
		BEGIN/END:	Nov. 83/May 85		
				CANMET:	$ 15 012
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 15 012

OBJECTIVES

The objectives of the contract were to examine the applicability of oil well engineering and civil engineering clay stabilization technology for the control of floor heave due to clay hydration in coal mines.

PROCEDURE

Literature review, engineering contacts, etc.

RESULTS

Three basic treatments were identified: potassium salts, calcium salts, and organic polymers. Toxicity of the chemicals is not expected to be a problem since most of the treatments are also used as food additives. Costs were not fully established.

Application by treatment of mine water is an attractive method of applying the chemicals.

APPLICATION AND ONGOING WORK

The method, if verified, has application to a wide range of coal mines where floor heave due to hy- dration of clays is a problem. The efficacy of the various treatments outlined in the final report will be tested in the laboratory in Phase 2 of the investigation, Contract No. 5-9011.

TITLE: IN SITU STRESS DETERMINATIONS IN THE SYDNEY COALFIELD

				FUNDING	
CONTRACTOR:	Golder Associates (Eastern Canada) Ltd.	FILE NUMBER:	3-9190		
		BEGIN/END:	Nov. 83/Feb. 84		
				CANMET:	$ 29 097
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 29 097

OBJECTIVES

Determine the in situ stress at No. 26 Colliery in the vicinity of rock and gas outburst locations, using the USBM gauge in three boreholes.

PROCEDURE

Diametrical deformation of a 38-mm pilot hole during overcoring by a 100-mm relief hole was measured using a USBM gauge. The deformation modulus of the rock was determined from biaxial tests on the recovered overcores.

In situ stresses were calculated using the least squares solution for the complete stress tensor.

RESULTS

The in situ stresses in the strata are fairly isotropic with low shear stresses. The major principal stress is 26.3 MPa and oriented in the E-W direction at an inclination of 25°. The ratio of major and minor principal stresses is about 1:1. The average vertical stress is about 15% higher than the static vertical stress calculated from the overburden weight. This is within the range of variation of vertical stresses measured in Canada and in other parts of the world.

APPLICATION AND ONGOING WORK

Results of this in situ stress determination will be used in the analysis of rock and gas outburst conditions existing at depth in the Sydney coalfield, and also in the feasibility study of hydrofracturing methods to control them.

TITLE: DESIGN, DEVELOPMENT AND CONSTRUCTION OF A RUGGED LOAD CELL TO REMOTELY MONITOR AND RECORD LOADS IN LONGWALL WASTES

				FUNDING	
CONTRACTOR:	Golder Associates (Eastern Canada) Limited	FILE NUMBER:	4-9100		
		BEGIN/END:	Aug. 84/March 85		
				CANMET:	$ 34 352
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 34 352

OBJECTIVES

Design, develop, and construct a rugged load cell to remotely monitor and record loads in longwall wastes.

PROCEDURE

Review available documentation on load cell construction and monitoring in Phase I of the contract. Development and construction were to be accomplished in this contract (Phase 2).

RESULTS

Phase I identified several methods of accomplishing the required objective:

1. Capacitance load cell hard wired to a measuring station.
2. As (1), but using a radio-monitor.
3. Stress cells installed below the waste in boreholes.

Phase 2 funds were not sufficient to fully develop (1) or (2). Instead, calibration of cells suitable for (3) was carried out.

APPLICATION AND ONGOING WORK

An RFP to develop the radio-monitoring device is currently with DSS.

The stress cells will be installed at an underground site in the near future.

TITLE: DEVELOPMENT AND USE OF TRIAXIAL ROCK TESTING PROCEDURES FOR SAMPLES OF STRATA FROM THE SYDNEY COALFIELD

CONTRACTOR:	Golder Associates (Eastern Canada) Limited	FILE NUMBER:	4-9097	FUNDING	
		BEGIN/END:	Sept. 84/March 85		
				CANMET:	$ 38 345
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 38 345

OBJECTIVES

Determine the criteria for explosive failure of sandstones with included methane under pressure as background data for the understanding and prevention of sandstone/gas outbursts in the Sydney coalfield.

PROCEDURE

The testing procedure was designed and then calibrated using a reference sandstone with constant physical parameters. A second suite of triaxial tests at varying applied stress rates and pore gas pressures was conducted on material from the Sydney coalfield considered to be outburst prone.

RESULTS

Explosive failure occurs when the effective confining stress is negative due to pore gas pressures. Outbursts were successfully simulated under laboratory conditions, and a failure criteria and mechanism defined.

APPLICATION AND ONGOING WORK

The results are of use to a variety of coal mining areas around the world experiencing similar phenomena. The results will be incorporated into laboratory research programs currently being undertaken.

A statement of work for further investigation of the phenomena, based on discoveries made in this project, is being prepared.

TITLE: HYDROFRACTURING FOR PREVENTION OF ROCK/GAS OUTBURSTS

CONTRACTOR:	Associated Mining Consultants Ltd.	FILE NUMBER:	4-9092	FUNDING	
		BEGIN/END:	Oct. 84/May 85		
				CANMET:	$ 78 686
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. T.R.C. Aston	TECHNOLOGY:	Mining	TOTAL:	$ 78 686

OBJECTIVES

Summarize the concepts of hydrofracturing. Identify, review, and evaluate available hydrofracturing technology for application to de-gassing and de-stressing coal and/or coal measure strata from within an underground coal mine. Propose a program of research and development that would lead to the demonstration of hydrofracturing techniques for coal and coal measures strata. Identify current and future needs for hydrofracturing in Canadian underground coal mines.

PROCEDURE

Literature review and contact with companies and individuals having state-of-the-art knowledge of underground coal mining, hydrofracturing theory, practice, and technology.

RESULTS

The contract found that considerable hydrofracturing expertise exists within the Canadian oil industry, but that very little of the technology has been applied to coal mining. However, before hydrofracturing can be applied for the prevention of rock/gas outbursts considerable research and development is needed in the following areas: geotechnical aspects (in situ stress determinations, reservoir, and rockmass characteristics), equipment design and modification, operational requirements and general testing (Gel tests and Sonde calibration).

APPLICATION AND ONGOING WORK

The contract forms a milestone in the long-term research program currently being undertaken in the Sydney coalfield to assess the application of hydrofracturing technology for outburst prevention.

TITLE: REVIEW OF UNDERGROUND COAL MINE DUST CONTROL

CONTRACTOR:	Brian Mountford and Associates Ltd.	FILE NUMBER:	9-9132	FUNDING	
		BEGIN/END:	Sept. 80/May 81	CANMET:	$ 33 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mining	TOTAL:	$ 33 000

OBJECTIVES

Review dust control research and achievements in major coal-mining countries: U.K., West Germany, France, U.S., and Canada.

PROCEDURE

Five coal-producing countries were visited and investigated.

RESULTS

The report discusses the legislation, sampling procedures, and control methods to combat the airborne dust hazard found in coal mines. Five countries were investigated, including Canada.

Legislation varies slightly from country to country, each dealing with the health problem in a way that has developed over many years.

Sampling methods all measure the amount of respirable dust that will probably be retained in the human lung. The results are expressed in mg's of dust per cubic metre of air.

Dust control practices vary, each location reflecting past experience. Evolution of control techniques develops directly from successful applications. The three main methods are the use of ventilation techniques, the application of water, and the use of dust collectors.

APPLICATION AND ONGOING WORK

Being presented as a report and at seminars; further studies expected on peculiar Canadian coal mine dust problems.

SUPPORTING DOCUMENTS

Final report: "A Review of Underground Coal Mine Dust Control in the United Kingdom, West Germany, France, the United States, and Canada.

TITLE: PASSIVE AND TRIGGERED BARRIER SYSTEMS FOR CANADIAN UNDERGROUND COAL MINING CONDITIONS

CONTRACTOR:	Brian Mountford and Associates	FILE NUMBER:	2-9050	FUNDING	
		BEGIN/END:	Aug. 82/March 83	CANMET:	$ 30 922
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 30 922

OBJECTIVES

1. Summarize the existing regulatory requirements, barrier systems in place, and mining methods of the Canadian underground coal-mining industry.

2. Summarize the research findings, types of barrier systems in place, and regulatory requirements related to barrier systems in the United States, United Kingdom, Federal Republic of Germany, and other underground coal-mining nations.

3. Consider the various barrier systems available and summarize their strengths and weaknesses as they relate to Canadian underground coal-mining conditions.

RESULTS

The study included an evaluation of barrier systems and regulations in the three nations listed in the objectives, and also those in Poland, Belgium, France, Australia, and Japan. For completeness, barriers in the U.S.S.R. and Romania were also reviewed, although few data were accessible to the study team.

The final report addresses all aspects of these objectives and is a useful compendium of barrier systems for Canadian underground coal-mining conditions.

TITLE: THEORETICAL REVIEW OF POSSIBLE TECHNIQUES TO IMPROVE THE DETECTION OF METHANE IN COAL MINE WORKINGS

CONTRACTOR:	Jacques, Whitford and Associates Limited	FILE NUMBER:	2-9051	FUNDING	
		BEGIN/END:	Aug. 82/March 83	CANMET:	$ 19 671
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 19 671

OBJECTIVES

Review possible techniques that could improve the detection of methane in underground coal mines, with emphasis on remote sensing as opposed to fixed position or hand held methanometry.

PROCEDURE

Collect information through correspondence and telephone communication, and summarize in final report.

RESULTS

Identification of promising techniques in remote sensing of hydrocarbons such as infrared differential absorption and spectroscopy.

APPLICATION AND ONGOING WORK

Consideration is being given to possible contracts to pursue one or both detection principles.

TITLE: STABILITY ENHANCEMENT OF COAL MEASURES STRATA WITH AQUEOUS BASED CHEMICAL AGENT

CONTRACTOR:	Jacques, Whitford and Associates Limited	FILE NUMBER:	3-9034	FUNDING	
		BEGIN/END:	Nov. 83/May 85		
				CANMET:	$ 15 012
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 15 012

OBJECTIVES

The objectives of the contract were to examine the applicability of oil well engineering and civil engineering clay stabilization technology for the control of floor heave due to clay hydration in coal mines.

PROCEDURE

Literature review, engineering contacts, etc.

RESULTS

Three basic treatments were identified: potassium salts, calcium salts, and organic polymers. Toxicity of the chemicals is not expected to be a problem since most of the treatments are also used as food additives. Costs were not fully established.

Application by treatment of mine water is an attractive method of applying the chemicals.

APPLICATION AND ONGOING WORK

The method, if verified, has application to a wide range of coal mines where floor heave due to hy- dration of clays is a problem. The efficacy of the various treatments outlined in the final report will be tested in the laboratory in Phase 2 of the investigation, Contract No. 5-9011.

TITLE: IN SITU STRESS DETERMINATIONS IN THE SYDNEY COALFIELD

				FUNDING	
CONTRACTOR:	Golder Associates (Eastern Canada) Ltd.	FILE NUMBER:	3-9190		
		BEGIN/END:	Nov. 83/Feb. 84		
				CANMET:	$ 29 097
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 29 097

OBJECTIVES

Determine the in situ stress at No. 26 Colliery in the vicinity of rock and gas outburst locations, using the USBM gauge in three boreholes.

PROCEDURE

Diametrical deformation of a 38-mm pilot hole during overcoring by a 100-mm relief hole was measured using a USBM gauge. The deformation modulus of the rock was determined from biaxial tests on the recovered overcores.

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Results of this in situ stress determination will be used in the analysis of rock and gas outburst conditions existing at depth in the Sydney coalfield, and also in the feasibility study of hydrofracturing methods to control them.

TITLE: DESIGN, DEVELOPMENT AND CONSTRUCTION OF A RUGGED LOAD CELL TO REMOTELY MONITOR AND RECORD LOADS IN LONGWALL WASTES

				FUNDING	
CONTRACTOR:	Golder Associates (Eastern Canada) Limited	FILE NUMBER:	4-9100		
		BEGIN/END:	Aug. 84/March 85		
				CANMET:	$ 34 352
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 34 352

OBJECTIVES

Design, develop, and construct a rugged load cell to remotely monitor and record loads in longwall wastes.

PROCEDURE

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RESULTS

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An RFP to develop the radio-monitoring device is currently with DSS.

The stress cells will be installed at an underground site in the near future.

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CONTRACTOR:	Golder Associates (Eastern Canada) Limited	FILE NUMBER:	4-9097	FUNDING	
		BEGIN/END:	Sept. 84/March 85		
				CANMET:	$ 38 345
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Cain	TECHNOLOGY:	Mining	TOTAL:	$ 38 345

OBJECTIVES

Determine the criteria for explosive failure of sandstones with included methane under pressure as background data for the understanding and prevention of sandstone/gas outbursts in the Sydney coalfield.

PROCEDURE

The testing procedure was designed and then calibrated using a reference sandstone with constant physical parameters. A second suite of triaxial tests at varying applied stress rates and pore gas pressures was conducted on material from the Sydney coalfield considered to be outburst prone.

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APPLICATION AND ONGOING WORK

The results are of use to a variety of coal mining areas around the world experiencing similar phenomena. The results will be incorporated into laboratory research programs currently being undertaken.

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TITLE: HYDROFRACTURING FOR PREVENTION OF ROCK/GAS OUTBURSTS

				FUNDING	
CONTRACTOR:	Associated Mining Consultants Ltd.	FILE NUMBER:	4-9092		
		BEGIN/END:	Oct. 84/May 85		
				CANMET:	$ 78 686
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. T.R.C. Aston	TECHNOLOGY:	Mining	TOTAL:	$ 78 686

OBJECTIVES

Summarize the concepts of hydrofracturing. Identify, review, and evaluate available hydrofracturing technology for application to de-gassing and de-stressing coal and/or coal measure strata from within an underground coal mine. Propose a program of research and development that would lead to the demonstration of hydrofracturing techniques for coal and coal measures strata. Identify current and future needs for hydrofracturing in Canadian underground coal mines.

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APPLICATION AND ONGOING WORK

The contract forms a milestone in the long-term research program currently being undertaken in the Sydney coalfield to assess the application of hydrofracturing technology for outburst prevention.

TITLE: REVIEW OF UNDERGROUND COAL MINE DUST CONTROL

CONTRACTOR:	Brian Mountford and Associates Ltd.	FILE NUMBER:	9-9132	FUNDING	
		BEGIN/END:	Sept. 80/May 81		
				CANMET:	$ 33 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mining	TOTAL:	$ 33 000

OBJECTIVES

Review dust control research and achievements in major coal-mining countries: U.K., West Germany, France, U.S., and Canada.

PROCEDURE

Five coal-producing countries were visited and investigated.

RESULTS

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APPLICATION AND ONGOING WORK

Being presented as a report and at seminars; further studies expected on peculiar Canadian coal mine dust problems.

SUPPORTING DOCUMENTS

Final report: "A Review of Underground Coal Mine Dust Control in the United Kingdom, West Germany, France, the United States, and Canada.

TITLE: PASSIVE AND TRIGGERED BARRIER SYSTEMS FOR CANADIAN UNDERGROUND COAL MINING CONDITIONS

CONTRACTOR:	Brian Mountford and Associates	FILE NUMBER:	2-9050	FUNDING	
		BEGIN/END:	Aug. 82/March 83	CANMET:	$ 30 922
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 30 922

OBJECTIVES

1. Summarize the existing regulatory requirements, barrier systems in place, and mining methods of the Canadian underground coal-mining industry.

2. Summarize the research findings, types of barrier systems in place, and regulatory requirements related to barrier systems in the United States, United Kingdom, Federal Republic of Germany, and other underground coal-mining nations.

3. Consider the various barrier systems available and summarize their strengths and weaknesses as they relate to Canadian underground coal-mining conditions.

RESULTS

The study included an evaluation of barrier systems and regulations in the three nations listed in the objectives, and also those in Poland, Belgium, France, Australia, and Japan. For completeness, barriers in the U.S.S.R. and Romania were also reviewed, although few data were accessible to the study team.

The final report addresses all aspects of these objectives and is a useful compendium of barrier systems for Canadian underground coal-mining conditions.

TITLE: THEORETICAL REVIEW OF POSSIBLE TECHNIQUES TO IMPROVE THE DETECTION OF METHANE IN COAL MINE WORKINGS

CONTRACTOR:	Jacques, Whitford and Associates Limited	FILE NUMBER:	2-9051	FUNDING	
		BEGIN/END:	Aug. 82/March 83		
				CANMET:	$ 19 671
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 19 671

OBJECTIVES

Review possible techniques that could improve the detection of methane in underground coal mines, with emphasis on remote sensing as opposed to fixed position or hand held methanometry.

PROCEDURE

Collect information through correspondence and telephone communication, and summarize in final report.

RESULTS

Identification of promising techniques in remote sensing of hydrocarbons such as infrared differential absorption and spectroscopy.

APPLICATION AND ONGOING WORK

Consideration is being given to possible contracts to pursue one or both detection principles.

TITLE: DEVELOPMENT OF EQUIPMENT AND TECHNIQUES TO EVALUATE BOUNDARY EFFECTS OF METHANE/COAL DUST EXPLOSIONS

CONTRACTOR: McGill University	FILE NUMBER: 2-9078	FUNDING	
	BEGIN/END: Oct. 83/March 84		
		CANMET:	$ 80 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: K.K. Feng	TECHNOLOGY: Mining	TOTAL:	$ 80 000

OBJECTIVES

Acquire the necessary fundamental and empirical knowledge to resolve the scale-up problem of methane/coal dust explosions.

PROCEDURE

1. Study turbulent combustion of dust and methane gas.
2. Investigate upward and horizontal propagation limits in hybrid mixture.
3. Study phenomena and mechanism of dust flame acceleration of obstacles.

RESULTS

1. Initial turbulence increases the maximum rate of pressure rise, but leaves the maximum pressure developed relatively unaffected.
2. The total turbulence intensity inside the testing chamber helps maintain a strong explosion at longer time delays.
3. It appears that for dust-air mixtures between the lean and saturated regions, admixing small amounts of methane gas causes slight increases in peak overpressure, and the maximum overpressure possible is limited.
4. The average explosion time is reduced, indicating that by addition of a premixed combustible gas the overall reaction rate must be increased.

APPLICATION AND ONGOING WORK

1. The fundamental knowledge could be used to solve the scale-up problem.
2. Influence of turbulence on dust explosions and the effect of methane on coal dust-air explosions.

TITLE: INFLUENCE OF TURBULENCE ON DUST EXPLOSION AND THE EFFECT OF METHANE ON COAL DUST EXPLOSION

CONTRACTOR: McGill University	FILE NUMBER: 4-9024	FUNDING	
	BEGIN/END: April 84/March 85	CANMET:	$ 60 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: K.K. Feng	TECHNOLOGY: Mining	TOTAL:	$ 60 000

OBJECTIVES

1. Study the influence of turbulence on the rate of burning of a dust-air mixture.
2. Study the flame propagation in a mixture that contains combustible dust as well as combustible gas.

PROCEDURE

1. A study of peak overpressure development in a 1-m diameter spherical vessel and in a new 58-cm diameter cylindrical vessel was made. Experimental diagnostics included dust concentration and turbulence measurements. A series of experiments were carried out with different dust concentrations and turbulence intensities to compare the data obtained from these two kinds of vessels and determine the influence of geometry.
2. Experiments were carried out in a 30-cm diameter cylindrical vessel. Experiments included flame speed and overpressure-time measurements. Experiments were carried out over a range of methane and coal dust concentrations in air to establish the mechanism involved.
3. A 15-cm diameter vertical flame acceleration tube was constructed, and experiments were carried out to assess the influence of repeated obstacles on flame acceleration in dust-air mixtures.

RESULTS

1. The characteristic decay time of the turbulence intensity was directly proportional to the smallest vessel dimension raised to the power of 1.2.
2. Peak overpressures were in fair agreement with one another, in spite of the widely different properties of the cornstarch used and of the characteristics of the experimental apparatuses. The Kst factor, on the other hand, varies over a wider range. The Kst value shows a remarkably linear increase with flow rate of air.
3. This study shows that for dust flames as well as gas flames, turbulence can play the dual role of enhancing as well as retarding flame propagation.
4. Admixed methane gas has a greater effect upon lean dust-air mixtures and a very small effect upon rich dust-air mixtures. The optimum dust concentration at which the greatest explosion pressure is generated, decreases almost linearly with increasing methane content.

APPLICATION AND ONGOING WORK

The experimental data could be used for designing a large explosion chamber.

SUPPORTING DOCUMENTS

Final Report: "The Influence of Turbulence on Dust Explosion and the Effect of Methane on Coal Dust Explosion".

TITLE: BIOLOGICAL CONTROL OF METHANE IN COAL MINES, COAL STORAGE SILOS AND SHIP HOLDS

CONTRACTOR:	Gemini Biochemical Research Limited	FILE NUMBER:	4-9001	FUNDING	
		BEGIN/END:	March 84/Nov. 84		
				CANMET:	$ 59 955
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. R.N. Chakravorty	TECHNOLOGY:	Mining	TOTAL:	$ 59 955

OBJECTIVES

Evaluate the possible application of biotechnology for control of methane in coal-mining operations, including coal storage silos and ship holds used during transportation of coal. This is in line with the general objective of the coal mine safety and research development projects.

PROCEDURE

A review of scientific literature indicated that microbiological control of methane is feasible and the physiological properties of some of the methane-oxidizing bacteria appear to be consistent with the conditions found in most coal mines in Canada.

Coal and water samples were collected from coal mines in western and eastern Canada. Methane-oxidizing bacteria were isolated from these samples and some of their characteristics studied in the laboratory. Chemical analysis of the water samples was performed to find out if the water contains any significant amount of potentially toxic compounds that may inhibit the activity of these microorganisms. The organisms were tested for their ability to oxidize methane when in contact with a number of different coals. The nature of bacterial activity over a period was studied under controlled laboratory conditions. A small laboratory model was also constructed for carrying out bacterial oxidation studies under dynamic conditions.

RESULTS

Methane-oxidizing bacteria, which can be grown easily under laboratory conditions, could be successfully isolated from a few western Canadian coal mines. These organisms remained active over an extended period and the rate of methane oxidation as observed from laboratory experiments was quite significant. When these organisms were tested for their activity in the presence of different coals, it was observed that with low-sulphur coals the activity appears to be quite significant. However, this activity was rapidly lost when the coal contained high levels of sulphur or where the pH of the mine water dropped to 5 or below.

Methane disappearance was appreciable under both static and dynamic conditions. The cultures were not inhibited when grown in mine water obtained from western Canadian mines producing low-sulphur coal. The results so far are quite encouraging and warrant further work to transform them into a viable technology.

APPLICATION AND ONGOING WORK

1. Detailed characterization of different types of methane-oxidizing bacteria identified during earlier studies.

2. Isolation and characterization of bacteria suitable for use in low pH and/or high-sulphur coals.

3. Scale-up tests.

TITLE: UNDERGROUND COAL MINE FIRE CONTROL WITH INERTING SYSTEMS

CONTRACTOR:	Associated Mining Consultants	FILE NUMBER:	3-9035	FUNDING	
		BEGIN/END:	Nov. 83/March 84		
				CANMET:	$ 55 195
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.B. Stewart	TECHNOLOGY:	Mining	TOTAL:	$ 55 195

OBJECTIVES

A comprehensive review of inerting technology for Canadian underground coal mines with actual case histories to guide mine site personnel who may be considering specific applications.

RESULTS

An excellent reference document that has been the subject of four technology transfer seminars (START) across Canada.

APPLICATION AND ONGOING WORK

An excellent state-of-the-art review of a mature technology presented in a way that allows mining engineers to consider the technology without previous experience.

TITLE: DEVELOPMENT AND DEMONSTRATION OF AN ANALYTICAL METHOD FOR ROUTINE DETERMINATION OF THE MINERALOGICAL AND ELEMENTAL COMPOSITION OF AIRBORNE DUST FROM UNDERGROUND COAL MINES

CONTRACTOR:	Atlantic Coal Institute	FILE NUMBER:	4-9093	FUNDING	
		BEGIN/END:	Oct. 84/Nov. 85		
				CANMET:	$ 45 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	C.Y. Hwang	TECHNOLOGY:	Mining	TOTAL:	$ 45 000

OBJECTIVES

Develop and validate a routine analytical methodology that will be used by CBCRL researchers to determine the mineralogical and elemental composition of coal mine dust.

This technique may be extended to analyze samples collected by industry to meet regulatory requirements.

PROCEDURE

Air samples of coal mine dust were collected on filters by the CBCRL dust survey team. Various procedures of analysis were studied and compared.

Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX) analysis was chosen to determine mineral and elemental composition by modal point count method, and neutron activation analysis was selected for trace element determination. For the SEM-EDX analysis, modal point count was performed only manually, not automatically as proposed, and its limitations were reported.

RESULTS

Average major mineralogy based on 500 point counts on six filter samples from a CBDC coal mine showed: coal (42%, by weight), illite (32%), calcite (3.9%), quartz (9.5%), kaolinite (2.3%), pyrite (2.5%), siderite (2.1%), and other (5.8%). Quartz content in the coal mine dust was unusually high. This must be validated by other independent analytical methods.

The neutron activation analysis showed some significant trace elements in the coal mine dust: Al (0.2%), Fe (0.1%), Na (200 ppm), Ti (100 ppm), Ag (1.0 ppm), As (1.0 ppm), Au (>15 ppb), V (200 ppm), Zn (50 ppm), etc.

Stone dust used in mines for fire control contributed to the coal mine dust composition. A copper-rich material was found in some of the samples. The source of this material is not known.

APPLICATION AND ONGOING WORK

Compositional analysis of coal mine dust is part of a respirable dust research program with the objective of reducing the risk of developing Coal Worker's Pneumoconiosis. A number of underground surveys to measure dust concentration have been, and will be, conducted to evaluate the long-term exposure of workers to coal mine dust. This research also identifies the dust sources for mine dust control purposes.

SUPPORTING DOCUMENTS

Division Report ERP/CRL 84-58(TR).

Division Report ERP/CRL 85-68(CF).

TITLE: DEVELOPMENT OF A TECHNIQUE FOR CONTACT ANGLE MEASUREMENTS ON IRREGULARLY SHAPED SOLID PARTICLES

CONTRACTOR:	University of Toronto	FILE NUMBER:	1-9039	FUNDING	
		BEGIN/END:	March 81/March 82		
				CANMET:	$ 85 171
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H.A. Hamza	TECHNOLOGY:	Preparation	TOTAL:	$ 85 171

OBJECTIVES

The main objective of this work was to develop a novel method called "freezing front technique", for characterization of the surface properties of coal powders and to extend the application of this technique to the measurement of surface properties of some gangue materials, clays, or other particulate material.

The interfacial tension and contact angle obtained from these experiments are used to characterize the hydrophobicity and hence the floatability of the various powders.

PROCEDURE

Freezing front experiments, to obtain contact angles, were performed on three bituminous and one subbituminous coal.

A study, on whether a longer storage (aging) of coals affects their surface properties and the hydrophobicity of the coal particles was also undertaken. The effects of the preparation of coal powders (wet & dry screening) on the surface properties of coal were also studied. An attempt was made to modify the surface properties of some of the coal powders by pretreatment with aqueous solutions of surfactants. The mineral composition of the coal samples was determined by neutron activation analysis (NAA), and the specific heats of the coal and clay samples were determined by Differential Scanning Calorimetry (DSC).

RESULTS

The freezing front technique works well for determination of interfacial tensions and contact angles of solid particles.

The effects of aging and oven-drying on the surface properties of coal particles can be monitored by means of the freezing front technique. Aging of coal samples changes the hydrophobicity of the surface of coal particles. The change depends on the type of sizing more than on the rank of the coal.

Pretreatment with surface active materials had only a minor effect on the surface properties of coal.

At very small particle sizes, of the order of 1 μm, Brownian motion and thermophoretic flows make freezing front measurements impossible.

APPLICATION AND ONGOING WORK

The results obtained from this study are mainly used in flotation and flocculation studies. The results obtained from aging effects on the surface properties of coals are used to improve the storage of coals and therefore their properties.

There is ongoing work on different methods of characterizing the surface properties of solid particles.

SUPPORTING DOCUMENTS

Final Report.

Two published papers (CIM Bulletin 74, 1981 and Fuel 61, 1982).

One paper accepted for publication (Can J of Chemistry) and two more papers were submitted.

TITLE: SURFACE CHARACTERIZATION RELEVANT TO ENERGY RESOURCES PROCESSING

CONTRACTOR:	University of Toronto	FILE NUMBER:	3-9121	FUNDING	
		BEGIN/END:	Sept. 83/March 84		
				CANMET:	$ 99 951
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Hamza	TECHNOLOGY:	Preparation	TOTAL:	$ 99 951

OBJECTIVES

The ability to predict, control, and monitor the wettability, flotability, and adhesion of coal particles in various coal dispersions is of great importance in coal beneficiation processes, and it requires a knowledge of the surface properties of coal powders. Since coal fines may be dispersed either in organic or aqueous media during transportation and utilization, a study of the surface behaviour of coal in both types of media is of immediate concern in coal processing.

The objective of this work was to characterize the surface tension and the stability of dispersions of coal powders originating from both western and eastern Canada using three different techniques.

PROCEDURE

The surface tensions of coal powders and stability of dispersions were measured using three techniques: the advancing solidification front, the particle adhesion, and the volume sedimentation techniques. The surface tensions of coal particles suspended in different liquids were measured by advancing solidification front.

The sedimentation behaviour and suspension stability of coal and polymer particles were studied using the particle adhesion technique.

Sedimentation volume experiments with well-characterized polymer powders were carried out to better understand the complexities observed in coal sedimentation.

RESULTS

It was observed from the freezing front technique that the surface tension of coal particles varies with the nature of the suspending liquid medium, i.e., coal is hydrophobic in organic liquids and hydrophilic in water.

The determination of the extent of coal particle adhesion to polymeric substrates provides a method for the determination of the surface tension of the various coal specimens.

The surface tension values obtained from coal adhesion studies are in good qualitative agreement with the values obtained from the freezing front technique.

It was found that the sedimentation volume (V_{sed}) changed with varying composition of the liquid mixtures, as did the surface tension. A maximum or minimum V_{sed} occurred when the surface tension of the suspending liquid was equal to that of the coal particles. Maxima occurred in the more polar mixtures, and minima in the non-polar or less polar liquid mixtures. The surface tension of the particles was found to change with particle size, in agreement with the findings from other independent techniques.

It was found that the surface tension of coal depends on the surrounding liquid, again in agreement with the results from other techniques.

APPLICATION AND ONGOING WORK

The results obtained from this study are mainly used in flotation and flocculation studies. There is ongoing work on different methods of characterizing the surface properties of solid particles and liquid/liquid system.

TITLE: SURFACE TENSION EFFECTS ON PROPERTIES OF COAL SUSPENSIONS

CONTRACTOR: University of Toronto	FILE NUMBER: 4-9162	FUNDING	
	BEGIN/END: March 85/Sept. 85		
		CANMET:	$ 14 978
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: H. Hamza	TECHNOLOGY: Preparation	TOTAL:	$ 14 978

OBJECTIVES

This study was designed to answer four principal questions:

1. Do surfactants adsorb irreversibly onto coal fines?
2. Is the extent of adsorption to a particular coal sample primarily determined by the charge or by the molecular weight features of the surfactant?
3. Does surfactant adsorption change the wettability of the coated coal particles?
4. Does surfactant adsorption affect the packing nature of the coal slurry?

PROCEDURE

The following methods were used:

1. Extent of surfactant adsorption to a given unit mass of coal was assessed spectrophotometrically by means of standard curves using the ultraviolet adsorption maxima of each surfactant.
2. The effect of surfactant charge and molecular weight properties was investigated by deliberately choosing various surfactants having different properties.
3. The wettability of surfactant coated and uncoated coal fines was determined by means of sedimentation volume studies.
4. The effect of surfactant coating on coal slurries was examined in two ways:
   a) qualitatively, by determining visually the ease with which a compacted slurry could be resuspended;
   b) quantitatively, by assessing with image analysis techniques the change in size of coal particle aggregate formation as a result of surfactant coating.

RESULTS

The coal particles used for this study were:

1. Pittsburgh No. 8 coal.
2. Devco coal.

These are the results:

1. Surfactant adsorption to coal occurs rapidly and is irreversible.
2. Surfactant adsorption decreases the surface tension of the coated coal particles.
3. The amount of surfactant adsorbed to a unit mass of coal is determined in part by the bulk concentration of the surfactant; that is, the amount adsorbed increases with increasing bulk concentration.
4. The amount of surfactant adsorbed per unit mass of coal decreases the surface tension of the coated coal particles.
5. Surfactant adsorption changes the nature of the coal slurry. The nature of this change is dependent both on the character of the adsorbing surfactant and on the surface concentration of the adsorbed surfactant.

APPLICATION AND ONGOING WORK

The results obtained from this study are used in flocculation tests.

There is ongoing work on the influence of surface properties of coal particles on flotation and flocculation processes.

TITLE: DEVELOP AND BUILD A TEST SYSTEM TO MEASURE SURFACE ELECTRICAL POTENTIAL

				FUNDING	
CONTRACTOR:	St. Francis Xavier University	FILE NUMBER:	4-9054		
		BEGIN/END:	May 84/March 85		
				CANMET:	$ 55 515
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	W. Friesen	TECHNOLOGY:	Preparation	TOTAL:	$ 55 515

OBJECTIVES

Develop an instrument for measuring surface electrical properties of non-homogeneous distributions of fine particles (such as coals and clays in the sub-millimetre size range) in an aqueous environment.

PROCEDURE

The operation of the instrument is based on fluidizing a bed of particles in a conical vessel with water at the desired pH and ionic concentration.

RESULTS

The instrument that was developed allows simultaneous measurement of electrical potential, solids fraction, water pH, temperature and conductivity.

APPLICATION AND ONGOING WORK

The instrument will be used in studies of the effect of surface oxidation and flotation and flocculating agents on surface charge properties of coals, clays, and sands.

TITLE: EFFECT OF HUMIC ACID ON FLOTABILITY OF COAL AND PYRITE

CONTRACTOR:	University of British Columbia	FILE NUMBER:	2-9122	FUNDING	
		BEGIN/END:	Sept. 82/March 83		
				CANMET:	$ 14 996
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	K.S. Moon	TECHNOLOGY:	Preparation	TOTAL:	$ 14 996

OBJECTIVES

Investigate the effect of humic acid on the selective flotability of coal and pyrite, with and without their oxidation.

PROCEDURE

The effect of humic acid on selective coal flotation from pyrite was studied using the following surface chemical studies:

1. Electrophoretic Mobilities.
2. Adsorption of Humic Acid.
3. Contact Angle.
4. Effect of pH.
5. Effect of Electrolyte.
6. Flotation of Coal and coal-pyrite.

RESULTS

Humic acid has been shown to adsorb on graphite, coal, and coal-pyrite, and to modify the surface properties of these materials. The surface of hydrophobic solids, such as graphite, become quite hydrophilic in the presence of humic acid. The flotability of graphite is effectively depressed in a solution containing a few ppm of humic acid. The effect of humic acid was more pronounced in the presence of inorganic electrolytes, e.g., KCl or KNO_3.

Humic acid was shown to depress coal as well as pyrite. It was found that the amount of humic acid needed for the depression varies for different coals.

Flotation of pyrite containing Devco coal in the presence of humic acid produces concentrates with a lower sulphur content, but the yield of concentrate is also reduced.

APPLICATION AND ONGOING WORK

Because of the encouraging investigation results, a new one-year contract program, "Comparison of Humic Acid, Dextrin and Carboxymethyl Cellulose as Modifying Agents in Coal and Coal-Pyrite Flotation", was granted to the original investigator.

SUPPORTING DOCUMENTS

Final Report: "Effect of Humic Acid on Flotability of Coal and Pyrite", by Dr. J.S. Laskowski.

TITLE: COMPARISON OF HUMIC ACID, DEXTRIN AND CARBOXYMETHYL CELLULOSE AS MODIFYING REAGENTS IN COAL AND COAL-PYRITE FLOTATION

CONTRACTOR:	University of British Columbia	FILE NUMBER:	3-9046	FUNDING	
		BEGIN/END:	July 83/March 84		
				CANMET:	$ 25 232
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	K.S. Moon	TECHNOLOGY:	Preparation	TOTAL:	$ 25 232

OBJECTIVES

Investigate the effect of humic acid, dextrin, and carboxymethyl cellulose (CMC) as modifying reagents in the selective flotation of coal and coal-pyrite.

PROCEDURE

The high-sulphur DEVCO coal has been subjected to the following studies:

1. A petrographic study of pyrite liberation during the comminution of the DEVCO high-sulphur coal.
2. Electrokinetic measurements and small-scale flotation experiments with low-sulphur bituminous coal.
3. Adsorption and electrokinetic studies of DEVCO pyrite and coal.
4. Bench-scale flotation of the low-sulphur bituminous and high-sulphur DEVCO coals.

RESULTS

1. For DEVCO coal, significant liberation of pyrite takes place only when the maximum size is reduced below 200 µm. Grinding 100% below 75 µm might result in the proper liberation of pyrite from coal.
2. Humic acid and CMC produce strong depression of coal floated with MIBC, only when added to the pulp before MIBC. Dextrin depresses coal flotation irrespective of the order of reagent addition. In flotation with kerosene, humic acid and dextrin depress coal flotation irrespective of the order of reagent addition. CMC did not produce any significant depression of coal flotation when kerosene is used.
3. The zeta potential of coal and pyrite particles, and of the oily collector droplets, is much more negative in the presence of humic acid and CMC. It appears that the increased negative electrical charge appreciably increases the hydrophilicity of pyrite, while the hydrophilicity of coal is not much affected.
4. While the electrical effects seem to determine the behaviour of humic acid, dextrin does not affect the zeta potential either of coal or of the oily collector droplets, and its influence on flotation does not depend on pH at all. The behaviour of CMC in coal flotation is strongly pH dependent.

APPLICATION AND ONGOING WORK

The use of humic acid and CMC in the flotation of finely ground high-sulphur DEVCO coal should be studied further.

SUPPORTING DOCUMENTS

Final Report: "Comparison of Humic Acid, Dextrin and Carboxymethyl Cellulose as Modifying Reagents in Coal and Coal-Pyrite Flotation", by Dr. J.S. Laskowski, University of British Columbia, Dept. of Mineral Engineering, March 1984 (17 Tables and 44 Figures).

TITLE: DEVELOPMENT OF A COAL FROTH FLOTATION CONTROL SYSTEM

CONTRACTOR:	Cambrian Engineering Group Limited	FILE NUMBER:	3-9048	FUNDING	
		BEGIN/END:	Feb. 84/March 85		
				CANMET:	$ 64 520
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	A. Salama	TECHNOLOGY:	Preparation	TOTAL:	$ 64 520

OBJECTIVES

Perform system design (electrical, mechanical, and control strategies) for purchase and installation of a froth flotation control system at ECRL at Devon, Alberta.

PROCEDURE

1. Investigate and review what others have done by means of literature search and review in regard to coal flotation process control.
2. Recommend optional control strategies that could be applied to an existing coal flotation process at ECRL.
3. Evaluate the feasibility of the recommended control strategies by the Scientific Authority in consultation with the contractor.
4. The agreed upon strategy will form the basis of the final design.
5. The final design includes electrical, mechanical, and control strategies for purchase and installation. Instrumentation and equipment specifications to be included.

RESULTS

The proposed control system includes:

1. Measure and control total slurry feed volume.
2. Measure specific gravity of slurry, calculate the per cent solids, and add dilution water to control the per cent solids of the feed slurry.
3. Measure slurry ash in feed stream.
4. Measure pH.
5. Use mass flow of coal to control the addition of reagents.
6. Measure and control pulp level.
7. Measure flow, SG, and ash of tailings.
8. Use mass balance calculation to determine product recovery and grade.
9. Measure air addition and impeller power, and control the specific power to the impellers by providing variable speed impellers.

The design includes:

1. Drawings of the process.
2. Drawings of the instrumentation.
3. Specifications of all instruments.
4. Drawings of the installation of ash analyzers.
5. Drawings of the electrical installation.
6. Specifications of a distributed control/shared display system for process control.
7. Cost estimates.

TITLE: DESIGN OF 10 TONNE/HOUR COAL PREPARATION PILOT PLANT FACILITIES AT DEVON, ALBERTA

CONTRACTOR:	Simon-Carves of Canada Limited	FILE NUMBER:	2-9038	FUNDING	
		BEGIN/END:	Aug. 82/March 83		
				CANMET:	$ 65 070
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	O. Humeniuk	TECHNOLOGY:	Preparation	TOTAL:	$ 65 070

OBJECTIVES

1. Design a new handling and crushing system to handle 10 tonnes/hour.
2. Provide layout of pilot plant equipment; including mechanical, electrical, and piping for the Devon site.
3. Provide flexibility in flowsheet design suitable for research and development programs.
4. Provide recommendations concerning new equipment with specifications.

PROCEDURE

Simon-Carves initially had two engineers spend several days at the Clover Bar pilot plant site gathering information and reviewing the existing equipment. After each progress report, a meeting with Simon-Carves (usually the project manager and one engineer) and CRL staff (S.A. Unit head and R.S.) was held to discuss the recommendations and to evaluate the progress.

RESULTS

Simon-Carves presented five progress reports and a final report that included over 125 drawings and sketches (mechanical, electrical, fabrication, P&I, mass balance). The progress reports constitute part of the final report and provide details necessary for pilot plant redesign at Devon, with recommendations and specifications for new equipment and future expansion.

APPLICATION AND ONGOING WORK

Will be used when pilot plant equipment is relocated to Devon, Alberta.

SUPPORTING DOCUMENTS

Final Report: "10 Tonne/Hour Coal Preparation Pilot Plant Facility at the Devon Coal Research Centre, Alberta".

TITLE: SPOC METHODOLOGY TRANSFER TO A COAL PROCESSING PLANT

CONTRACTOR:	Cape Breton Development Corporation	FILE NUMBER:	3-9017	FUNDING	
		BEGIN/END:	Aug. 83/March 84		
				CANMET:	$ 9 498
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D. Lagultton	TECHNOLOGY:	Preparation	TOTAL:	$ 9 498

OBJECTIVES

Demonstration of the applicability of the "Simulated Processing of Ore and Coal" (SPOC) computer-based methodology to the coal-processing industry.

PROCEDURE

Task 1 - Data collection for sampling design

Selective grab sampling and flow measurements by tracers will be performed to determine the major unknown density and size distributions, ash and sulphur contents, and flowrates of the Victoria Junction plant. One of the two parallel circuits will be selected for the entire study.

Task 2 - Sampling planning

The detailed preparation of the sampling campaign will be done, including:

a) selection of sampling points;
b) selection of the type of sample analyses to be done;
c) selection of the sample sizes, sampling tools, sample storage methods, and sampling procedure;
d) recommendations on required access to sampling points;
e) constitution of a sampling team.

Deviations from the procedures advocated in Chapter 2 of the SPOC manual will be recorded for updating the manual.

RESULTS

The results of this phase of the work have provided information for the design of a full-scale sampling experiment and pointed out circuit irregularities that can be resolved prior to the detailed sampling. The No. 26 washery was selected because of its size (3 parallel circuits versus 5 for the Lingan coal). The heavy medium distributor box was shown to split flows in a very uneven way between the three lines. Time series samples of coal showed that sampling periods of over 10 min were necessary to avoid sample correlations. The feed automatic sampler was restored for the experiment and should continue to provide reliable samples.

APPLICATION AND ONGOING WORK

As Phase 2 of the project was about to start, a fire in the No. 26 mine brought production to a full stop and no alternative plans were drawn in time for an immediate continuation of the work.

SUPPORTING DOCUMENTS

1. Report on Phase 1 sampling experiment with No. 26 primary coal circuit at DEVCO by J. Merks.

2. SPOC project - progress report by J. Landry.

TITLE: DESIGN AND DEVELOPMENT OF A MOBILE FINE COAL CLEANING PLANT

CONTRACTOR: Fenco Engineers Inc.	FILE NUMBER: 3-9049	FUNDING	
	BEGIN/END: Feb. 84/Jan. 85		
		CANMET:	$ 80 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: J. Szymanski	TECHNOLOGY: Preparation	TOTAL:	$ 80 000

OBJECTIVES

A mobile fine coal cleaning plant, with its ability to operate at existing coal preparation plants across Canada, and with its flexibility in implementing flowsheet options and in close monitoring of fine coal circuit variables, is ideally suited to solve fine coal cleaning problems. The mobile plant objectives were to:

1. Design and optimize flowsheets.
2. Evaluate and improve fine coal cleaning circuit operations.
3. Test new process monitoring and control equipment.

PROCEDURE

The first stage of the project was to prepare a literature survey reviewing the fine cleaning processes - a state-of-the-art report. The recommendations were evaluated by the Scientific Authority, and process options were selected in the Phase 2 report - Process Options Selection. Following agreement on the basic process flowsheet, liquid and equipment flowsheets were developed. Preliminary drawings were prepared showing possible lay-outs of selected equipment and were discussed with the Scientific Authority. Following agreement on the general arrangement drawings, specifications were prepared for all plant equipment and a detailed design completed to allow construction and operation of the mobile fine coal cleaning plant. All engineering and design information is contained in the Phase 3 report - Detailed Design.

RESULTS

Only two fine coal cleaning processes - two-stage froth flotation and spiral concentrator - are to be accommodated in the mobile plant.

The hydrocyclones' circuit has been excluded from design consideration because of the physical restrictions that prohibit its inclusion with the above processes on one trailer. Each engineering discipline process - electrical, instrumentation, and structural - has been fully integrated to ensure a practical and competent mobile plant design.

The design of the plant has been complicated by the fact that the designer has not had certified construction drawings for the equipment. If Fenco has no further involvement with this project, the construction contractor will have to confirm all mounting details of the preselected equipment with the designer.

APPLICATION AND ONGOING WORK

The design permits construction and operation of the mobile fine coal cleaning plant that will greatly assist in solving beneficiation problems experienced with Canadian fine coals.

TITLE: INVESTIGATION OF LOW COST TECHNOLOGY IN COAL CLEANING USING THE SZEGO GRINDING MILL SYSTEM

CONTRACTOR:	General Comminution	FILE NUMBER:	3-9045	FUNDING	
		BEGIN/END:	Sept. 83/Dec. 84		
				CANMET:	$ 33 475
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. K.S. Moon	TECHNOLOGY:	Preparation	TOTAL:	$ 33 475

OBJECTIVES

Provide an efficient, ultrafine grinding system for the preparation of clean coal from the high-sulphur coal at the Victoria Junction Coal Preparation Plant of DEVCO during the pilot-plant investigation of a flotation column.

PROCEDURE

1. A self-contained "Szego Grinding Mill System" was installed at the Victoria Junction Coal Preparation Plant of DEVCO to be used in conjunction with a flotation column.

2. A series of grinding tests were performed to identify the optimum conditions of various grinding variables for the ultrafine grinding of high-sulphur coals.

3. The contractor trained the operators on-site during the initial start-up period.

4. The contractor handed over the grinding system to CANMET after its successful operation with a final report that indicated the optimum operating conditions.

RESULTS

1. The "Szego Grinding Mill System", Model SM-460-I, was installed and tested as specified.

2. The optimum conditions for the system were identified as follows:
   Pulp density: 60-62 % w/w
   Feed rate: 0.55 t/h
   Mill rotational speed: 600 rpm.

3. Under the optimum grinding conditions, the product size d_{50} of 11 μm was obtained from the feed size d_{50} of 250 μm.

APPLICATION AND ONGOING WORK

The knowledge gained from the present study and the equipment used are being utilized in the ongoing project on pilot-plant investigation of high-sulphur coal at the Victoria Junction Coal Preparation Plant of DEVCO using the Szego Grinding Mill and Flotation Column.

SUPPORTING DOCUMENTS

Final Report: "Investigation of Low Cost Technology in Coal Cleaning Using the Szego Grinding Mill System".

TITLE: BENEFICIATION OF ULTRAFINE HIGH SULPHUR COAL

CONTRACTOR:	University of British Columbia	FILE NUMBER:	4-9134	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 29 441
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	K.S. Moon	TECHNOLOGY:	Preparation	TOTAL:	$ 29 441

OBJECTIVES

The physico-chemical desulphurization of high-sulphur coal calls for an ultrafine grinding of the material for proper liberation. Knowledge of the effects of humic acid and other modifying agents in selective separation of pyritic sulphur from coal is utilized to enhance the recovery of fine clean coal.

PROCEDURE

1. Studies on pyrite liberation during fine grinding of high-sulphur coal from eastern Canada.
2. Dissolved air flotation for separation of clean coal and pyrite.
3. Oil agglomeration separation of fine coal and pyrite. The Otisca T process was also tested.
4. Bench-scale froth flotation tests using various modifying agents.

RESULTS

1. Because of the bimodal pyrite particle size distribution, crushing below 0.5 mm liberates one-third of the pyrite in the coal. The other part has a modal size of 4 μm.
2. Oil agglomeration, dissolved air flotation, and two-stage reverse flotation, with dextrin as the only modifying agent, did not give satisfactory results.
3. Although isopropanol gave better selectivity than MIBC, frother-only flotation did not give proper recovery of coal.
4. Humic acid with kerosene and MIBC resulted in good selectivity between coal and pyrite.
5. Best selectivity was observed in direct flotation of coal with kerosene and MIBC in the presence of Carboxymethyl cellulose as a modifying agent, under alkaline conditions at about pH 9. After a few cleanings, high-grade coal concentrates (0.5% pyritic sulphur) were obtained. This process is being considered for a patent application.

APPLICATION AND ONGOING WORK

The results of the present investigation will be incorporated in the ongoing program of pilot-plant investigation of selective separation of pyrite from coal at Victoria Junction Coal Preparation Plant, DEVCO, Sydney, Nova Scotia.

SUPPORTING DOCUMENTS

Paper: "Desulphurizing Flotation of Eastern Canadian High-Sulphur Coal", by J. Laskowski, M. Bustin, K.S. Moon, and L.L. Sirois.

TITLE: DRY MAGNETIC SEPARATION OF EASTERN COAL

CONTRACTOR:	Allis-Chalmers (Sala Magnetics Operation)	FILE NUMBER:	4-9163	FUNDING	
		BEGIN/END:	Nov. 84/Aug. 85	CANMET:	$ 17 710
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. G.I. Mathieu	TECHNOLOGY:	Preparation	TOTAL:	$ 17 710

OBJECTIVES

1. Beneficiate high-sulphur and high-ash coals by commercial dry high-gradient magnetic separation (HGMS) at fine size and provide preliminary operating and capital costs for the operation.

PROCEDURE

1. Using Sala HGMS unit, magnetically test three Canadian coals by varying the following parameters to remove ash and sulphur:
   a) size range (3 fractions);
   b) matrix design according to the various sizes;
   c) field strength and flow velocity (3 levels each).

2. Evaluate the results using conventional criteria, e.g., selectivity index, grade-recovery data, etc.

3. Calculate the matrix loading (re unit capacity) and compute preliminary capital and operating costs for the best conditions found in the testing.

RESULTS

Analysis of results showed that:

1. Dry separation efficiency is comparable to the wet procedure (previous work) provided prededusting is made at 0.04 mm.

2. Flow velocity and field strength can be balanced to provide optimum selectivity for each matrix and size range.

3. Fifty-two to 92% of the ash, and 18 to 30% of the total sulphur (depending on the coal liberation), can be removed with minimal loss of combustibles (less than 8%).

4. Cost Study:
   a) Capital Cost: $60 000-90 000 per ton/hour capacity.
   b) Power Consumption: 10-15 kWh/ton feed.

TITLE: DRY MAGNETIC SEPARATION OF EASTERN COAL

CONTRACTOR:	Eriez Magnetics Co.	FILE NUMBER:	4-9165	FUNDING	
		BEGIN/END:	Nov. 84/Sept. 85		
				CANMET:	$ 18 580
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. G.I. Mathieu	TECHNOLOGY:	Preparation	TOTAL:	$ 18 580

OBJECTIVES

1. Beneficiate high-sulphur and high-ash coals by commercial dry high-gradient magnetic separation (HGMS) at fine size, and provide preliminary operating and capital costs for the operation.

2. Run a few comparative wet magnetic separation tests under similar conditions.

PROCEDURE

1. Using Eriez HGMS superconducting unit, test three Canadian coals by varying the following four parameters to remove ash and sulphur:
   a) size range (2 or 3 fractions)
   b) field strength (3 levels)
   c) flow velocity (3 levels)
   d) matrix configuration.

2. Evaluate the results using conventional criteria, e.g., the Gaudin Selectivity Index, grade-recovery data, etc.

3. Calculate the matrix loading (re unit capacity) and compute preliminary capital and operating costs for the best conditions found in the testing.

RESULTS

Analysis of results showed that:

1. Dry separation efficiency is comparable to the wet procedure when the size is over 0.04 mm.

2. Flow velocity and field strength can be balanced to provide optimum selectivity for each matrix and size range.

3. Fifty to 90% of the ash and 20 to 30% of the total sulphur (depending on the coal liberation) can be removed with minimal loss of combustibles (less than 8%).

4. Operating costs were comparable to conventional flotation.

TITLE: EVALUATE THE EFFECTIVENESS OF AGGLOMERATION METHODS IN THE RECOVERY AND BENEFICIATION OF PREPARATION PLANT COAL FINES FROM THE PRINCE MINE

CONTRACTOR:	Scotia Liquicoal Limited	FILE NUMBER:	4-9214	FUNDING	
		BEGIN/END:	Oct. 84/March 85		
				CANMET:	$ 96 450
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	C.E. Capes	TECHNOLOGY:	Preparation	TOTAL:	$ 96 450

OBJECTIVES

Evaluate the Spherical Agglomeration Process for the recovery and beneficiation of preparation plant fines from Prince Mine coal of the Cape Breton Development Corporation.

PROCEDURE

Cleaning trials on this coal were done on tonnage samples at the Homer City facility. Samples of flotation circuit feed and effluent from those tests were provided by the Scotia Liquicoal facilities in Dartmouth, N.S. An initial laboratory investigation involved the parameters of oil dosage, type of oil (No. 2 and No. 4 fuel oils), and method of agglomerate separation. A second phase of the work demonstrated the optimal agglomeration conditions on a pilot-plant scale.

RESULTS

Excellent results were obtained in all phases of the work. Using 1 to 2 wt % No. 4 fuel oil based on feed solids, products in the 10-15% ash content range were obtained with about 90% combustible recovery. The preferred process involved oil agglomeration with separation by a floc recovery method. A further water wash produced products in the 5-7% ash range.

APPLICATION AND ONGOING WORK

Results will provide a basis for design of improved cleaning plants for Prince coal. Demonstrated processes will improve yield of conventional coal preparation plants.

Combustion trials and coal-water fuel preparation with agglomerated fines have been suggested by the contractor.

SUPPORTING DOCUMENTS

Full final report on contract is confidential. A summary report for general release is under preparation by the contractor.

TITLE: BENEFICIATION OF COAL BY OXYGEN REMOVAL

CONTRACTOR: SNC Inc.	FILE NUMBER: 2-9099	FUNDING	
	BEGIN/END: Sept. 82/Jan. 83		
		CANMET:	$ 16 500
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: Dr. E. Furimsky	TECHNOLOGY: Carbonization	TOTAL:	$ 16 500

OBJECTIVES

1. Develop a novel process for removing oxygen from coal.
2. Perform beneficiation of coal by oxygen removal.

PROCEDURE

Treatment of coal with aqueous solutions of iron salts at 100° and 150°C in an autoclave.

RESULTS

Four Canadian coals (Bienfait, Onakawana, Sundance, and Forestburg) were evaluated. The extent of oxygen removal and the change in heating values during the treatments are summarized in several tables.

APPLICATION AND ONGOING WORK

The process appears to be very suitable for beneficiation of some low-rank coals.

TITLE: BENEFICIATION OF LOW RANK CANADIAN COALS WITH HEAVY RESIDUA

CONTRACTOR: Gulf Canada Limited	FILE NUMBER: 3-9024	FUNDING	
	BEGIN/END: Nov. 82/Sept. 84		
		CANMET:	$ 99 840
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	99 840
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: D.P.C. Fung	TECHNOLOGY: Carbonization	TOTAL:	$ 199 680

OBJECTIVES

1. Develop a viable process to transform Canadian low-rank coal and heavy residua into a competitive, marketable thermal coal for combustion and gasification processes.

2. Design a 0.5 t/day capacity pilot plant for the thermal upgrading of the low-rank coals.

3. Establish the preliminary economics of this upgrading process.

PROCEDURE

In the Gulf process, low-rank coals were immersed for a given period of time in a hot petroleum residuum. Moisture and some labile oxygen were driven out from the coals and their calorific value increased. The calorific value of the coal was further increased by surface coating and internal adsorption of the residuum. The residuum protected the coal product from moisture readsorption and greatly reduced the tendency of the coal to spontaneous combustion. The handling properties of the coal were also enhanced by the protective residuum layer. There should be no need to spray this coal product. Residua derived from the heavy oils and bitumen found in large quantities in Alberta were suitable for use in this process.

RESULTS

All the low-rank coals treated by the Gulf process were found to increase in calorific value as compared to the untreated coals. High-moisture coals showed significantly greater increase in calorific value than the low-moisture coals. The tendency for spontaneous combustion of the treated coal was substantially reduced and dusting problems were essentially solved. Coal quality, particle size, residuum quality, and processing conditions had an impact on the quality and product yield. A description of two designs of a pilot plant (500 kg/day) for the Gulf process was given.

APPLICATION AND ONGOING WORK

This work is continued in a 1984-85 cost-shared contract with Gulf Canada Limited.

TITLE: DEGRADATION OF COKE IN THE BLAST FURNACE

CONTRACTOR:	Mcmaster University	FILE NUMBER:	I-9136	FUNDING	
		BEGIN/END:	Jan. 82/March 83		
				CANMET:	$ 40 331
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. J.F. Gransden	TECHNOLOGY:	Carbonization	TOTAL:	$ 40 331

OBJECTIVES

Alkalis in the blast furnace cause coke degradation, which means lower furnace productivity and higher fuel rates. The objective of this contract is to determine the mechanism by which alkalis decrease coke strength so that their effect can be minimized.

PROCEDURE

Several commercial cokes from three steel plants were investigated. Coke textures were quantitatively measured by optical microscopy, and surface areas measured by BET and moisture absorption. Samples were oxidized in gas mixtures containing CO_2 before and after doping with potassium vapour. The amount of "water soluble" potassium in the cokes was determined.

RESULTS

Analysis of optical texture before and after oxidation, and before and after potassium absorption, showed selective oxidation of some texture types. However, for all cokes only preferred oxidation of inerts was conclusively identifled. The reactivity was closely related to specific area and increased as the surface area increased. Pore wall surfaces are less reactive than fracture surfaces. Potassium absorption increases the specific surface area and makes the pore surfaces as reactive as fracture surfaces.

APPLICATION AND ONGOING WORK

The relationship between surface area and reactivity will be investigated for a larger selection of cokes.

TITLE: CHEMICAL REACTIVITY OF METALLURGICAL COKE

CONTRACTOR:	McMaster University	FILE NUMBER:	3-9097	FUNDING	
		BEGIN/END:	Aug. 83/March 84		
				CANMET:	$ 33 287
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	S.F. Gransden	TECHNOLOGY:	Carbonization	TOTAL:	$ 33 287

OBJECTIVES

Potassium is recycled in the blast furnace process and is a major cause of coke degradation, which in turn leads to poor furnace productivity. Potassium both weakens the coke mechanically and increases its reactivity. The objective is to determine how cokes can be made resistant to this attack.

PROCEDURE

The reactivities of 25 commercial and test oven cokes were measured before and after potassium impregnation. Cokes were examined in a SEM at various stages and a light microscope was used for the quantitative determination of coke textures. The surface area was determined by absorption of moisture. The effect of hydrogen on the coke reactivity to CO_2 was measured, and also the conductivity of coke before and after potassium impregnation.

RESULTS

SEM examination showed that pore surfaces were more resistant to attack than fracture surfaces. Potassium impregnation caused the growth of new phases, the formation of fine cracks, and a large increase in reactivity. There was no general trend between reactivity and surface area as measured by moisture absorption, for all cokes. However, related samples, i.e., cokes made from the same coal blend but at different coking rates, showed clearly that reactivity increases with surface area. Mosaic coke textures were more resistant to reaction than either the domain textures or the inerts. At low-potassium contents the electrical conductivity of the coke increased because, it is suggested, of formation of intercalation compounds, but at high contents it decreased because of crack formation. Hydrogen gas was found to change the relative order of reactivity of the cokes and this is considered important since hydrogen is present in the blast furnace.

TITLE: INDIRECT EVALUATION OF THE REACTIVITY OF INERTINITES IN WESTERN CANADIAN COKING COALS

CONTRACTOR:	David E. Pearson & Associates Ltd.	FILE NUMBER:	3-9063	FUNDING	
		BEGIN/END:	July 83/April 84		
				CANMET:	$ 47 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.T. Price	TECHNOLOGY:	Carbonization	TOTAL:	$ 47 000

OBJECTIVES

1. Improve the present techniques of coal petrography for western Canadian coals to confidently predict coke quality.

2. Determine reliably the amount of semi-fusinite macerals (or inert macerals) that are reactive for any western Canadian coal.

3. Better assess the commercial value of Canadian coals.

PROCEDURE

On a suite of 76 samples, which had previously been carbonized and for which coke strength data were available, R_o max., a parameter of rank, was determined. Two new parameters: calculated inerts and the reactive cutoff, were computed for each of these samples. Calculated inerts is the theoretical quality of inertinite macerals and mineral-matter required to produce the determined coke strength; whereas the reactive cutoff is the random reflectance value separating reactive from inert macerals that will provide this required level of calculated inerts.

RESULTS

It was found that for the range of vitrinite reflectances studied (0.89-1.63%) there is a good linear relationship between R_o max. and the reactive cutoff. This implies that for any coal the reactive cutoff can be calculated and the distinction between reactive and inert macerals can be made wholly on the basis of random reflectance.

Among the sample suite, it was found that the proportion of reactive semi-fusinite required to correctly predict coke strength varied between 12% and 43%.

By using the reactive cutoff method to distinguish between inert and reactive macerals during coal-type analysis, it is no longer necessary to be able to recognize semi-fusinite macerals or what proportion of semi-fusinite are reactive. Indications are that this method of coal-type analysis is likely to be universally applicable.

APPLICATION AND ONGOING WORK

The results of this study should improve the reliability of petrography in assessing the coking quality of Canadian coals, and should prove of considerable benefit to the export coal industry of western Canada.

Work is continuing to determine if this technique can be automated to improve the consistency of petrographic analysis.

TITLE: RHEOLOGY AND RHEOLOGICAL TESTING OF WESTERN CANADIAN BITUMINOUS COAL - PHASE I

CONTRACTOR: University of Waterloo	FILE NUMBER: 3-9110	FUNDING	
	BEGIN/END: Aug. 83/Dec. 84		
		CANMET:	$ 55 660
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: Dr. J. Price	TECHNOLOGY: Carbonization	TOTAL:	$ 55 660

OBJECTIVES

1. Determine why many western Canadian coals that have good coking properties have low thermal rheological properties, i.e., dilatation and Gieseler fluidity.
2. Compare thermal rheological properties of western Canadian coals of similar rank, maceral and ash compositions.
3. Determine if thermal rheological test procedures developed primarily for carboniferous coals are unsuitable for Canadian coals.

PROCEDURE

1. Three Appalachian and three western Canadian coals of similar rank were solicited for FSI, Gieseler fluidity, Ruhr dilatations, and petrography.
2. A western Canadian and an Appalachian coal of identical rank were selectively crushed and separated by specific gravity; thermal rheological, petrographic, and proximate measurements were run on each fraction.
3. Coal fractions from the western Canadian coal were blended to match the maceral and ash composition of the Appalachian blend.

RESULTS

1. Higher heating rates improved thermal rheological properties of all coals.
2. Removal of fines (-100 mesh material) from coals showed that fines inhibit contraction and dilatation.
3. Dilatations for Appalachian coals were generally much higher than for western Canadian coals having the same vitrinite content.
4. A good overall petrographic match of Appalachian and western Canadian coal was achieved by blending western Canadian coal fractions to target the ash and inertinites of the Appalachian coal. Dilatations were still lower for the western Canadian coal and may be a result of inherent differences in the vitrinites. However, FSI results for the two coal types were more similar; perhaps the higher heating rates of an FSI test may be better for ranking coking properties.

APPLICATION AND ONGOING WORK

Results can be used by the Canadian coal industry to explain anomalous thermal rheological behaviour of western Canadian coking coals and as an aid for marketing purposes.

SUPPORTING DOCUMENTS

Final Report: "Rheology and Rheological Testing of Western Canadian Bituminous Coals - Parts 1 and 2".

TITLE: CHARACTERIZATION OF COAL SURFACES BY ION MICROPROBE MASS ANALYSIS - PHASE I

CONTRACTOR:	University of Western Ontario	FILE NUMBER:	I-9137	FUNDING	
		BEGIN/END:	April 83/June 84		
				CANMET:	$ 33 440
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.A. MacPhee	TECHNOLOGY:	Carbonization	TOTAL:	$ 33 440

OBJECTIVES

Application of Secondary Ion Mass Spectrometry (SIMS) to the study of coal surfaces. Coals from various Canadian sources to be examined.

Ion Microscopy, a type of Secondary Ion Mass Spectrometry, is a highly sensitive analytical technique capable of detecting virtually all chemical elements in microscopically small regions. It is considered a promising approach to characterizing the complex heterogeneous structures typical of coal.

The Cameca IMS-3F ion microprobe in the Surface Science Laboratory is to be used to evaluate the potential of coal microanalysis. This particular model of ion microprobe is considered the most technically advanced available, with a capability of detecting many elements in the part per million range. Analytically difficult elements such as carbon and hydrogen are also detectable and their distribution determined to a resolution of 0.5 µm. Thus, both organic and inorganic phases can be characterized.

PROCEDURE

1. Determination of appropriate instrumental conditions and sample preparation methods.

2. Detailed characterization of three distinct types of macerals using high-resolution ion microscopy to determine fractional molecular weight values of the major organic ions. The fragmentation patterns produced by surface bombardment using O_2^+ will be compared with those obtained by Fast Atom Bombardment (FAB) using a second mass spectrometer.

3. Characterization of pollshed sections of fifteen samples of Canadian coals selected by CANMET. This will be accomplished using:

   a) Mass spectra up to mass 500 of large regions of each coal;
   b) Ion imaging, giving the distribution of major ions produced on the surface;
   c) Line scans across the face of the coal sample, showing the distribution of major elements.

4. Microscopic analysis of coal specimens to be analyzed by ion microprobe mass analysis, both before and after SIMS analysis, for fifteen samples.

RESULTS

Secondary Ion Mass Spectrometry (SIMS) has been used to analyze both the inorganic and organic constituents of coal. The high spatial resolution of the ion microscope has been particularly important in obtaining characteristic spectra from this very heterogeneous material. Three distinct types of coal macerals: Vitrinite, Fusinite, and Exinite, have been characterized as well as several examples of soft coal. Some preliminary SIMS studies of the oxidation of vitrain are also reported.

APPLICATION AND ONGOING WORK

These studies of coal microstructure represent the first stage of a larger effort to use SIMS to determine mechanisms of coal surface oxidation. Since oxidation rates will likely be strongly affected by local compositional differences, the use of a highly sensitive microanalytical technique such as SIMS is of particular importance to this work. A preliminary examination of surface oxidation by SIMS is described in this report.

SUPPORTING DOCUMENTS

Final Report: "Characterization of Coal Surfaces by Secondary Ion Mass Spectrometry".

TITLE: CHARACTERIZATION OF COAL SURFACES BY ION MICROPROBE MASS ANALYSIS - PHASE 2

CONTRACTOR:	University of Western Ontario	FILE NUMBER:	3-9098	FUNDING	
		BEGIN/END:	Sept. 83/Nov. 85		
				CANMET:	$ 42 827
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.A. MacPhee	TECHNOLOGY:	Carbonization	TOTAL:	$ 42 827

OBJECTIVES

Detection of surface oxidation in discrete coal macerals.

Ion microscopy, a type of secondary ion mass spectrometry (SIMS), is a highly sensitive analytical technique capable of detecting virtually all chemical elements in microscopically small regions. It is considered a promising approach to characterizing the complex heterogeneous structures typical of coal.

The Cameca IMS-3F Ion Microprobe in the Surface Science Laboratory (unique in Canada) is to be used to evaluate the potential of coal microanalysis. This particular model of ion microprobe is considered the most technically advanced available, with a capability of detecting many elements in the part per million range. Analytically difficult elements such as carbon and hydrogen are also detectable, and their distribution determined to a resolution of 0.5 μm. Thus, both organic and inorganic phases can be characterized.

PROCEDURE

1. Examine four fresh coals from eastern and western Canada (characterization of macerals: vitrinite, fusinite, semi-fusinite).

2. Examine the same four fresh coals after being subjected to laboratory oxidation in order to characterize the changes taking place during oxidation.

3. Examine four additional naturally oxidized coals from western Canada.

4. All 12 of the above samples will be examined using ion microprobe techniques to generate ion images of various portions of the samples. In addition, all regions examined by ion microprobe will be examined using reflected light optical microscopy and photo-micrographs made of each region. This is vital to this study to enable petrographic (i.e., maceral) identification of all regions under investigation. Optical and ion images of all samples examined will be provided by the investigator.

RESULTS

Results deal with the inherent reactivity of discrete coal macerals.

Procedures for the reaction of ^{18}O with coal specimens have been developed, and SIMS methods for the detection of ^{18}O in microscopic coal regions have been devised. The method has been proven using coal specimens containing previously characterized macerals of vitrinite, fusinite, and liptinite. Fusinite surfaces have been shown to absorb more than ten times more oxygen than vitrinite at temperatures of 100-150°C.

Using the SIMS specimen isolation effect, the fixation of ^{18}O within microscopic regions of the coal can be determined for concentrations of a few per cent. Reactions between a number of coal maceral types and ^{18}O have been carried out at 100°C. The reversible uptake of oxygen is a function of both the rank and the maceral type. The presence of mineral matter in the coal has no significant effect on the rate of oxygen uptake. The chemical oxidation of coal surfaces using dichromate ion has also been studied by SIMS. The dramatic changes in the negative secondary ion spectrum suggest a strong alteration in the organic surface structure. Such differences are strong enough to be imaged in the SIMS, thus allowing the effect of oxidation on various macerals

to be assessed visually.

APPLICATION AND ONGOING WORK

Relevant to characterization of coals for combustion and carbonization processes.

SUPPORTING DOCUMENTS

Final Report: "Characterization of Coal Surfaces by Ion Microscopy - Phase 2: Surface Oxidation".

TITLE: SCANNING AND TRANSMISSION ELECTRON MICROSCOPE STUDIES OF MACERALS AND PORE STRUCTURE IN COALS OF DIFFERENT RANK

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	4-9007	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 45 410
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	K. Thambimuthu	TECHNOLOGY:	Carbonization	TOTAL:	$ 45 410

OBJECTIVES

Develop and test electron microscopy techniques for the study of coal macerals, coal minerals, and pore structures and apply these techniques to four coals of different rank.

PROCEDURE

SEM and TEM analysis of prepared coal specimens.

RESULTS

The study examined an eastern high-volatile bituminous coal, a western low- and a medium-volatile bituminous coal, and a Saskatchewan lignite. The results showed SEM analysis to be of limited utility for the study of coal maceral structure. However, SEM/EDXA used in concert with optical microscopy was able to identify mineral-maceral relationships in a particular coal. TEM analysis was useful in observing the porosity of particular coal macerals.

APPLICATION AND ONGOING WORK

None anticipated at this time.

TITLE: PETROGRAPHIC ANALYSES OF COAL CONVERSION FEEDSTOCKS AND RESIDUES - PHASE 3

CONTRACTOR: University of Regina	FILE NUMBER: 1-9054	FUNDING	
	BEGIN/END: Sept. 81/March 82		
		CANMET:	$ 34 147
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: B.N. Nandi	TECHNOLOGY: Gasification	TOTAL:	$ 34 147

OBJECTIVES

Explore the possibility of using petrography as a tool for predicting the behaviour of different coal feedstocks during gasification and for measuring levels of oxidation in feedstock.

PROCEDURE

1. Gasify coal in a laboratory-scale gasification unit.
2. Analyze the chemical composition of gas produced from the laboratory-scale gasifier with Carle Model 111-H gas chromatograph.
3. Analyze by petrographic method feedstocks of different ranks of coal and corresponding residues after gasification.

RESULTS

The different macerals reacted differently under relatively mild conditions for gasification of coal. Some variations in petrographic composition occur in lignite, subbituminous coal, and bituminous coal. The reactivities of different coal macerals during oxidation and devolatilization were reported. The initial intent of acquiring petrographic expertise in this field was partly achieved.

APPLICATION AND ONGOING WORK

Continuation of Contract No. 9-9176.

TITLE: TECHNICAL AND ECONOMIC ASSESSMENT OF THE REACTIVITY OF SASKATCHEWAN LIGNITE COALS AS THEY RELATE TO GASIFICATION PROCESSES - PHASE 4

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	0-9139	FUNDING	
		BEGIN/END:	Oct. 81/Jan. 83		
				CANMET:	$ 74 752
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	L. Mysak	TECHNOLOGY:	Gasification	TOTAL:	$ 74 752

OBJECTIVES

1. Evaluate the effects of alkaline ion exchangeable metals on gasification rates.

2. Determine the effects of inherent mineral matter on lignite char gasification.

PROCEDURE

Gasification runs were conducted in a pressurized fixed bed reactor (51 mm I.D., 1525 mm long) with Estevan and Coronach lignite chars containing different mineral matter contents. The composition of char material was modified using control ion exchange treatments by varying the pH, concentration, and ionic strength of the ion exchange solutions. The experimental tests were conducted in temperature ranges 800°C-950°C, pressures up to 2 MPa, and reactant gases of air/steam or steam.

Char samples of Coronach and Estevan lignite were prepared and gasified. Gasification experiments were conducted on chars obtained from acid-washed Coronach and Estevan lignites.

Calcium- and sodium-exchanged chars were gasified, and their effect on gasification rates studied.

RESULTS

The results show that the reactivity of demineralized chars was significantly reduced as compared to the reactivity of corresponding run-of-mine (ROM) or ion-exchanged lignite chars. The catalytic effects of calcium and sodium in the steam gasification of lignite chars were found to be similar when the cation concentration was expressed on a mole/gram of fixed carbon basis.

Correlation between enriched lignite sodium or calcium concentration and steam gasification char reactivity provided a good approximation of ROM char gasification behaviour. Analysis of char gasification behaviour in both steam and steam/air atmospheres was most accurately and conveniently performed using the method based on a dimensionless time parameter.

APPLICATION AND ONGOING WORK

Development of Canadian expertise in the area of coal conversion and also an increase in the database from which results could be obtained to aid in the design and installation of future full-scale gasifiers.

TITLE: TECHNICAL ASSESSMENT OF THE REACTIVITY OF SASKATCHEWAN LIGNITE COALS AS THEY RELATE TO GASIFICATION PROCESSES - PHASE 5

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	2-9014	FUNDING	
		BEGIN/END:	July 82/Dec. 83		
				CANMET:	$ 60 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	L.P. Mysak	TECHNOLOGY:	Gasification	TOTAL:	$ 60 000

OBJECTIVES

Appraise work completed in Phases 1-4 in order to develop a generalized description of lignite gasification kinetics in relation to its properties.

PROCEDURE

The gasification data detailed in Phases 1 through 4 were analyzed and presented in the form of reactivity correlated to lignite composition, temperature, and steam/air ratio. These Phases have centered on the following: (1) the gasification potential of lignite in relation to its petrographic analysis; (2) the optimization of process variables; (3) the environmental pollution potential of effluent streams from a lignite gasification reactor; and (4) the catalytic potential of coal minerals (sodium and calcium) in steam gasification of lignite char.

A computer program was developed for reduction of all data to one common basis to correlate the reactivity of various coals and chars.

RESULTS

1. An APL computer language program was developed to reduce all data to a common basis for further analysis. Through this analysis, an accurate method was developed and tested for the rapid determination of gasification reactivity parameters of various lignite samples under diverse reaction conditions. The kinetic expression developed is: $k/k^* = 1.16 + 1.24\ (Y) \times 10^3$ where Y is the concentration of calcium or sodium in moles per gram of fixed carbon in the lignite, and k, k^* are the apparent rate constants for the cation-enriched and acid-washed samples, respectively.

   The equation permits prediction of the extent of the char/steam reaction and, when combined with other information such as air flowrates, etc., it allows the design of a gasification reactor based on chemical reaction engineering principles.

2. Throughout the experimental work of the past four Phases, data have been acquired on all facets of the gasification reactivity question. It is felt that the range of conditions under which testing was carried out was wide enough to encompass the operation of most commercially run gasifiers. Results obtained on the bench-scale gasifier correlated well with available commercial data. Saskatchewan Power is confident, therefore, that the design data generated in this Phase of the study are relevant to commercial design. Enough information and procedures are contained herein for a potential coal gasifier operator to conduct sensitivity and feasibility studies to determine the appropriateness of the economics of entering the lignite gasification market.

APPLICATION AND ONGOING WORK

The results from this study will provide criteria helpful in selecting gasification processes for production of low energy gases for generation of electricity and process heat from Saskatchewan lignites.

TITLE: GASIFICATION REACTIVITIES OF ULTRASONICALLY TREATED COAL REJECTS

CONTRACTOR: Carleton University	FILE NUMBER: 4-9211	FUNDING	
	BEGIN/END: Oct. 84/May 85		
		CANMET:	$ 20 880
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: Dr. B.N. Nandi	TECHNOLOGY: Gasification	TOTAL:	$ 20 880

OBJECTIVES

Study the feasibility of the application of ultrasonic treatment to coal rejects (the sink part obtained after washing the coal) to separate the inorganic portion (mineral matter) intimately associated with the coal macerals (organic carbon portion in coal). It has been reported in several papers that application of ultrasonic power enhanced significantly the separation of mineral matter from coal.

PROCEDURE

1. Sample preparation from coal rejects by:
   a) crushing
   b) sieving samples to required particle size.
2. Physical and chemical analyses of the samples.
3. Perform ultrasonic treatment at different power levels on prepared samples of coal rejects of different particle size at various temperatures of medium.
4. Complete analyses of the treated sample.
5. Report.

RESULTS

There is no significant effect on the removal of ash regardless of whether or not ultrasound was applied. The ash and sulphur contents were not significantly affected by any of the treatments.

TITLE: FEASIBILITY STUDY OF UNDERGROUND GASIFICATION IN THE BOWRON AND TULAMEEN COALFIELDS

				FUNDING	
CONTRACTOR:	B.C. Hydro & Power Authority	FILE NUMBER:	2-9018		
		BEGIN/END:	May 82/March 83		
				CANMET:	$ 13 670
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	13 670
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.P.C. Fung	TECHNOLOGY:	Gasification	TOTAL:	$ 27 340

OBJECTIVES

1. Identify the regions of the Bowron River and Tulameen Coalfields that are most suitable for underground gasification, taking into account access to the site, ownership of the coal rights, data for the coal seams, competing uses of resources, and the potential for alternate development of the coal resources.

2. Determine and compare the costs, or ranges of costs, of producing low-heating-value gas, medium-heating-value gas, and synthetic natural gas from gasification plants in the Bowron River and Tulameen Coalfields. This is to include a survey of the literature for previous economic analyses and definition of a production scenario. Estimates will be made for the cost of transporting the possible products based on data made available by B.C. Hydro and Power Authority.

3. Formulate an outline for development of underground gasification at the most attractive site.

4. Provide an outline of the environmental effects and potential problems arising from underground gasification.

PROCEDURE

Dolmage Campbell & Associates Ltd. and B.H. Levelton & Associates Ltd. were subcontracted to perform the work. The former company was responsible for compiling geological, coal quality, seam quality, location, and geographical data. These data were needed for a regional evaluation of the coalfield.

B.H. Levelton & Associates Ltd. was responsible for:

1. Project coordination.

2. Specification of data to be compiled by Dolmage Campbell & Associates.

3. Estimation of capital investment and operating costs for plants producing synthetic natural gas and synthesis gas.

4. Recommendation of the most attractive scenario for gas production.

RESULTS

It has been determined that the main seams of both the Bowron and the Tulameen coalfields are suitable for underground gasification. The nominal output capacities of the plants are 1.5×10^6 m^3/d and 3.8×10^6 m^3/d for synthetic natural gas (SNG) and synthesis gas (Syngas), respectively. Capital investment and operating costs for the Bowron and Tulameen Coalfields were estimated (Jan. 1983 price) as follows:

Coalfield	Product Gas	Capital Investment $ \times 10^6$	Operating Cost $ \times 10^6$	Product Price G/J
Bowron	SNG	344.9	22.2	4.2
	Syngas	305.6	19.9	3.6
Tulameen	SNG	333.7	22.0	3.4
	Syngas	294.4	20.0	2.8

TITLE: REVIEW AND ASSESSMENT OF PROCESSES FOR INDIRECT LIQUEFACTION OF ONTARIO LIGNITE INTO METHANOL AND OTHER LIQUID FUELS

CONTRACTOR:	Ontario Energy Corporation	FILE NUMBER:	2-9092	FUNDING	
		BEGIN/END:	Dec. 82/July 84		
				CANMET:	$ 99 840
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	99 840
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D.P.C. Fung	TECHNOLOGY:	Gasification	TOTAL:	$ 199 680

OBJECTIVES

1. Assess the feasibility and viability of producing methanol from Ontario lignite via the gasification process.

2. Compare the suitability of the commercial gasification processes for the production of 2500 tonnes per day of methanol.

3. Conduct gasification tests at the laboratory of the process developer.

PROCEDURE

The feasibility study was subcontracted to Kilborn Limited of Toronto. The gasification tests were performed by Rheinbraun Consulting of West Germany.

RESULTS

Of the five processes studied, the High-Temperature Winkler technology developed by Rheinbraun-Uhde (West Germany) was found suitable for the gasification of Ontario lignite for the production of 2500 tonnes per day of methanol. It has been determined that the lignite-to-methanol route is not likely to be competitive with the natural gas-to-methanol route in the 1980's because of the high process efficiency of the latter route. However, the lignite-to-methanol route would be economically attractive if the price of lignite remains at $16 per tonne and the price of natural gas rises above 20¢ per 1000 m^3 in the mid-1990's.

APPLICATION AND ONGOING WORK

Further work on the gasification of lignite by the Ontario Government is not anticipated. Application of gasification technology for methanol production from Ontario lignite may be economically attractive in the mid-1990's.

TITLE: HIGH TEMPERATURE GAS CLEAN-UP

CONTRACTOR: Ebastec Lavalin Inc.	FILE NUMBER: 2-9021	FUNDING	
	BEGIN/END: Oct. 82/March 83		
		CANMET:	$ 75 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: E. Furimsky	TECHNOLOGY: Gasification	TOTAL:	$ 75 000

OBJECTIVES

Review the status of hot gas clean-up research and development. Compare hot gas clean-up with low-temperature clean-up for the fixed bed, fluidized bed, and entrained bed gasification systems.

PROCEDURE

This was a paper study, therefore there was no experimental procedure involved. The usual economic and technical calculations were performed to obtain the cost of hot and cold gas clean-ups.

RESULTS

One case was identified where the hot gas clean-up was more economical than cold clean-up - the fixed bed reactor. For the other two reactors, the cold gas clean-up appears to be more economical. The areas of additional research are identified to improve the economy of these two reactors (fluidized and entrained bed reactors).

APPLICATION AND ONGOING WORK

On the basis of this work, the in-house research has been designed. This research program is now in progress.

SUPPORTING DOCUMENTS

The final report is available in the files of the Pyrolysis and Gasification Section.

TITLE: APPLICATION OF FLUID-BED GASIFICATION TECHNOLOGY AND ABSORBENTS FOR UTILIZATION OF HIGH SULPHUR NEW BRUNSWICK COAL

CONTRACTOR: SNC Inc.	FILE NUMBER: 2-9104	FUNDING	
	BEGIN/END: Oct. 82/March 84		
		CANMET:	$ 91 763
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: Dr. D. Fung	TECHNOLOGY: Gasification	TOTAL:	$ 91 763

OBJECTIVES

Apply fluid-bed gasification technology and absorbents for utilization of New Brunswick coal and limestone resources for the production of low and medium calorific value gas.

PROCEDURE

The Department of Chemical Engineering of Queen's University was the subcontractor. All the coal preparation and gasification experiments were performed at Queen's University. A 38 x 41 cm fluidized-bed gasifier was used for the experiments.

RESULTS

The coal under investigation was a caking coal with a free-swelling index of 5.0-5.5 and a low ash fusion point. Particle agglomeration was a major problem in the gasification experiments. It led to desulphurization, development of local zones of overheating, and loss of temperature control in the bed. It was estimated that the synthesis gas from a 3.88 h run had a gross heating value of 3230 kJ/m^3.

The use of limestone as a sorbent reduced the H_2S content of the synthesis gas. At a Ca/S ratio of 3, the sulphur capture by the bed solid was about 90%.

APPLICATION AND ONGOING WORK

This project is completed and no further work is anticipated in the near future.

TITLE: GASIFICATION OF WESTERN CANADIAN COAL IN A SPOUTED BED - CONTINUATION

CONTRACTOR:	University of British Columbia	FILE NUMBER:	3-9082	FUNDING	
		BEGIN/END:	Aug. 83/June 84		
				CANMET:	$ 131 026
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. D.P.C. Fung	TECHNOLOGY:	Gasification	TOTAL:	$ 131 026

OBJECTIVES

Continue the R&D effort on spouted bed gasification technology by investigation of potential scale-up problems, evaluation of deleterious raw gas constituents, and development of a mathematical model for the UBC gasifier.

PROCEDURE

A series of pilot-plant modifications were made for the operation of dry and agglomerating modes. Experiments were carried out with air and oxygen gasification of the Forestburg and Balmer coals in beds of chars.

RESULTS

The spouted bed gasifier can be efficiently operated in the char-bed ash agglomerating mode with air, and with oxygen as oxidant on bituminous (Balmer) and subbituminous (Forestburg) coals. Gas heating values of 9.6 MJ/m^3 have been obtained with oxygen/steam gasification for both the Balmer and Forestburg coals. Suitable geometry and flow conditions have been found to operate in the ash agglomerating mode. Catalytic gasification with potassium carbonate appears to raise efficiency and reduce the H_2S levels in the produced gas. A kinetic model of the spouted bed gasifier has been developed to predict axial and radial composition profiles in the gasifier.

APPLICATION AND ONGOING WORK

The spouted bed technology will be used for gasifying Syncrude and Suncor cokes in a study in fiscal year 1984-85.

TITLE: GASIFICATION OF OIL SANDS COKE

CONTRACTOR:	University of British Columbia	FILE NUMBER:	4-9018	FUNDING	
		BEGIN/END:	May 84/March 86		
				CANMET:	$ 141 484
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. D. Fung	TECHNOLOGY:	Gasification	TOTAL:	$ 141 484

OBJECTIVES

Assess cokes arising from two commercial oil sands plants, Suncor and Syncrude, as feedstocks for oxygen/steam gasification to produce either a clean burning fuel gas or a synthesis gas.

PROCEDURE

Experiments were conducted in a 0.305 m I.D. atmospheric pressure gasifier operated either in a fluidized or a spouted bed mode depending on the size of the coke and/or the bed material.

Depending on the experimental conditions, the bed material consisted of silica sand (16 mesh), dolomite (-18 + 50 mesh), or char. The initial static bed depth of a typical run was about 0.45 m, and the bed material was charged from the top of the reactor. The reactor was preheated to 500°C using propane gas. The bed was spouted or fluidized using air before coke was blown into the reactor using pure oxygen. The propane gas was gradually decreased and shut off when the reactor temperature reached 750°C. The reactor temperature was controlled at the desired value by adjusting the steam and pure oxygen flowrates.

RESULTS

Suncor coke of particle size 1.5 mm could be readily gasified by a steam-oxygen mixture in a spouted bed to yield a gas of about 33-38% H_2, 22-28% CO, and 38-44% CO_2 on a dry basis at carbon conversions up to 94%. The heating value of the gas was 8.8 MJ/m^3. Potassium carbonate increased the extent of carbon conversion and steam decomposition at temperatures some 50-100°C lower than that (930°C) of non-catalytic runs. Dolomite reduced the sulphur content of the produced gas.

Syncrude coke of particle size 0.2 mm, gasified at 980°C in a fluidized bed, had lower carbon conversion levels but higher CO_2 contents than did Suncor coke. The gas had a heating value of 8 MJ/m^3 (N_2 free basis) and chemical composition of about 28-38% H_2, 16-24% CO, and 36-55% CO_2. The results suggested that temperatures in excess of 1000°C would be required to give carbon conversions higher than 80% with the existing gasifier system. Potassium carbonate raised the carbon conversion to the 80% level at temperatures of about 880°C.

APPLICATION AND ONGOING WORK

No further work is planned in the near future.

TITLE: SIMULTANEOUS LIQUEFACTION AND TRANSPORTATION OF COAL

CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	0-9089	FUNDING	
		BEGIN/END:	March 81/May 83		
				CANMET:	$ 46 227
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Sawatsky	TECHNOLOGY:	Liquefaction	TOTAL:	$ 46 227

OBJECTIVES

The objective of this study was to explore the feasibility of liquefying lignites in a pipeline to produce sufficient liquids for slurry pipeline transportation of lignite. This required investigating the possibility of initiating liquefaction at a normal liquefaction temperature and then obtaining significant further liquefaction at lower temperatures. This would simulate the situation at the lignite source and further down the pipeline with cooling. It would allow the liquefying reactions to continue over long periods of time, but at lower temperatures, and might lead to the generation of sufficient amounts of liquids for pipeline transport.

PROCEDURE

Lignite was treated as a slurry in a mixture of tetralin and anthracene with reducing gases in an autoclave. The conditions for significant liquefaction were determined. Then, the extent of liquefaction was determined when liquefaction was initiated at 385°C for 20 minutes and then cooled to 300°C and kept at this temperature for 11.5 hours.

RESULTS

The liquefaction of Saskatchewan (Estevan) lignites readily occurred if synthesis gases were used. Pure hydrogen did not appear to be very effective. A 3:1 molar ratio of carbon monoxide to hydrogen in the synthesis was somewhat more effective than a 3:1 ratio. When the liquefaction systems were cooled to 300°C, little additional liquefaction occurred.

Thus, it is not technically feasible to obtain satisfactory liquefaction in the unheated portion of a pipeline.

TITLE: LIQUEFACTION OF NOVA SCOTIA COALS - PHASE 4

CONTRACTOR:	Nova Scotia Research Foundation Corporation	FILE NUMBER:	0-9172	FUNDING	
		BEGIN/END:	June 81/Aug. 83		
				CANMET:	$ 97 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	NOVA SCOTIA	
AUTHORITY:	D.K. Faurschou	TECHNOLOGY:	Liquefaction	DEPARTMENT OF MINES:	97 000
				TOTAL:	$ 194 000

OBJECTIVES

1. Modify the continuous donor solvent coal liquefaction unit (1500 cm^3 stirred tank reactor) to ensure reliable operation and determination of mass balances to ±1%.

2. Assess the influence of feedstock, temperature, pressure, slurry treat rate, and random variables on single-stage hydrogen donor liquefaction of selected Nova Scotia coals.

3. Screen catalysts to improve distillate yields.

4. Review the literature on separation and characterization of coal-derived liquids.

PROCEDURE

1. The continuous liquefaction tests were conducted in a system, operated up to 460°C and 20.68 MPa, which includes a:
   - 1500 cm^3 stirred tank reactor
   - hydrogen flow control system
   - digital load cell monitoring of feedstock
   - automated product let-down
   - magnetic drive stirring
   - gamma ray level control.

2. Twenty-four continuous runs were conducted using Hub seam (Prince Mine) and Harbour seam (Lingan and No. 26 Mines) coals. Sixteen of these tests were conducted in a 2^4 randomized factorial design to quantitatively assess the primary variables affecting yield.

3. The catalysts were screened in batch autoclaves.

RESULTS

Statistical analysis shows that the continuous liquefaction unit produces highly reproducible results. The influence of feedstock (Lingan and No. 26), slurry feedrate (1 and 2 kg/h), and temperature (440 and 460°C), for example, were each significant at a confidence level of 99% on the yields of gas, oil, asphaltenes, and preasphaltenes.

In general, at high severity operating conditions the coal conversions (THF solubles plus gases) ranged from 85 to 89%; however, the oil yields ranged from 20 to 34%. The uncatalyzed oil yields are particularly sensitive to coal characteristics, tending to decrease going from Prince to Lingan to No. 26 coal, i.e., oil yield decreases as coal rank increases. Autoclave tests, however, showed that catalysts can dramatically increase oil yields.

APPLICATION AND ONGOING WORK

Phase 5 has been initiated to investigate the performance of catalyzed single-stage and two-stage continuous liquefaction of Nova Scotia coal to achieve enhanced yields of distillable oil and improved hydrogen utilization.

SUPPORTING DOCUMENTS

Final Report: "Liquefaction of Nova Scotia Coals - Phase 4, Studies on High Pressure Donor Solvent Liquefaction and Catalytic Hydrogenation of Sydney Area Coals", by J.J. Starzomski and D.M. Jay, August 1983 (148 pages).

TITLE: PRODUCTION OF OIL FROM LOW RANK CANADIAN COALS BY CONTINUOUS LIQUEFACTION - PHASES 2 AND 3

CONTRACTOR:	Sandwell Beak Research Group	FILE NUMBER:	1-9031/0-9170	FUNDING	
		BEGIN/END:	Sept. 81/Oct. 83		
				CANMET:	$ 370 501
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	370 500
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	J.F. Kelly	TECHNOLOGY:	Liquefaction	TOTAL:	$ 741 001

OBJECTIVES

1. Extend the knowledge on the liquefaction properties of two Canadian low rank coals through experimentation in a continuous mode in the PDU, using both a once-through and recycle mode of operation.

2. Evaluate the influence on conversion and liquid yield of such conditions as temperature, pressure, reaction time, recycle oil fraction, and gas mixture composition.

3. Development of preliminary economics of a process for direct liquefaction based on the results of the experimental program and a plan for a demonstration at a larger scale.

PROCEDURE

A total of 14 experiments were conducted in the once-through mode of operation. Anthracene oil was employed as a solvent in most cases, except for two experiments that used a partially lignite-derived solvent and a hydrogenated coal-derived solvent obtained from the Wilsonville, SRC-I pilot plant. Experiments were conducted using Estevan lignite and Roselyn subbituminous coal. Except for one experiment, hydrogen gas was used as the reducing gas.

Three recycle experiments were conducted using filtration, vacuum distillation, and centrifugation as the means of solvent fractionation. All recycle runs were conducted on the same coal under identical operating conditions.

A separate study on solids separation was undertaken to develop a PDU system for the separation of solids from coal-derived liquefaction product. This report discussed the results of a literature review on this subject and bench-scale testing of several of the alternatives. Work is continuing leading to the demonstration of a new process for solids separation and product recovery.

A number of equipment improvements, design changes, and additions were completed during the year to make the unit safe, reliable, and efficient to operate. These improvements as well as run histories and equipment performance are described.

RESULTS

During the first full year of operation of the PDU, the unit operated for more than 500 h and generally performed very well.

Three experimental runs were conducted with recycle of the product as solvent. In the most successful runs, the recycle solvent was a mixture of 250-450°C vacuum distillation cut and non-distilled as-received slurry product. Thus, a portion of solids was returned. Stable operation was achieved after four passes. Compared to once-through operation under similar conditions, the conversion increased from 84.1% to 95.3% maf of fresh coal. Similarly, liquid yields increased from 61.4% to 68.4%. This corresponds to gross yields of 4.4 bbl/tonne maf coal. These are excellent results, as good as those obtained by any other process on lignitic coals.

In the other recycle runs, employing vacuum filtration and centrifugation for solids separation, stable operation was not achieved. These runs revealed the importance of maintaining the appropriate ratio of preasphaltene and asphaltene compounds relative to oils (cyclohexane soluble material) in the recycle streams. The recycle runs clearly indicate that conversions greater than 90%

can be achieved and that excellent liquid yields can be obtained, although the products need further upgrading.

For most of the experiments, an anthracene oil was used as a solvent. Tests were also conducted with a distilled fraction of once-through lignite-derived product and with Wilsonville hydrogenated solvent. The conversions obtained were similar to those produced with anthracene oil. Liquid yields varied greatly, however, with the partially lignite-derived solvent increasing the total liquid yield, albeit of generally lower quality. The tests with Wilsonville hydrogenated coal-derived solvent resulted in a reduction of liquid yield.

One experiment was conducted with a gas mixture of CO and H_2. It was expected that larger conversions would be produced with syngas, but conversions of only 76.4% were obtained. The liquid yield was higher than a comparable test with hydrogen, which suggests that further research on this option should be conducted.

Four experiments were conducted with an Alberta subbituminous-C coal (Roselyn Mine). On inspection and comparison of the results with the lignite runs at similar LHSV rates, the subbituminous coal gives comparable results to the lignite.

The solids separation part of the direct liquefaction process is a critical step in the entire process. This program has resulted in some new separation process concepts, which are expected to optimize the product recovery, solids separation, and solvent selectivity aspects of this unit operation. In the next stage of the program, these concepts will be developed and demonstrated.

APPLICATION AND ONGOING WORK

Phase 4 program to be initiated in 1983 with special emphasis on development of a new solids separation process.

SUPPORTING DOCUMENTS

Final Report: "Study Relating to the Production of Oil from Low Rank Canadian Coals by Continuous Liquefaction - Phases 2 and 3", October 1983 (Contract Report No. OSQ81-00022/24).

TITLE: PRODUCTION OF OIL FROM LOW RANK CANADIAN COALS BY CONTINUOUS LIQUEFACTION - PHASE 4

CONTRACTOR:	Sandwell and Company Ltd.	FILE NUMBER:	2-9199	FUNDING	
		BEGIN/END:	March 83/April 83		
				CANMET:	$ 220 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. J.F. Kelly	TECHNOLOGY:	Liquefaction	TOTAL:	$ 220 000

OBJECTIVES

1. Continue the evaluation of the liquefaction of low-rank Canadian coals.

2. Design and construct the first-generation prototype equipment to demonstrate the Sandwell product recovery and solids separation process.

3. Operate the PDU in an integrated mode with the solids separation equipment.

4. Compare PDU runs conducted with hydrogen and CO/H_2 reducing atmospheres.

PROCEDURE

Three continuous runs were conducted in solvent recycle mode using coal-derived product as start-up solvent. The first of these runs was carried out at 440°C and 24.1 MPa for 63 h, using vacuum distillation for recovery of a solvent fraction, accomplishing 6 passes through the unit. The objective was to improve the hydrogen content of the product to be used in the subsequent runs. A second recycle run was undertaken using a mixture of hydrogen and carbon monoxide at similar conditions. A process simulation of the solids separation process was carried out in the third run using first-generation prototype equipment. The equipment that was used was designed and constructed within the financial restrictions of the program, and provided an initial demonstration of some of the fundamental process concepts. Solids separation was integrated with the operation of the liquefaction PDU to provide a complete self-sustaining coal liquefaction plant. The solids separation process was successful in removing solids, asphaltenes, and pre-asphaltenes. At the same time it separated sufficient recycle solvent for the slurrying of coal to maintain solvent balance. The unconverted coal and ash (solids) were, in essence, completely separated from the coal-derived products and coal-derived recycle solvents. The final solids by-product carries with it only very small amounts of liquid product. This results in near maximum liquefied coal material recovery that, coupled with a high total conversion and low gas production in the liquefaction reactor, provides for very high yields.

RESULTS

During this year of operation of the PDU, the unit operated for 120 h and generally performed very well. Numerous improvements were made throughout the year to improve reliability, safety, sampling, flow measurement and control, operational range, and efficiency of operation. The following summarizes the main findings:

1. Two runs were conducted with hydrogen and gave very similar results in terms of overall conversions of 90.3 and 90.0%, and total gross liquid yields of 63.8 and 67.1%. The tests confirmed the benefit of recycle of coal-derived liquids as solvent material giving better conversion and yields. Although six passes were completed, the test periods were of insufficient duration to establish steady-state conditions. In the recycle solvents, the concentration of non-distillates was increasing progressively although at slower rates. However, extended tests are required to determine the preferred combination and selection of recycle solvents to produce stable operation over long periods.

2. Although operating problems prevented a full recycle experiment, using a mixture of CO/H_2 in a feed gas ratio of 40/60 resulted in superior liquid yields compared to using hydrogen only. Despite a slightly lower conversion of 88.2% compared to 90.3%, the liquid yield was 72.4%, almost 10% higher than obtained in

the runs with pure hydrogen. The distillate yields were substantially improved as a result of using syngas mixtures. The benefits observed are considered to be related to the presence of nascent hydrogen produced as a result of the water shift reaction, as well as of the scavenging reactions of carbon monoxide with oxygen ether bonds present in the coal.

3. A separate run confirmed the fundamental concepts of the Sandwell solids separation process. For three passes, the amount of primary product liquid recovered exceeded 98%, thus proving the efficiency of the process as a superior means of product recovery.

4. An economic model was developed to provide a relative comparison between the cost of a commercial plant based on vacuum distillation for product recovery, and separation by the Sandwell process. The model estimated a 28% reduction in the cost of producing liquid fuels as a result of the Sandwell process.

APPLICATION AND ONGOING WORK

Phase 5 program not expected to start until 1984/85 fiscal year.

SUPPORTING DOCUMENTS

Final Report: "Study Relating to the Production of Oil from Low Rank Canadian Coals by Direct Liquefaction - Phase 4".

TITLE: TECHNICAL AND ECONOMIC FEASIBILITY OF LIGNITE LIQUEFACTION IN SASKATCHEWAN

CONTRACTOR:	Saskatchewan Oil and Gas Corp.	FILE NUMBER:	2-9203	FUNDING	
		BEGIN/END:	Sept. 81/March 83		
				CANMET:	$ 206 525
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	206 525
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	L.P. Mysak	TECHNOLOGY:	Liquefaction	TOTAL:	$ 413 050

OBJECTIVES

The main objectives of the study of advanced processes considered for commercialization by 1990 were as follows:

Stage 1 - Process Evaluation and Prescreening

1. Determination of state-of-the-art technology and predict behaviour of Estevan and Willow Bunch lignite in the processes, based on available data and previous experience of the process developers with similar coals.

2. Prescreening and ranking of the processes for further techno-economic assessment.

Stage 2 - Techno-Economic Assessment of Preselected Processes

1. Techno-economic assessment and comparison of preselected processes using Willow Bunch lignite as feedstock.

2. Selection of the promising process(es) for liquefaction of Willow Bunch lignite to produce synfuels substituting conventional transportation fuels.

3. Determination of constraints toward commercialization for selected process(es).

Also, a preliminary review of new processes or concepts considered for commercialization around 1995.

PROCEDURE

Review and evaluation of various direct and indirect coal liquefaction and pyrolysis processes for production of liquid fuels from designated Saskatchewan lignites were carried out in accordance with the main objectives of the study. Product yields and distribution, product quality, process status, and suitability of Saskatchewan lignites were also examined. Processes selected in the prescreening evaluation (Stage 1 of the study) were considered further in a more detailed technical and economic assessment (Stage 2 of the study). Willow Bunch lignite was designated as a coal feedstock for techno-economic assessment of the preselected processes.

RESULTS

1. For direct coal liquefaction, the LSE process was ranked first.

   For indirect coal liquefaction, the Koppers Totzek gasifier appears to be the most suitable for Saskatchewan lignites.

   For pyrolysis of Saskatchewan lignites, the Lurgi-Ruhrgas process may be viable for Estevan lignite. For Willow Bunch lignite, this process is not viable because of very low liquid product yields.

   The LSE process and the Mobil-MTG with K-T gasifier are comparable: the LSE process has a higher estimated liquid product yield [2.27 bbl/t vs 1.5 bbl/t maf coal, and higher liquid product efficiency (54% vs 31.4%)].

   Capital investment for a 25 000 t/d plant processing Willow Bunch lignite is $2 213 million for Mobil-MTG compared to $2 639 million for the LSE process. Investment per daily barrel production of transportation fuels is $90 000 per bbl/day for LSE vs $114 750 per bbl/day for Mobil-MTG. If gasoline is the only desired product, the investment per daily barrel for Mobil-MTG would be almost half that of the LSE process.

2. Evaluation of new processes or concepts con-

sidered for commercialization around 1995 was carried out outlining their present demonstration scale and R&D status, including funding status. Conclusion and recommendations are presented.

APPLICATION AND ONGOING WORK

Future coal liquefaction studies in Saskatchewan will most probably be an extension of this work.

TITLE: PILOT SCALE CONVERSION OF ESTEVAN LIGNITE INTO HYDROCARBON DISTILLATE BY HYDROPROCESSING

CONTRACTOR:	Sandwell Beak Research Group	FILE NUMBER:	4-9187	FUNDING	
		BEGIN/END:	Oct. 84/Jan. 85		
				CANMET:	$ 73 102
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	C. Fairbridge	TECHNOLOGY:	Liquefaction	TOTAL:	$ 73 102

OBJECTIVES

Produce 25 L of coal-derived distillate from Estevan lignite, by hydroliquefaction. The report includes a description of the equipment and procedures used, a summary of the process development unit (PDU) operation, data acquisition, and the material balance. Also included are the characterization of the lignite coal, start-up solvent, and the final product.

PROCEDURE

For the production of the distillate as required in the contract, a continuous run was carried out on the 0.1 t/day PDU in recycle mode at 410°C reactor temperature and 24 MPa pressure with hydrogen. About 75 kg of fresh coal was fed into the unit.

The start-up solvent was lignite-derived oil fraction 230-450°C from Sandwell's stock of previously produced material. During the run, the product was vacuum distilled for the recovery of the solvent fraction.

The -250°C fraction was accumulated and shipped to CANMET as naphtha fraction. At the conclusion of the run, 50 kg of heavy product was vacuum distilled and 21 kg of the -350°C fraction was shipped to CANMET. The remaining product was distilled for production of start-up solvent to be returned to the standby stock.

RESULTS

The material balance closure for this run was 97.2%. The coal conversion was 75% wt maf, lower than previously obtained in our runs with Estevan lignite - this could be attributed to the lower reactor temperature applied in this run or the fact that the new lot of lignite may have been less reactive.

An investigative batch test conducted prior to the run also resulted in low conversion, which points to the lower reactivity of this coal shipment.

The liquid yield was also lower - only 51.5% wt maf. The distillate fractions produced for CANMET had a density at 21°C of:

0.9335 for the -250°C fraction
1.0335 for the -350°C fraction

The simulated distillation results show that 80-90% of the material boiled in the desired range, with the balance boiling up to 470°C.

The elemental composition indicated good oxygen removal but a fairly low hydrogen content, confirming that in the thermal liquefaction step at the applied conditions, most hydrogen consumed goes into the gas and water making.

APPLICATION AND ONGOING WORK

The naphtha and middle distillate produced will be utilized in in-house work on distillate upgrading and catalyst development.

TITLE: CONTINUOUS LIQUEFACTION OF HAT CREEK COAL

CONTRACTOR:	British Columbia Research Laboratories	FILE NUMBER:	3-9060	FUNDING	
		BEGIN/END:	July 83/July 84		
				CANMET:	$ 171 857
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. S. Fouda	TECHNOLOGY:	Liquefaction	TOTAL:	$ 171 857

OBJECTIVES

1. Confirmation of high batch-test coal conversions in a continuous system.
2. Investigation of primary liquid product quality.
3. Evaluation of continuous fixed bed catalytic hydrotreating of primary liquid products.
4. Evaluation of a heterogeneous catalyst for primary liquefaction.

PROCEDURE

1. A tubing bomb batch system was used for both the initial liquefaction tests and the catalyst evaluation tests.
2. A continuous bench scale (2 kg/h) hydroliquefaction unit was used for the continuous flow tests.
3. A continuous fixed bed catalytic hydrotreater was used for upgrading the primary products, and the bottoms were recycled to the hydroliquefaction unit.

RESULTS

1. It was found that an equilibrium recycle solvent can be reached after the fourth cycle.
2. Satisfactory conversions were obtained in the continuous system ($\geq$90%) with about 80% of C_5+ liquid yields.
3. After the hydrotreating stage, the net liquid products contained high yields of naphtha (75% based on calorific value of coal) and typical gas yields were 14-17%.
4. The bottoms from the hydrotreater can be recycled to the liquefaction unit without affecting the high conversion.
5. It was not possible to determine the effect of catalysts on the primary liquefaction within the budget of this contract.

APPLICATION AND ONGOING WORK

Preliminary economic analysis showed that the liquefaction of Hat Creek coal is economically viable. Currently, a new contract addresses more aspects of the process such as detailed material balance closures on the liquefaction and hydrotreater units, stability of THF as a separation solvent, net product optimization, product compatibility for a specific end use, waste disposal options, and more detailed economic analysis.

TITLE: DEVELOPMENT OF EQUIPMENT AND PROCESS INFORMATION RELATED TO THE FLASH HYDROPYROLYSIS OF COAL

CONTRACTOR: Kilborn Limited	FILE NUMBER: 9-9151	FUNDING	
	BEGIN/END: Oct. 82/Dec. 83		
		CANMET:	$ 377 826
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: P. Sears	TECHNOLOGY: Liquefaction	TOTAL:	$ 377 826

OBJECTIVES

Design and construction of a 1 kg/h coal flash hydropyrolysis (FHP) unit at Ontario Research Foundation, Mississauga.

PROCEDURE

1. Design and construction of the FHP unit.

2. Commissioning and shakedown of the FHP unit.

RESULTS

The unit has been constructed and is now in operation.

The report describes the results of the testwork performed during commissioning and shakedown of the flash hydropyrolysis unit. The testwork was divided into three categories:

- coal feeder demonstration
- pressure testing of the FHP unit
- pilot plant runs.

APPLICATION AND ONGOING WORK

An experimental program using this piece of equipment in the hydropyrolysis of coal and pitch is underway.

TITLE: PRELIMINARY STUDIES OF CANADIAN COALS USING THE COAL FLASH HYDROPYROLYSIS UNIT AT ONTARIO RESEARCH FOUNDATION

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9225	FUNDING	
		BEGIN/END:	Jan. 84/May 84		
				CANMET:	$ 69 785
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P. Sears/J. Kelly	TECHNOLOGY:	Liquefaction	TOTAL:	$ 69 785

OBJECTIVES

1. Conduct preliminary experiments on the recently commissioned CANMET flash hydropyrolysis unit at Ontario Research Foundation, Mississauga.

2. Conduct a series of flash hydropyrolysis experiments on Forestburg subbituminous coal.

3. Investigate the possibility of operating the unit with Prince Mine (Nova Scotia) high-volatile bituminous coal as feed.

PROCEDURE

The existing hydropyrolysis unit was used to conduct a series of ten runs using Forestburg subbituminous coal as feed. Temperature, pressure, and hydrogen feed rate were varied in order to investigate their effects. Tests were also made using Prince mine coal.

RESULTS

The Forestburg subbituminous coal was found to be a good feedstock for the unit. No operating problems were encountered, and encouraging yields of liquid hydrocarbon products were obtained. The dependence of the product yields on the operating variables is indicated by the data obtained, and this will assist in directing future work.

The processing of Prince mine high-volatile bituminous coal in the unit was beset with difficulty. Nevertheless, experience obtained during the course of this contract will be of great value in subsequent work.

APPLICATION AND ONGOING WORK

Coal pyrolysis and hydropyrolysis are possible ways of skimming off liquid hydrocarbon products from coal, leaving a burnable char. This work is directed at gaining experience in this field and obtaining data for Canadian coals. The contractor is continuing work with both coals used in this study.

TITLE: CHARACTERIZATION OF LIQUID FUELS FROM SPOUTED BED PYROLYSIS AND CANADIAN COALS

CONTRACTOR:	University of British Columbia	FILE NUMBER:	2-9093	FUNDING	
		BEGIN/END:	Oct. 82/May 84	CANMET:	$ 199 926
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	M. Skubnik	TECHNOLOGY:	Liquefaction	TOTAL:	$ 199 926

OBJECTIVES

1. Carry out a series of rapid pyrolysis tests on selected Canadian coals in a spouted bed reactor.

2. Develop a suitable methodology for detailed identification of hexane and benzene soluble fractions of coal tars.

PROCEDURE

1. Design and construct a spouted bed micro-reactor with a diameter and length of 25 and 150 mm, respectively, operational temperatures up to 950°C, and tar residence time of 0.1 second.

2. Carry out pyrolysis tests on Sukunka, Fording, Devco, Minto, Forestburg, and Onakawana coals and lignite, and establish the relationship of distribution of products to major variables.

3. Use individually or in combination devices such as high-performance liquid chromatography (HPLC), high-resolution (capillary) gas chromatography (HRGC), and mass spectrography (MS) for the separation, classification, and identification of individual components of hexane and benzene soluble fractions of tars.

RESULTS

Short residence time pyrolysis of coals in N_2 atmosphere resulted in a rapid devolatization. With the exception of Sukunka, all bituminous coals exhibited severe agglomeration of chars within the bed limiting tests to very low feed rates. The relative yields [mass/(time x volume of reactor)] of hexane and benzene soluble fractions were 3.8, 3.0, 1.4, and 0.4 for Sukunka, Forestburg, Devco, and Minto coals, respectively.

Hydrocarbon and homolog-type analyses were performed by a combination of solvent fractionation, flash chromatography, HPLC, and GC/MS. The compositions of hexane and benzene soluble fractions were characterized in depth. In general, about 120 to 200 individual compounds were identified by a combination of HPLC elution sequence, HRGC retention index, and mass spectra.

APPLICATION AND ONGOING WORK

In follow-up contract 4-9074 the characterization methodology will include identification of S, N, and O containing species of coal tars, and the storage stability of hydrogenated and non-hydrogenated fractions of tars will be investigated.

TITLE: SCREENING PROGRAM ON SHORT RESIDENCE TIME PYROLYSIS OF COAL

CONTRACTOR: University of Waterloo	FILE NUMBER: 2-9101	FUNDING	
	BEGIN/END: Sept. 82/March 84		
		CANMET:	$ 59 907
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: S. Fouda	TECHNOLOGY: Liquefaction	TOTAL:	$ 59 907

OBJECTIVES

Test a number of Canadian coals of widely varying character to determine the optimum conditions for pyrolysis, and the effects of some pre-treatments or alternative processing methods on liquid yields.

1. Determine the liquid yields as a function of temperature for three bituminous coals, one lignite, and two subbituminous coals.
2. Determine the effect of particle size for a coal of each rank.
3. Test the effect of pyrolysis atmosphere on liquid yields for a coal of each rank.
4. Test the effect of preoxidation on caking behaviour and yields for subbituminous coal.
5. Test the effect of acid washing for lignite.

PROCEDURE

A continuous bench-scale fluid bed atmospheric pyrolysis unit was used to run the experiments. The unit provided information on tar yields, BTX yields, gas yields and char yields, as well as on water formation. A full experimental run can be performed in one day, excluding the elemental analysis of the products. The gaseous components were detected by gas samples taken from the gaseous effluent of the reactor. Water was detected by Karp Fischer filtration of the tars. The elemental analysis of the products was carried out using a Perkin-Elmer 240C analyzer.

RESULTS

1. Maximum hydrocarbon liquid yields were obtained from high-volatile bituminous Devco coal (18.4 wt % based on maf coal). The coal showed difficulty in running, however, due to caking problems.
2. Most of the lignite and subbituminous coals tested showed maximum liquid yields of about 10 wt % maf coal at 650°C.
3. The H/C atomic ratios of the product tars decreased with increasing temperature.
4. The tar yields decreased with increasing vapour residence time.
5. The use of Co-Mo catalyst in the reactor did not enhance the tar yields.
6. Use of CO_2 as a pyrolysis atmosphere had little effect, while the use of H_2 as a pyrolysis atmosphere decreased the tar yields and enhanced gas formation.
7. Acid washing of lignite improved the liquid yields.
8. Preoxidation of the high-volatile bituminous coal improved the caking behaviour but had a detrimental effect on the liquid yields.
9. Studying the effect of particle size showed that there is a minimum particle size requirement, but the maximum limit was not determined.

APPLICATION AND ONGOING WORK

The contract revealed information on the flash pyrolysis of a number of Canadian coals. It identified the operating conditions for maximum liquid yields for each coal. Currently, more emphasis is being given to the effect of lignite acid washing as well as the effect of pyrolysis atmosphere. It would also be beneficial to confirm the results obtained on the lab-scale unit (15 g/h) using a pilot-scale unit (2 kg/h).

TITLE: SUPERCRITICAL GAS EXTRACTION OF CANADIAN COALS

CONTRACTOR: Raylo Chemicals Limited	FILE NUMBER: 2-9098	FUNDING	
	BEGIN/END: Nov. 82/Feb. 83	CANMET:	$ 101 425
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: P.L. Sears	TECHNOLOGY: Liquefaction	TOTAL:	$ 101 425

OBJECTIVES

1. Study the supercritical gas extraction of Forestburg coal in a semi-continuous reactor system.

2. Test the feasibility of supercritical gas extraction of a high-volatile bituminous Nova Scotia coal.

PROCEDURE

A new experimental apparatus was constructed and operated. A Nova Scotia coal was tested.

RESULTS

The new apparatus was successful and the difficulties encountered with the new coal type were largely overcome.

APPLICATION AND ONGOING WORK

The technique has definite possible applications, but the current funding situation does not permit further work now.

TITLE: SOLUBILITY OF CARBON MONOXIDE AND HYDROGEN - PHASE 2

CONTRACTOR: University of Alberta	FILE NUMBER: 2-9163	FUNDING	
	BEGIN/END: April 81/March 82		
		CANMET:	$ 24 216
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: J.A. McPhee	TECHNOLOGY: Liquefaction	TOTAL:	$ 24 216

OBJECTIVES

Study the equilibrium solubilities of carbon monoxide and hydrogen in Athabasca bitumen, and in slurries of subbituminous coal and bitumen. Solubilities were to be measured for each gas separately and for gas mixtures up to 300°C.

PROCEDURE

A stirred high-pressure high-temperature autoclave was used in conjunction with gas chromatography for gas analysis.

RESULTS

Tables of solubilities are presented along with correlations using modified equations of state.

TITLE: DEVELOPMENT AND ASSESSMENT OF BENCH-SCALE METHODS FOR PREDICTING SLAGGING AND FOULING CHARACTERISTICS OF LIGNITE ASH

CONTRACTOR:	Saskatchewan Power Corp.	FILE NUMBER:	I-9138	FUNDING	
		BEGIN/END:	May 82/Aug. 83		
				CANMET:	$ 56 047
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Conventional Combustion	TOTAL:	$ 56 047

OBJECTIVES

1. Study, using a laboratory technique, the fouling tendencies of lignites relative to a power plant environment.

2. Study the effects of additives on the fouling tendencies of lignites as in (1).

PROCEDURE AND RESULTS

1. Survey of current methods used to predict slagging and fouling tendencies.

   A detailed literature survey of the state-of-the-art of empirical formulae used to predict lignite ash fouling and slagging shall be completed before conducting sintering tests and developing suitable laboratory methods for ash preparation and sintering.

2. Assessment of the ash sintering test as a practical bench-scale method for predicting fouling characteristics of coal ashes.

   An evaluation will be conducted on the influence of both ASTM and low-temperature (plasma) ashing on the sintering strength of ash from eight samples of Saskatchewan lignite with different Ca/S ratios. Sintering tests, in accordance with the agreed upon procedure, shall be done for a range of sintering trials and temperatures. Results shall be correlated with mineral and elemental ash compositions to identify trends for predicting ash fouling and slagging propensity, and to establish the applicability of other laboratory fouling and slagging methods.

3. Testing ash produced by pilot combustion systems

   Special experiments will be performed on 12-16 samples of slag and superheater deposits produced in the CCRL pilot-scale research boiler from Bienfait lignite treated with different intermittent and continuous dosage rates of limestone. Results of these tests will be compared with the corresponding laboratory ashes, ASTM and plasma, prepared from Bienfait lignite and limestone used to generate CCRL deposits. Samples of Bienfait lignite and limestone and the pilot-scale boiler deposits shall be obtained from CCRL.

4. Comparison of predictions from the sintering test with experience of power-generating stations.

   A survey of selected SPC power plants - Boundary Dam, Coronach, and Estevan - shall be conducted and an assessment made of the results of the sintering tests in Tasks 2 and 3 with respect to fouling and slagging in operating boilers at various loads.

   Special emphasis will be placed on assessing the relationship between the ash deposition rate and strength of the deposits, and the ability of the ash sintering test to predict each of these parameters.

5. Use of the sintering test to assess the potential of various additives to combat fouling.

   The effect of four or more additives, including one calcium and one magnesium-based compound, on the sintering strength of ASTM and plasma ash from four lignites with different Na/Ca ratios.

   These tests will be conducted with two or more additive dosage rates for each lignite. Calculations will be performed to elucidate the kinetic mechanisms by which the different additives decrease or enhance sinter strength.

APPLICATION AND ONGOING WORK

An RFP has been issued by CANMET/ERL/CCRL to study an alternative CEGB developed laboratory ashing technique as a diagnostic tool.

SUPPORTING DOCUMENTS

1. "Prediction of Boiler Fouling by Lignite Ash", by D.W. Smith and A. Szladow. 32nd Canadian Chemical Engineering Conference.

2. Final Report: "Prediction of Slagging and Fouling by Lignite Ash", by D.W. Smith and A.J. Szladow.

3. "Prediction of Alleviation of Fouling Problems at S.P.C.", by D.W. Smith, A.J. Szladow, H. Whaley, and G.K. Lee, Copper Mountain Conference on Slagging and Fouling, Engineering Foundation, Copper Mountain, Colorado, August 1984.

TITLE: REDUCTION OF LIGHT OIL USAGE IN COAL FIRED FOSSIL STATIONS

CONTRACTOR:	Ontario Hydro	FILE NUMBER:	3-9040	FUNDING	
		BEGIN/END:	Feb. 84/June 84		
				CANMET:	$ 49 689
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	49 689
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	---
AUTHORITY:	P. Hughes	TECHNOLOGY:	Conventional Combustion	TOTAL:	$ 99 378

OBJECTIVES

Study current alternatives to light oil for light off and flame maintenance in coal-fired stations.

PROCEDURE

A survey was conducted of various manufacturers and end users to determine current techniques and their technical and financial feasibility.

RESULTS

The following alternatives (in order of viability) could offer long-term savings in money in most cases:

a) Natural gas
b) Coal oil mixture
c) Partial plasma arc.

APPLICATION AND ONGOING WORK

This has direct application to our off-oil efforts. Work is currently being done to study coal liquid mixtures as fuels.

TITLE: BURNER VELOCITY PROFILE MEASUREMENTS

CONTRACTOR:	University of Ottawa	FILE NUMBER:	4-9036	FUNDING	
		BEGIN/END:	April 84/Aug. 84		
				CANMET:	$ 7 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	P.M.J. Hughes	TECHNOLOGY:	Conventional Combustion	TOTAL:	$ 7 000

OBJECTIVES

Measure velocity profiles in the tunnel furnace facility at a variety of axial locations and at two mass flow rates.

PROCEDURE

Velocity vectors are to be measured at the exits of the swirl generator and the quarl, and at three axial positions in the tunnel furnace. The two air flowrates simulate the gas velocities during combustion.

RESULTS

1. The relationship between swirl number and dial setting was found.
2. Non-axisymmetric flow conditions were determined.
3. The velocity field in the furnace has been determined.
4. These results were used as input for a computer model of the tunnel furnace.

APPLICATION AND ONGOING WORK

These results were used to determine the recirculation zones and initial conditions for a contract to model the phenomena occurring inside the furnace.

TITLE: FLUIDIZED-BED HEATING PLANT - CFB SUMMERSIDE PHASE 3

CONTRACTOR:	Dominion Bridge Co. Ltd.	FILE NUMBER:	9-9012	FUNDING	
		BEGIN/END:	Jan. 80/March 81		
				CANMET:	$ 470 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F. Friedrich	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 470 000

OBJECTIVES

The overall objectives of the Summerside Fluid Bed Project are:

1. Demonstrate fluidized bed combustion (FBC) as a viable means of burning coal in a heating plant boiler.
2. Demonstrate FBC of high-sulphur coal in a limestone bed as an economical and practical alternative to flue gas scrubbing as a means of controlling SO_2 emissions.
3. Demonstrate the use of wood chips as a supplementary fuel to coal in an FBC boiler.
4. Transfer foreign FBC technology to at least two Canadian suppliers.

The objectives of the present contract are:

1. Develop a detailed design for a complete heating plant incorporating two fluidized bed boilers, which would be an addition to the existing No. 2 plant at CFB Summerside.
2. Obtain a firm price quotation for the subject FBC heating plant.

PROCEDURE

A 6-phase program was developed as follows:

1. Conceptual design of fluidized-bed boiler.
2. Conceptual design of heating plant to accommodate two FBC boilers.
3. Detailed design and cost proposal of heating plant addition with one FBC boiler.
4. Construction of heating plant addition with one FBC boiler.
5. Testing and demonstration of FBC boiler using a range of coals and other solid fuels.
6. Procurement of second FBC boiler.

All work was carried out by contract and to meet Objective 4, Phases 1, 2, and 3 were carried out by two competing contractors. The present contractor prepared a detailed design to meet requirements stipulated by DND and EMR, and submitted a firm price proposal for building it.

RESULTS

The Dominion Bridge design was carefully compared with the competing design (from Foster Wheeler Ltd.), resulting in Foster Wheeler Ltd. being awarded a construction contract for approximately $13 million. Completion was scheduled for December 1982.

APPLICATION AND ONGOING WORK

No further work resulting from this contract.

TITLE: SUMMARY REPORT ON CFB SUMMERSIDE, P.E.I.

CONTRACTOR: M.E.D. Taylor	FILE NUMBER: 1-9118	FUNDING	
	BEGIN/END: Jan. 82/May 82		
		CANMET:	$ 11 491
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: F. Friedrich	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 11 491

OBJECTIVES

Summarize in a single report, suitable for technology transfer purposes, the two designs of a coal-fired, fluidized-bed-combustion heating plant that were obtained under contract as part of the CFB Summerside demonstration project.

PROCEDURE

A consulting engineer was contracted to prepare a draft report describing the background of the project, the performance criteria and feedstock specified for the plant and boiler designs, the design ultimately tendered by Foster Wheeler Ltd., the design ultimately tendered by Dominion Bridge-Sulzer Ltd., and the reasons for selecting the Foster Wheeler Ltd. design.

RESULTS

The final report is entitled:

"The CFB Summerside Project - Canadian State-of-the-Art in AFBC Boilers", by M.E.D. Taylor and F.D. Friedrich, Division Report ERP/ERL 82-10(TR); April 1982.

The report describes two approaches to the design of a heating plant that will demonstrate the combustion of coal in atmospheric fluidized-bed boilers. The designs were prepared in response to competitive tenders sought for the supply and installation of a heating plant to operate in conjunction with an existing steam plant at Canadian Forces Base Summerside, Prince Edward Island. One design was based on British technology and the other on North American technology.

The report has been widely circulated, including the IEA Committee on Atmospheric Fluidized-Bed Combustion and the Canadian Institute of Energy/CANMET Workshop on Fluidized-Bed Combustion held in Calgary, May 1982.

APPLICATION AND ONGOING WORK

The report describes the FBC heating plant subsequently installed at CFB Summerside. This is Canada's first full-scale application of FBC technology. A three-year demonstration period is planned, and subsequent reports will document the performance of the plant in generating steam from high-sulphur coal and wood chips.

SUPPORTING DOCUMENTS

1. "Detailed Design and Proposal for a Fluidized-Bed Heating Plant for CFB Summerside, P.E.I."; DCL Project File No. SM050 10; Dominion Bridge-Sulzer Inc. Contract No. 565-037 (4 volumes).

2. "Detailed Design of a Fluidized-Bed Heating Plant, CFB Summerside, P.E.I. - Phase 3"; Final report by Foster Wheeler Ltd., Contract No. 9-9011 (1 volume and several hundred drawings).

TITLE: OPERATING, MAINTENANCE, AND FUEL COST COMPARISON OF FLUIDIZED-BED COMBUSTION BOILERS VERSUS STOKER-FIRED BOILERS AT CFB SUMMERSIDE, PEI

CONTRACTOR: Lavalin Inc.	FILE NUMBER: 2-9158	FUNDING	
	BEGIN/END: Oct. 82/Dec. 82		
		CANMET:	$ 8 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: V.V. Razbin	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 8 000

OBJECTIVES

Compile an estimate of personnel, operating, maintenance, fuel, and limestone costs for two FBC boilers at CFB Summerside.

Compare the operating cost of a FBC boiler plant to an equivalent stoker-fired boiler plant and an equivalent oil-fired boiler plant.

Note:

The FBC is burning high-sulphur coal while the stoker is burning low-sulphur coal without the use of tailend scrubbing equipment.

Both boilers meet the same environmental guidelines.

PROCEDURE

Consultant built up cost estimates using best available information.

RESULTS

Present value of 20-year operating costs indicates that stoker-fired boilers burning low-sulphur coal have the lowest operating cost, and oil-fired boilers the highest.

The advantage of FBC boilers over conventional stoker-fired boilers is in their ability to utilize high-sulphur coal. In eastern Canada, indigenous coal is not necessarily cheaper than imported low-sulphur coal. In the future, depending on demand and availability, the price of coal could be considerably less than that of imported low-sulphur coal. In that case, the economics of operating the FBC boilers would be more favourable.

TITLE: SUMMARY REPORT ON FBC OF COAL WASHERY REJECTS

CONTRACTOR:	Gordon Robb & Associates	FILE NUMBER:	1-9139	FUNDING	
		BEGIN/END:	March 82/June 82		
				CANMET:	$ 3 400
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F. Friedrich	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 3 400

OBJECTIVES

Summarize the final report from a previous contract (Fluidized Bed Combustor for a Coal Dryer, File No. 9-9067) into a conference-type paper, following the style of a CANMET Division Report.

PROCEDURE

The contractor abstracted from the final report of the previous contract, and from two other references, prepared figures and flow diagrams in appropriate format, and drafted a new text.

RESULTS

The material prepared by the contractor was further revised and edited by CANMET staff, and published as Division Report ERP/ERL 83-50, "An Atmospheric Fluidized Bed Design Study for Utilization of Coal Washery Rejects at Coal Valley, Alberta".

TITLE: COMBUSTION OF SYNCRUDE COKE IN A RECIRCULATING FLUIDIZED BED

CONTRACTOR: A. Ahlstrom Osakeyhtio	FILE NUMBER: 0-9101	FUNDING	
	BEGIN/END: March 81/April 82		
		CANMET:	$ 34 220
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: D. Desai	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 34 220

OBJECTIVES

1. Study the effect of temperature on combustion efficiency.
2. Determine Ca/S mole ratio required for 90% or more sulphur retention.
3. Establish the input conditions that would optimize combustion efficiency and sulphur capture.

The secondary objectives were to establish the levels of NO_x emission and the fate of vanadium in the coke.

PROCEDURE

Eighteen tons of Syncrude coke was shipped to Hans Ahlstrom Laboratory in Finland. Eight tests were conducted under 7 to 10 h of steady state conditions. The major input parameters were bed temperature and recycling of baghouse ash. The bed temperature was controlled by adjusting fuel feed rate and cooling probes.

Test No. 1 was carried out without limestone injection to establish baseline SO_2 emission and sulphur capture by coke ash. The remaining seven tests were carried out at temperatures ranging from 820°C to 950°C and corresponding fluidizing velocities of 2.4 m/s to 5.5 m/s using Swedish limestone for sulphur capture.

The baghouse ash was recycled to the combustor in Tests No. 5 and 6 to determine its effect on combustion efficiency and sulphur capture. Tests No. 4 and 8 were carried out at minimum and maximum load conditions, respectively.

RESULTS

1. Syncrude coke containing about 6.8% sulphur can be burned successfully in an atmospheric recirculating fluidized bed combustor, with combustion efficiency ranging from 95.8% to 99% at temperatures between 820°C and 950°C.
2. The fuel ash captured about 13.5% of the sulphur in the coke. A total sulphur capture of over 90% can readily be achieved with high-calcium limestone at Ca/S mole ratios from 1.72 to 2.09.
3. The combustion efficiency increased with the increased in the bed temperature, but a bed temperature of 900°C appeared to be optimum for higher efficiencies of combustion and sulphur retention.
4. Baghouse ash recycle appeared to improve modestly the efficiency of sulphur capture.
5. CaO, required in large amounts to capture sulphur, appeared to be effective in retaining most of the vanadium in the fuel, particularly at bed temperatures of 890°C and higher.

APPLICATION AND ONGOING WORK

The burning of high-sulphur, high-ash coals, coke, and wood wastes cleanly and efficiently in a recirculating fluidized-bed combustor. It can eventually lead to the design and development of a commercial-scale recirculating fluidized-bed boiler to burn Syncrude coke, which is now stockpiled in excess of 2000 t/day. Further comprehensive pilot-scale tests are planned with Syncrude coke using Fort McMurray limestone.

SUPPORTING DOCUMENTS

1. "Combustion of Syncrude Coke In Pyroflow Pilot-Plant", by A. Ahlstrom Ltd., Finland.

2. "Fluidized Combustion of Petroleum Coke", by F.D. Friedrich, G.K. Lee, and D.L. Desai.

TITLE: CONCEPTUAL DESIGN OF ATMOSPHERIC RECIRCULATING FLUID BED COMBUSTION RESEARCH FACILITY

CONTRACTOR:	Montreal Engineering Co. Ltd.	FILE NUMBER:	1-9130	FUNDING	
		BEGIN/END:	March 80/Sept. 82		
				CANMET:	$ 60 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	D. Desai	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 60 000

OBJECTIVES

1. Prepare a conceptual design of a pilot-scale atmospheric recirculating fluidized-bed combustor, consisting of the following tasks:
   a) Select a preferred size and heat input capacity for the pilot-scale unit.
   b) Identify and list all the components including the combustor, recirculating cyclone, and auxiliary equipment, including controls and the budget cost.
   c) Identify the service requirements and prepare a layout to accommodate the system in a given area of approximately 6 m x 6 m, and specify any modifications required in the roof.

PROCEDURE

The contractor, in consultation with an established designer and supplier of recirculating fluidized beds, established the size of the combustor, maximum and minimum fluidizing velocities, fuel feed rates, and various ash stream rates.

The process flow diagram was prepared and various components were identified to complete the system. Preliminary specifications for each component were prepared. Prospective suppliers were identified and budge price was obtained.

A layout was prepared to accommodate the equipment in the given space and head room requirements were identified.

RESULTS

The conceptual design of the ARFBC research facility indicated that the system can be accommodated in the given area of about 6 m x 6 m. A roof penetration and a penthouse will be required for retracting, removing, and inserting the combustor cooling tubes.

A 405 mm diameter x 6 m high combustor will be appropriate to generate reliable data for combustion studies and scale up applications. The maximum operating conditions will be 7 m/s fluidizing velocity, 1100°C combustor temperature and 2600 MJ/h heat input rate.

APPLICATION AND ONGOING WORK

Successful completion of the conceptual design will now lead to the next phase of design work and, finally, procurement and commissioning of the ARFBC test facility.

SUPPORTING DOCUMENTS

International presentation and publications:

1. Presentation at 4th Coal Congress, May/84, Zonguldak, Turkey.
2. Presentation at USBM Pittsburgh, Sept./83 for the arrangement of 2nd Workshop on Mine Subsidence.

TITLE: COMMISSIONING A PILOT SCALE FLUIDIZED BED COMBUSTION RESEARCH APPARATUS AND CONDUCTING A SERIES OF TESTS TO ESTABLISH A STANDARD TEST PROCEDURE TO ASSESS THE PERFORMANCE OF CANADIAN LIMESTONE AND COALS IN FLUID BED COMBUSTION

CONTRACTOR:	Queen's University	FILE NUMBER:	1-9033	FUNDING	
		BEGIN/END:	April 81/March 83		
				CANMET:	$ 287 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.J. Anthony	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 287 000

OBJECTIVES

Commission a pilot-scale FBC and study two maritime high-sulphur coals: Minto and Devco Prince.

PROCEDURE

The apparatus was commissioned and combustion trials were carried out in a pilot-scale FBC.

RESULTS

The apparatus was successfully commissioned and over 500 h of successful combustion runs were logged on the two coals. A standard test procedure with this rig has been developed.

APPLICATION AND ONGOING WORK

Supports the Summerside Industrial FBC Demonstration Program. A follow-up contract has been let.

TITLE: PILOT PLANT STUDIES OF FLUIDIZED-BED COAL COMBUSTION

CONTRACTOR: Queen's University	FILE NUMBER: 3-9019	FUNDING	
	BEGIN/END: June 83/April 85		
		CANMET:	$ 332 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: E.J. Anthony	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 332 000

OBJECTIVES

1. Study eastern Canadian high-sulphur coals and eastern Canadian limestones to determine their suitability for FBC combustion.

2. Study TVA coal and limestone to provide scale-up data for predicting sulphur capture, combustion data in industrial-sized units, and a cross comparison with Canadian high-sulphur fuels.

3. Study the use of Syncrude coke (a coke produced from the oil sands plants in Fort McMurray, Alberta) and Athabasca limestone in a bubbling bed FBC.

PROCEDURE

Pilot-scale trials in Queen's FBC reactor plus ancillary bench-scale tests with cold model.

RESULTS

Combustion of high-sulphur eastern Canadian coals (Evans and Devco), with the addition of eastern Canadian limestones (Havelock, Sysco, and Calpo) for sulphur capture, has been studied in a pilot-scale atmospheric fluidized-bed combustion (AFBC) system. In addition, an Appalachian coal (Kentucky No. 9) with an Appalachian limestone (Reed) was investigated. The coals, with the exception of the Evans, behaved very much like Minto (eastern Canadian) and Devco coals as described in a previous report. The Evans coal, however, gave evidence of higher reactivity, showing greater sensitivity to recycle of cyclone catch and generally higher combustion efficiencies. The Sysco, Calpo, and Reed limestones were similar in performance and not as good as the Havelock; Havelock generally requires one unit less of Ca/S ratio to achieve equal sulphur capture, other conditions being equal.

One other important high-sulphur Canadian fuel of a very different nature, namely Syncrude coke (residue of tar sands processing) was tested, using a western (Athabasca) limestone for sulphur capture. Fitting these results to correlations of combustion efficiency developed for the coals suggested a remarkable similarity of magnitudes. However, closer examination suggests that the effects of bed temperature and recycle are considerably greater than for the coals. Sulphur capture in the Syncrude coke runs remained surprisingly high (over 80%) up to just over 1000°C but then fell rapidly, becoming negligible around 1100°C. The finding of good sulphur capture at quite high temperatures agrees with results reported by Friedrich, Lee, Desai, and Kulvalainen on tests of burning Syncrude coke in an atmospheric recirculating fluidized-bed (ARFBC) system at the Hans Ahlstrom Laboratory. Syncrude coke is quite high in vanadium; it was determined that the vanadium effectively remains fixed in the ash of the coke and does not become concentrated in any of the leaving solids streams, except to the degree that the ash does so.

APPLICATION AND ONGOING WORK

This work was extended with a follow-up contract to study FBC combustion with the aim of obtaining fundamental data and developing a mathematical model of FBC as Canada's contribution to the IEA.

SUPPORTING DOCUMENTS

1. Final Report: "Pilot-Plant Studies of Fluidized Coal Combustion".

2. Paper on Combustion of High Sulphur Eastern Canadian Fuels presented to 8th International Symposium on FBC Combustion.

TITLE: ASSESSMENT OF LIMESTONES FOR FLUIDIZED-BED COMBUSTION

CONTRACTOR: Dr. Irving Johnson	FILE NUMBER: 2-9103	FUNDING	
	BEGIN/END: Feb. 82/Sept. 82		
		CANMET:	$ 12 000
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: C.A. Hamer	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 12 000

OBJECTIVES

Assess the suitability of 20 limestones for use in fluidized-bed coal combustion to control SO_2 emissions.

PROCEDURE

1. Prepare and analyze samples.
2. Determine the extent of calcium sulphation.
3. Determine decrepitation by shock calcination.
4. Predict SO_2 retention vs Ca/S ratio by modelling.
5. Write reports on results.

RESULTS

The samples were tested and modelled for the Summerside FBC. Limestone usage varied widely depending upon the source of the material. Limestones from Nova Scotia, New Brunswick, and Alberta were tested.

APPLICATION AND ONGOING WORK

This work makes up part of an ongoing project on SO_2 sorbent utilization.

SUPPORTING DOCUMENTS

Final Report: "Characterization and Testing of Syncrude, Canstar, and Irish Cove Limestones for use in Summerside FBC".

The report contains four test reports by Dr. Johnson. This work will not have a great deal of meaning to others without background information that is not included in the report. However, the work will be included in future reports by Hamer.

TITLE: PARAMETRIC FLUIDIZED-BED TESTS USING A COMBUSTOR OF MINIMAL CROSS-SECTIONAL AREA OF AT LEAST 0.10 SQUARE METRE

CONTRACTOR:	Babcock & Wilcox Industries Limited	FILE NUMBER:	2-9077	FUNDING	
		BEGIN/END:	Dec. 82/July 83		
				CANMET:	$ 156 517
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	I. Lau	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 156 517

OBJECTIVES

1. Investigate coal-water slurry combustion using a fluidized-bed combustor as an alternative to conventional boilers.

2. Examine fluidized-bed combustion as a potential incineration method for thickener underflow coal tailings (containing a high percentage of moisture and ash) produced as a by-product of a coal beneficiation process.

PROCEDURE

The test program was conducted in B&W's 30.5 cm x 30.5 cm (1 ft x 1 ft) fluidized-bed combustion test facility at the company's Alliance Research Center.

The test program included stable combustion of three coal-water slurries - (1) beneficiated, (2) unbeneficiated, and (3) thickener underflow, and parametric testing in various operating conditions.

RESULTS

Stable combustion was attained for both beneficiated and unbeneficiated coal-water slurries. In burning thickener underflow, additional heat input in the form of supplemental coal feed to maintain bed temperature was required for stable combustion. Attempts at burning the thickener underflow alone resulted in bed agglomeration and defluidization.

Parametric testing revealed some good correlations between performance and various operating conditions. Combustion efficiencies of 92% to 98% were achieved when burning the beneficiated and unbeneficiated slurries.

TITLE: WORKSHOP ON ATMOSPHERIC FLUIDIZED-BED COMBUSTION AND PUBLICATION OF PROCEEDINGS

CONTRACTOR:	Canadian Institute of Energy	FILE NUMBER:	2-9004/2-9202	FUNDING	
		BEGIN/END:	April 82/May 83		
				CANMET:	$ 31 363
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	F. Friedrich	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 31 363

OBJECTIVES

1. Organize and present a workshop on atmospheric fluidized-bed combustion, to be held in Calgary on May 27, 1982.

2. Prepare and publish the workshop proceedings.

RESULTS

The purpose of the workshop was to present an overview of current technology in atmospheric fluidized-bed combustion in Canada, Japan, and the United States, and to outline and encourage potential applications of this technology in Canadian industry.

Approximately 85 people from the major industries involved in AFBC attended the workshop. Six papers were presented and discussion was extensive.

A permanent record of the workshop was produced and distributed in a Proceedings volume.

APPLICATION AND ONGOING WORK

This was essentially a technology transfer activity. CANMET subsequently distributed copies at a conference on FBC sponsored by the Technical University of Nova Scotia, in June 1983.

SUPPORTING DOCUMENTS

Final Report: "Potential Applications of Fluidized-Bed Combustion in Canadian Industry"; Proceedings of a workshop co-sponsored by The Canadian Institute of Energy and CANMET, May 27, 1982, Calgary (Contract Report No. OGS82-00033).

TITLE: MATHEMATICAL MODELLING OF FLUIDIZED-BED COMBUSTION

CONTRACTOR: Queen's University	FILE NUMBER: 3-9146	FUNDING	
	BEGIN/END: Sept. 83/Nov. 83		
		CANMET:	$ 4 950
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: F.D. Friedrich	TECHNOLOGY: Fluidized-Bed Combustion	TOTAL:	$ 4 950

OBJECTIVES

1. Obtain, on behalf of Canada, expert input to a special workshop on Mathematical Modelling of Fluidized-Bed Combustion, sponsored by the IEA Implementing Agreement for Cooperation in the Field of Atmospheric Fluidized-Bed Combustion in Industrial or District Heating Boilers.

2. Obtain an expert opinion, in light of the present state-of-the-art, on whether it would be beneficial for Canada to participate in joint activities on mathematical modelling, proposed under the above-named Agreement.

PROCEDURE

Queen's University was contracted to provide the services of Prof. H.A. Becker to:

1. Present a paper on his recent work to the workshop on Mathematical Modelling of Fluidized-Bed Combustion.

2. Review and assess the papers presented by other participants.

3. Submit to CANMET a report assessing the potential of mathematical modelling as a cost-effective tool in designing commercial FBC equipment, and making recommendations as to whether Canada should participate further in joint activities in mathematical modelling under the IEA Agreement.

RESULTS

Professor Becker made useful contributions to the workshop, and submitted to CANMET an excellent review indicating that in the near term, mathematical modelling can provide an economic means of optimizing the design of certain components of an FBC system, but that total models predicting the performance of a complete combustion system will take years to develop.

APPLICATION AND ONGOING WORK

CANMET will participate in further information exchange on mathematical modelling sponsored under the IEA Agreement, and is sponsoring other contracts related to FBC modelling.

SUPPORTING DOCUMENTS

Final report:

1. Assessment of the Practical Potential of Mathematical Modelling of Fluidized-Bed Combustion and Recommendations for Canadian Participation in IEA Joint Projects on Modelling.

2. Review of Papers Presented at the Special Session on Mathematical Modelling at the Seventh Technical Meeting of the IEA Committee on AFBC.

Contract Report No. OST83-00108.

TITLE: GAS SAMPLING AT POINT TUPPER AFBC FACILITY

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	5-9025	FUNDING	
		BEGIN/END:	April 85/Sept. 85		
				CANMET:	$ 25 540
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.J. Anthony	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 25 540

OBJECTIVES

Sample gas concentrations and profiles, specifically O_2, CO_2, CO, NO_x, and SO_2, within the atmospheric fluidized-bed combustor (AFBC) at Point Tupper in order to provide further insights into the corrosive phenomena operating inside the bed, and the combustion and sulphur capture taking place in the bed and the freeboard. An additional aim was to discover the cause of anomalous readings for O_2 and CO_2 concentrations.

PROCEDURE

The procedure involved building a specially designed gas sampling probe able to quench gas phase reactions without affecting the true gas concentrations from the Point Tupper AFBC. The probe was then inserted into the bed through specially designed ports, and gas concentrations were determined as a function of bed geometry and height.

RESULTS

The probe disclosed the existence of leaks in the combustor. When corrected, this resulted in a significant improvement in the performance of the combustor. A complete set of gas concentration profiles were obtained and these results are now being incorporated into an on-going $8 million study of FBC corrosion carried out with the Point Tupper facility.

TITLE: PREPARATORY STUDY AND REPORT ON PRESSURIZED FLUIDIZED BED COMBUSTION

CONTRACTOR:	University of British Columbia	FILE NUMBER:	2-9113	FUNDING	
		BEGIN/END:	Sept. 82/March 83		
				CANMET:	$ 26 618
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	E.J. Anthony	TECHNOLOGY:	Fluidized-Bed Combustion	TOTAL:	$ 26 618

OBJECTIVES

Carry out a survey of existing pilot-plant pressurized fluidized bed combustion (PFBC) facilities to evaluate the various approaches in carrying out PFBC research. Also, make recommendations as to what type of research in this area Canada should support.

PROCEDURE

Carry out literature surveys and site visits in Europe and North America to examine existing facilities.

RESULTS

Visits were made to PFBC rigs in Sweden, Germany, England, and the U.S.A. Detailed investigations of these facilities were carried out. An 80-page report describing and evaluating those projects, together with recommendations on the types of Canadian involvement that would be appropriate in PFBC research, have been prepared as a result.

APPLICATION AND ONGOING WORK

The report prepared as a result of this contract will be the basis of an experimental program on PFBC, assuming that funding can be found.

TITLE: EVALUATION OF BURNER PERFORMANCE IN COAL-OIL MIXTURE COMBUSTION - PHASE 2

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	0-9105-2	FUNDING	
		BEGIN/END:	April 81/Oct. 81		
				CANMET:	$ 130 220
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 130 220

OBJECTIVES

1. Assess the wear characteristics of two existing generation industrial burners (internally mixed and externally mixed types) when using a 40 wt % COM made from eastern Canadian coal (Prince mine CBDC/NS).

2. Assess wear-resistant materials for critical burner components.

PROCEDURE

1. Test the vortometric burner (externally mixed) and a Peabody burner (internally mixed), each rated at 10 GJ/h, with a 40 wt % COM made from Prince Mine coal (Nova Scotia) in a 10 GJ/h test facility.

2. Burn COM at 8 GJ/h for 300 h and withdraw each nozzle for wear examination at periods of 50 h.

3. Conduct by wear evaluation photographic, flow, and gravimetric techniques.

4. Make full boiler performance tests, including emissions, during the tests.

5. Prepare final report.

RESULTS

The results established that rapid wear occurs using CLM fuels if internal mixing of the fuel and atomizing media occurs. This can be alleviated by appropriate choice of wear-resistant materials. A change of atomizing principal, i.e., external atomization, significantly reduces wear.

APPLICATION AND ONGOING WORK

This work led to two further contracts and the establishment of a similar wear-testing capability in the Maritimes using hot spray methods.

SUPPORTING DOCUMENTS

1. Final Report: "Wear Data from Extended COM Firing Tests Using Beneficiated Prince Mine Coal", by L. Bruno and A.S. Deshpande.

2. "Coal/Oil Slurry Combustion and Tribology - A Canadian Experience", by L. Bruno, A.S. Deshpande, and H. Whaley, Contract No. 1-9114, Contract Report No. OSQ81-00143. This report is published as Division Report ERP/ERL 82-4(OP), February 1982, and in the Proceedings of the 4th International Symposium on Coal-Oil Mixture Combustion, Orlando, Florida, May 10-12, 1982.

TITLE: PRODUCTION OF A PEABODY F14, 1-0-75-F9 HZ BURNER FUEL TIP AND ASSESSMENT OF PERFORMANCE FOR COAL LIQUID MIXTURE COMBUSTION

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	1-9127	FUNDING	
		BEGIN/END:	March 82/Aug. 82	CANMET:	$ 4 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 4 000

OBJECTIVES

Assess the performance of a hardened Peabody Y jet-nozzle before and after 200 hours of hot spray testing using coal-oil emulsion.

PROCEDURE

1. Produce a Peabody F14 1-0-75-F9 HZ burner fuel tip from M2 tool steel, hardened and nitrided to 70 RC.
2. Test and determine the flow characteristics on a flow test-rig before using fuel.
3. Ship burner tip to CANMET for 200 hours of hot spray testing.
4. Repeat (2) on used tip.
5. Produce final report.

RESULTS

The report covers the wear evaluation tests conducted on a nitrided Peabody fuel tip. The test program consisted of the following analyses:

1. Weight Loss Analysis.
2. Micro-Photographic Analysis.
3. Mass Flow Resistance Analysis.

APPLICATION AND ONGOING WORK

Part of a continuing evaluation of atomizer components for abrasive CLM use.

TITLE: PRESENTATION OF A TECHNICAL PAPER RELATING TO THE EVALUATION OF BURNER PERFORMANCE IN COAL-OIL MIXTURE COMBUSTION

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	I-9114	FUNDING	
		BEGIN/END:	Dec. 82/May 83		
				CANMET:	$ 6 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 6 000

OBJECTIVES

Transfer technology from previous CANMET/ORF contracts addressing burner wear using CLM fuels (Contracts 7-9055, 0-9104-1, and 0-9105-2).

PROCEDURE

1. Attend the Atlantic CLM Working Group meeting and make a technical presentation; Dec. 14-16, 1981.
2. Attend an ERL Seminar and make a presentation; Feb. 18, 1982.
3. Attend the 4th International Coal Slurry Combustion Conference and make a presentation; May 10-12, 1982, Orlando, Florida.
4. Prepare a written report in collaboration with the CANMET scientific authority.

RESULTS

The paper discusses the technical aspects relating to the wear characteristics of present-generation burner fuel management systems while operating with a typical coal/oil slurry consisting of high-ash coal from eastern Canada. Two 300-hour firing tests were carried out using two industrial burners; one employed external atomization while the other utilized internal atomization. The tests were successfully carried out in a water tube test boiler originally designed to operate on oil. The major objective of the project was to evaluate the wear characteristics of a fuel delivery system and of burner fuel tips employed during the 300-hour long combustion tests.

The test procedures used to evaluate wear in the fuel nozzles and to assess the overall performance of the boiler are presented. Instrumentation used in the tests is discussed. Analyses and evaluations relating to boiler efficiency, carbon conversion, fly ash characteristics, ash deposition, particulate and gaseous emissions, and wear are also addressed.

APPLICATION AND ONGOING WORK

This activity is part of an ongoing collaborative CANMET effort with industry addressing the burner wear problem. One million dollars is allocated under the NEP/S.A.I. to develop burners resistant to the abrasive action of CLM.

SUPPORTING DOCUMENTS

Final Report: "Coal/Oil Slurry Combustion and Tribology - A Canadian Experience", by L. Bruno, A.S. Deshpande, and H. Whaley; Contract Report No. OSQ81-00143.

This report is also published as Division Report ERP-ERL 82-4(OP), February 1982, and in the Proceedings of the 4th International Symposium on Coal-Oil Mixture Combustion, Orlando, Florida, May 10-12, 1982.

TITLE: DEVELOPMENT OF AN EROSIVITY TEST FOR THE CHARACTERIZATION OF COAL-WATER LIQUID FUELS

CONTRACTOR:	New Brunswick Research and Productivity Council	FILE NUMBER:	2-9063	FUNDING	
		BEGIN/END:	July 82/July 83		
				CANMET:	$ 75 482
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. G.R. Hoey	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 75 482

OBJECTIVES

Devise a recycle test loop simulating the erosion at the burner tip caused by coal-water fuel and use it to characterize the abrasiveness of coal-water fuels on recycling.

PROCEDURE

1. Use a recycle test loop to determine the abrasiveness of coal-water fuel containing 50 wt % Devco thermal coal.

2. Determine the effect of recycling coal-water fuel on the erosion of target materials and on the degradation of the fuel.

RESULTS

1. The erosivity of a 50% coal-water slurry increased initially, peaked, and then fell. The decrease in the slurry's erosiveness after the erosion peak coincided with a large increase in slurry viscosity. This viscosity increase is believed to be responsible for the erosivity decline.

2. Erosion testing by recycling could be conducted until the viscosity increased rapidly.

3. The slurry particles became progressively smaller, and quite clearly rounded as recycling proceeded.

4. Alumina was the most erosion-resistant of the four materials employed. The other three, in order of decreasing erosion resistance were: cemented tungsten carbide, hardened type 416 martensitic stainless steel, and pure aluminum metal.

APPLICATION AND ONGOING WORK

This work will be presented at an ASTM Symposium in June 1984, at Denver Co. and it will be published in an ASTM Special Technical Publication. Authors: C. Thornley and K. Sedman, RPC and G.R. Hoey, CANMET.

Planning is in progress to continue studies on erosion of coal-liquid mixtures. S. Whiteway, NRC is the project manager.

TITLE: TESTING OF PROTOTYPE COAL-WATER MIXTURE BURNERS AT CHATHAM, NEW BRUNSWICK

CONTRACTOR:	New Brunswick Electric Power Commission	FILE NUMBER:	4-9149	FUNDING	
		BEGIN/END:	Oct. 84/March 85		
				CANMET:	$ 49 867
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 49 867

OBJECTIVES

Test two prototype coal-water fuel (CWF) atomizer/ burners in Unit No. 1 at the Chatham Generating Station.

PROCEDURE

1. Provide enough fuel (∿40 tonnes) of CBDC CWF and transport it from Sydney, Nova Scotia to Chatham, New Brunswick.
2. Acquire the two atomizers.
3. Conduct preliminary tests on atomizers in the burner wind-boxes in Unit No. 1.
4. Conduct short feasibility tests on both atomizers.
5. Demonstrate the combustion of CWF for a visiting international delegation of the IEA/CLM agreement.

RESULTS

1. Excellent results were obtained on one atomizer, poor results on the other. More development work is indicated for the latter.
2. Feasibility tests were conducted only on one atomizer for the reason given above.
3. The CWF combustion demonstration took place on October 13, 1984 and was favourably received by the visitors.

APPLICATION AND ONGOING WORK

This work has led to another two contracts at Chatham in which the successful atomizer is being further optimized and tested with other CWFs. See Contract No. 4-9323 and 4-9299.

SUPPORTING DOCUMENTS

Final Report: "Testing of Prototype CWF Burners, Chatham, New Brunswick", by NBEPC, D.M. Rankin, Project Manager.

TITLE: COMPUTER-AIDED DERATING ASSESSMENT OF OIL-DESIGNED FRONT-WALL FIRED UTILITY BOILERS

CONTRACTOR:	Babcock & Wilcox Canada Limited	FILE NUMBER:	1-9134	FUNDING	
		BEGIN/END:	Oct. 82/April 83		
				CANMET:	$ 50 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 50 000

OBJECTIVES

Assess the probable derating (loss of generating capacity) when oil-designed front-wall fired boilers of 60 and 200 MW(e) capacity, and of two typical Canadian designs, are fired with coal-water mixture fuels and pulverized coal.

PROCEDURE AND RESULTS

1. Using computer-aided boiler simulation and design experience, assess the probable derating of a Babcock box-type furnace (equivalent Babcock and Wilcox El Paso design) with horizontal convective passes followed by horizontal convective surfaces.

2. Using computer-aided boiler simulation and design experience, assess the probable derating of a Babcock two pass boiler (equivalent Babcock and Wilcox Carolina design) having pendant high-temperature surface followed by low-temperature convector surface.

Each of (1) and (2) will be repeated for all the following conditions:

a) Boiler Capacity*: 60 MW(e) and 200 MW(e);
b) Coal Ash Level (dry basis): 3% and 9%;
c) Water in Fuel: 20% (slurry) and 10% (pulverized coal).

3. Prepare a report giving schematics of the boiler configuration studied, assessment of the derating effects of the coal-water fuel compared to No. 6 fuel oil, and detailing as many of the assumptions made in the methodology as is possible without divulging proprietary information. The report will contain:
   a) Recommended maximum (continuous) evaporation levels on coal-water fuels and on the reference fuel oil.
   b) Slagging and fouling characteristics.
   c) Erosion assessment.
   d) Details of possible boiler modifications.
   e) Suitability of existing auxiliary equipment.

*Maximum rating when firing No. 6 fuel oil (heavy fuel oil).

APPLICATION AND ONGOING WORK

See Contract 2-9057.

SUPPORTING DOCUMENTS

Final Report: "Computer Aided Derating Assessment of Oil-Designed Wall-Fired Utility Boilers Using Coal-Water Slurry Fuels".

(See also ERL 83-64(OP) by S.R. Griffin, W.A. Shaw, and H. Whaley.)

TITLE: COMPUTER-AIDED DERATING ASSESSMENT OF OIL-DESIGNED TANGENTIALLY-FIRED UTILITY BOILER

				FUNDING	
CONTRACTOR:	Babcock & Wilcox Canada Limited	FILE NUMBER:	2-9057		
		BEGIN/END:	Oct. 82/Sept. 83		
				CANMET:	$ 30 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 30 000

OBJECTIVES

Assess the probable derating (loss of generating capacity) when oil-designed tangentially fired boilers of 60 and 200 MW(e) capacity, and of two typical Canadian designs, are fired with coal-water mixture fuels and pulverized coal.

PROCEDURE AND RESULTS

1. Using computer-aided boiler simulation and design experience, assess the probable derating of a tangentially fired box-type furnace (equivalent Combustion Engineering box-type design) with horizontal convective passes followed by horizontal convective surfaces.

2. Using computer-aided boiler simulation and design experience, assess the probable derating of a tangentially fired pendant panel boiler (equivalent Combustion Engineering pendant panel design) having pendant high-temperature surfaces followed by low-temperature convector surfaces.

Each of (1) and (2) will be repeated for all the following conditions:

a) Boiler Capacity*: 60 MW(e) and 200 MW(e)
b) Coal Ash Level (dry basis): 3% and 9%
c) Water in Fuel: 20% (slurry) and 10% (pulverized coal).

*Maximum rating when firing No. 6 fuel oil (heavy fuel oil).

3. A report will be prepared giving schematics of the boiler configurations studied, providing assessments of the derating effects of the coal-water fuel compared to No. 6 fuel oil, and detailing as many of the assumptions made in the methodology as is possible without divulging proprietary information. The report will contain:
   a) Recommended maximum (continuous) evaporation levels on coal-water fuels and on the reference fuel oil.
   b) Slagging and fouling characteristics.
   c) Erosion assessment.
   d) Details of possible boiler modifications.
   e) Suitability of existing auxiliary equipment.

APPLICATION AND ONGOING WORK

A derating assessment will possibly be required in connection with the proposed Charlottetown CWM Demonstration.

SUPPORTING DOCUMENTS

Final Report: "Computer Aided Derating Assessment of Oil-Designed Tangentially-Fired Utility Boilers using Coal-Water Slurry Fuels".

TITLE: DETERMINATION OF THE COMBUSTION AND HEAT TRANSFER PARAMETERS OF FOUR COAL-WATER MIXTURES

CONTRACTOR:	International Flame Research Foundation	FILE NUMBER:	3-9093	FUNDING	
		BEGIN/END:	Oct. 83/Oct. 84		
				CANMET:	$ 193 741
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 193 741

OBJECTIVES

Overall objective: Study a number of coal-water fuels (CWF) covering at least four commercial suppliers and a range of coal types. The combustion, heat transfer, and emission characteristics of flames from selected CWFs are to be determined under optimum combustion conditions.

The purpose of this contract was to provide fundamental combustion data to assist in the application of CWF technology to larger and oil-designed boilers.

This project was conducted in collaboration with the Netherlands Energy Agency (NEOM) as part of an IEA CLM technology exchange program.

PROCEDURE AND RESULTS

1. Test in a furnace of 2.5 MW(t) rated capacity, seven CWF fuels (four Canadian, three Netherlands) covering at least four manufacturers and a range of volatile matter in coal contents of 20-30% DAF.

   Optimize the combustion performance of each CWF tested before proceeding.

2. Operate on No. 6 fuel oil before and after (1) for reference purposes.

3. Make detailed in-flame measurements of gas temperature, concentrations, solids loadings, radiative and convective heat transfer, flame emissivity, and flame boundaries throughout (1) and (2).

4. Draft final report to be issued followed by final reports.

APPLICATION AND ONGOING WORK

Further work on CWF combustion is being planned under the IEA CLM agreement under a proposed cost-shared annex.

A program on a specific CWF being tested at Chatham, N.B., in two boilers has just been completed, with backup R&D being conducted at TUNS-CES.

SUPPORTING DOCUMENTS

1. "A Study of the Combustion Characteristics of a Number of Coal-Water Slurries", E.D. Engelberts and S. Bortz, IFRF Report F093/a/2, October 1984.

2. "Study of the Combustion Characteristics of a Number of Coal-Water Slurries", S. Bortz, E.D. Engelberts, and W. Schreier, Proceedings 6th International Conference on Coal Slurry Combustion and Technology, Orlando, Florida, June 1984.

TITLE: POTENTIAL COAL-LIQUID MIXTURE FUEL UTILIZATION IN CANADA - PHASES 2 AND 3

CONTRACTOR:	Montreal Engineering Company Limited (Monenco)	FILE NUMBER:	1-9080-1	FUNDING	
		BEGIN/END:	Feb. 82/Oct. 82		
				CANMET:	$ 107 143
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 107 143

OBJECTIVES

Phase 2

1. Provide an inventory of oil-burning equipment used in utility boilers, industrial boilers, and process combustors in the provinces of Newfoundland, Prince Edward Island, and New Brunswick. The survey will include all installations rated above 21.08 GJ/h (20 million Btu/h) thermal input.

2. Provide data for these provinces on the fuel resources as well as regulations and emissions standards as they pertain to coal and oil utilization.

Phase 3

3. Provide an inventory of oil-burning equipment used in utility boilers, industrial boilers, and process combustors in the provinces of Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia. The survey will include all installations rated above 52.70 GJ/h (50 million Btu/h) thermal input.

4. Provide data for these provinces on the fuel resources as well as regulations and emissions standards as they pertain to coal and oil utilization.

PROCEDURE AND RESULTS

For each of Phases 2 and 3, liaison with provincial government departments, crown agencies, industry associations and private corporations is required to provide complete data. Monenco was required to provide complete data from each province as follows:

1. Fuel resources (coal and oil), fuel transportation, and CLM preparation plants.

2. Inventory of oil-burning equipment in the following categories:

   a) Utility boilers oil-fired and:
      - coal designed
      - oil designed, future coal capable
      - oil designed, liberal design
      - oil designed, compact design

   b) Industrial boilers, oil-fired and:
      - coal designed
      - oil designed, package firetube
      - oil designed, modular and field erected

   c) Industrial process combustors, oil-fired and:
      - coal designed
      - oil designed.

3. Environmental emissions data. Established and recorded the local (provincial) regulations with respect to environmental factors of CLM fuel utilization. In addition, recorded the equivalent Federal Environmental Guidelines, and compared both regional and national standards from the viewpoint of oil replacement by coal-liquids mixtures.

APPLICATION AND ONGOING WORK

Part of IEA CLM Cooperative Agreement Annex I for cooperation in assessment and planning for coal-liquid mixture technology utilization signed by U.S.A., Holland, Sweden, Japan and Canada on March 23, 1981. Also part of on-going EMR Technology Development Program.

SUPPORTING DOCUMENTS

1. Final Report: "Assessment of Potential Coal-Liquid Mixture Fuel Utilization in Canada - Phase I", File No.: I-9080, Aug. 82.

2. Final Report: "Assessment of Potential Coal-Liquid Mixture Fuel Utilization in Canada - Phases 2 and 3", File No.: I-9080-I, Oct. 82.

3. Data Guidelines for Annex I: Cooperation and Planning for Coal-Liquid Mixtures (CLM) Technology Utilization, May 29, 1981.

TITLE: CATALOGUE OF OIL AND COAL FIRED BURNERS FOR UTILITY AND INDUSTRIAL APPLICATIONS

CONTRACTOR:	Ralph Grossman Limited	FILE NUMBER:	2-9028	FUNDING	
		BEGIN/END:	June 82/Oct. 83		
				CANMET:	$ 38 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	H. Whaley	TECHNOLOGY:	Coal-Liquid Mixture Combustion	TOTAL:	$ 38 000

OBJECTIVES

In addressing R&D initiatives concerned with industrial oil combustion, the scale-up of research data, and the transfer of pilot-scale technology to industry, EMR/CANMET has identified a need for an up-to-date comprehensive survey of oil and newly developed CLM burners that may be available to Canadian industry.

The objective of this work is to contact known suppliers of oil-burning equipment, as well as those developing burners for CLMs in North America.

PROCEDURE

1. Data Collection

   The major oil burner suppliers in North America will be contacted to obtain basic data on burner design principles.

   The following information will be reported for each contact:

   a) Manufacturer's name.
   b) Manufacturer's location.
   c) Manufacturer's burner equipment for coal or liquid fuels.
   d) Burner principle (e.g., internal atomized oil, etc.).
   e) Performance specifications (fuel capacity, turn down capability, pressures, temperatures, etc.).
   f) Manufacturer's technical support (trouble shooting, R&D design capability, etc.).

   Copies of manufacturer's drawings, brochures, technical information, and technical reports obtained during Task I will be furnished as appendices to the final report. Pertinent summaries of major features will be tabulated in the text.

2. Review of R&D in Burner Technology and New Developments

   During the implementation of (1) it will become apparent that some companies have considerable R&D design support for their activities. Insofar as is possible, this will be reported and any experience with CLMs detailed.

3. Report Preparation

   A draft and then final report will be submitted to the Scientific Authority upon completion of the work. This will include a description of the basic types of burners (i.e., the principle behind the generic type) as well as the specific details obtained. A cross index of each burner with the generic type will be provided in tabular form.

RESULTS

Most of the major North American burner manufacturers, as well as some of those abroad, were contacted during the period August 82 to July 83.

During this time, the contractor kept CCRL advised of the detailed progress of the work, which included much information covered by (2).

APPLICATION AND ONGOING WORK

It is clear from this work that there is much ongoing R&D in CLM burner development that has not yet produced commercial CLM burners. A second contract to obtain the latest status in this area is being considered.

TITLE: LOW NO_x BURNER AND LIMESTONE INJECTION SYSTEM

CONTRACTOR: G.A. Robb Associates	FILE NUMBER: I-9119-1	FUNDING	
	BEGIN/END: April 82/March 83		
		CANMET:	$ 9 001
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: G.K. Lee	TECHNOLOGY: Combustion Technologies for Pollution Abatement	TOTAL:	$ 9 001

OBJECTIVES

1. Develop a request for proposal for the design, supply, and installation of low NO_x pulverized coal burners and powdered limestone injection system, to be retrofitted to an existing hot water boiler at CFB Gagetown.

2. Assist in the adjudication of bids and recommend two bidders for detailed design work.

3. Develop Work Statements for contracts covering fabrication, installation, and testing of low NO_x and SO_x burners and limestone injection system.

4. Prepare reports on the economic assessment of use of limestone and the trade-offs in using coals with different sulphur contents, and on the results of baseline field tests carried out on the unmodified boiler at CFB Gagetown.

PROCEDURE

1. The request for proposal was prepared in collaboration with the Technical Committee and the Scientific Authority.

2. Bids were received and recommendations made in collaboration with the Technical Committee.

3. Work Statements were prepared using information gained from bidders on the first stage, and discussions with other interested parties.

4. The reports were prepared using data generated as a result of visits to Gagetown, to limestone suppliers, and from data on coal obtained from CCRL.

RESULTS

The RFP was completed in accordance with requirements. As a result of this, contracts for design of the equipment were awarded.

Two reports were completed. The first covered the baseline field tests carried out in March 1982 on the hot water boiler and CFB Gagetown Central Heating Plant. The second covered the costs of purchasing limestone compared with on-site pulverizing and the costs of using various coals with sulphur levels ranging from 0.5% to 6% using limestone to control the SO_x emissions.

APPLICATION AND ONGOING WORK

As a result of this contract, G.A. Robb Associates were awarded a further contract to coordinate the testing of the retrofit burners and limestone injection system.

TITLE: DESIGN OF PULVERIZED COAL BURNERS FOR THE COMBINED REDUCTION OF NITROGEN AND SULPHUR OXIDES AT CANADIAN FORCES BASE GAGETOWN, NEW BRUNSWICK

CONTRACTOR:	Foster Wheeler Limited	FILE NUMBER:	2-9094-1	FUNDING	
		BEGIN/END:	Oct. 82/March 83		
				CANMET:	$ 75 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	G.K. Lee	TECHNOLOGY:	Combustion Technologies for Pollution Abatement	TOTAL:	$ 75 000

OBJECTIVES

1. Advance burner technology for simultaneous reduction of nitrogen and sulphur oxides (NO_x and SO_x) during combustion of pulverized coal.

2. Accelerate the transfer of this technology from offshore to Canadian manufacturers and users.

PROCEDURE

1. Produce a detailed design for the two retrofit pulverized coal burners, capable of simultaneously reducing sulphur and nitrogen oxide emissions by 40 to 50% while burning coal in Boiler No. 2 at CFB Gagetown.

2. Design an unloading, storage, feeding, metering, and injection system for use with powdered limestone or other additive, for sulphur sorption.

3. Formulate a detailed technical proposal and cost breakdown for follow-up work involving the fabrication, supply, installation, commissioning, and performance testing of the burners and the limestone or additive system in the central heating plant at CFB Gagetown.

RESULTS

The design report detailing the theoretical basis of the simultaneous nitrogen and sulphur oxide reduction technology, together with design details, specifications, equipment layouts, and details covering the retrofit burners and additive handling and injection system was satisfactorily completed. The report also included a cost breakdown for follow-up supply and installation of the system described.

APPLICATION AND ONGOING WORK

No contracts for further work were awarded as a result of this proposal and cost breakdown for the follow-up work. The Foster Wheeler proposal, although acceptable, was ranked below that received from Volcano Inc., the successful bidder in the design competition.

TITLE: DESIGN OF PULVERIZED COAL BURNERS FOR THE COMBINED REDUCTION OF NITROGEN AND SULPHUR OXIDES AT CANADIAN FORCES BASE GAGETOWN, NEW BRUNSWICK

CONTRACTOR: Volcano Inc.	FILE NUMBER: 2-9094-2	FUNDING	
	BEGIN/END: Nov. 82/March 83		
		CANMET:	$ 109 500
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Coal	OTHER:	--
AUTHORITY: G.K. Lee	TECHNOLOGY: Combustion Technologies for Pollution Abatement	TOTAL:	$ 109 500

OBJECTIVES

1. Advance burner technology for simultaneous reduction of nitrogen and sulphur oxides (NO_x and SO_x) during combustion of pulverized coal.

2. Accelerate the transfer of this technology from offshore to Canadian manufacturers and users.

PROCEDURE

1. Produce a detailed design for the two retrofit pulverized coal burners, capable of simultaneously reducing sulphur and nitrogen oxide emissions by 40 to 50% while burning coal in Boiler No. 2 at CFB Gagetown.

2. Design an unloading, storage, feeding, metering, and injection system for use with powdered limestone or other additive, for sulphur sorption.

3. Formulate a detailed technical proposal and cost breakdown for follow-up work involving the fabrication, supply, installation, commissioning, and performance testing of the burners and the limestone or additive system in the central heating plant at CFB Gagetown.

RESULTS

The design report detailing the theoretical basis of the simultaneous nitrogen and sulphur oxide reduction technology, together with design details, specifications, equipment layouts, and details covering the retrofit burners and additive handling and injection system was satisfactorily completed. The report also included a cost breakdown for follow-up supply and installation of the system described. Volcano Inc. negotiated an agreement for the Canadian rights to a German low NO_x and SO_x burner design.

APPLICATION AND ONGOING WORK

As a result of the proposal and cost breakdown for the follow-up work, Volcano Inc. was awarded a further contract for the fabrication, supply, installation, commissioning, and performance testing of the retrofit burners and additive injection system at CFB Gagetown.

TITLE: EVALUATION OF STRESS-RUPTURE PROPERTIES OF STAINLESS ALLOYS IN FLUIDIZED BED COMBUSTION ENVIRONMENTS - PHASE I

				FUNDING	
CONTRACTOR:	Sherritt Gordon Mines Ltd.	FILE NUMBER:	2-9053		
		BEGIN/END:	Oct. 82/Feb. 86		
				CANMET:	$ 252 863
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	Dr. D. Briggs	TECHNOLOGY:	Materials for Coal Utilization and Conversion	TOTAL:	$ 252 863

OBJECTIVES

Determine the effects of the operating environments in coal conversion processes on the mechanical properties of alloys.

PROCEDURE

Stress-rupture tests on four stainless alloys were conducted under conditions simulating the environment in a fluidized bed coal combustor. Testing was done at 800°C and 900°C in a flowing synthetic combustion gas that was high in sulphur dioxide. Rupture times were in the range of 10 to 1000 h.

RESULTS

At 800°C and low stress, rupture lives were generally shorter than would be expected in air, an effect attributable to the gas having a sulphidizing potential. When the same gas was used in tests at 900°C, the equilibrium shifted to lower sulphur potential and higher oxygen potential, with the result that stress-rupture lives at 900°C were similar to those for tests in air. Metallography revealed greater sulphidation in the 800°C test specimens.

APPLICATION AND ONGOING WORK

The results add to the knowledge of performance of materials being contemplated for use in heat exchangers and hardware in fluidized bed coal combustors, in particular those alloys undergoing testing in the Nova Scotia Power Corporation FBC pilot project. Phase 2 of this contract, now underway, comprises determining the stress-rupture lives of the same alloys (1) in a more highly sulphidizing gas at 900°C, and (2) enveloped in a FBC deposit and synthetic combustion gas at 800°C.

SUPPORTING DOCUMENTS

"Evaluation of Stress-Rupture Properties of Stainless Alloys in Fluidized Bed Combustion Environments - Phase I", by K.G. Reid and M.J.H. Ruscoe, Contract Report No. 0SQ82-00148.

TITLE: DESIGN, CONSTRUCTION AND TESTING OF A HIGH-TEMPERATURE EROSION TEST FACILITY - PHASES 2 AND 3

CONTRACTOR:	Montreal Engineering Company Limited	FILE NUMBER:	2-9084	FUNDING	
		BEGIN/END:	Sept. 82/Sept. 84		
				CANMET:	$ 124 729
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	A.W. Lui	TECHNOLOGY:	Materials for Coal Utilization and Conversion	TOTAL:	$ 124 729

OBJECTIVES

The objective is to design, construct, and test a facility for evaluating the performance of materials used in the high-temperature erosive-corrosive environments characteristic of particulate laden hot gas streams.

PROCEDURE

Phase I of the work comprised a detailed design of the equipment, including materials of construction and performance characteristics. In Phase 2, construction of the equipment was carried out according to the design of Phase I. Software for control of furnaces, gas heaters, gas flowmeters, and interlocking safety features was developed, and all set points and deviation input data and measured variables were present in printouts. In Phase 3, the equipment was tested for its functionality under various experimental conditions.

RESULTS

The work is now complete. The equipment can operate over a temperature range from ambient to 1000°C in 0.5% of SO_2 gas. It can deliver particle velocities from 5 to 40 m/s for particles from 10 to 250 µm and loading rates from 1 to 10 g/min. Sample specimens can be studied at impingement angles from 0 to 90 degrees. The equipment will be used in the high-temperature corrosion laboratory in the years to come.

APPLICATION AND ONGOING WORK

This equipment will be used to carry out high-temperature erosion studies that may help in understanding the erosion phenomena in particulate laden hot gas streams, such as in atmospheric fluidized-bed coal combustion.

SUPPORTING DOCUMENTS

Final Report: "High Temperature Corrosion/Erosion Test Facility Instruction Manual", by Centre for Energy Studies, Technical University of Nova Scotia.

Phase I: Contract No. 1-9001.

TITLE: COAL-OIL SLURRY SEPARATION BY CONTINUOUS SCREEN BOWL CENTRIFUGE

				FUNDING	
CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	0-9073		
		BEGIN/END:	April 81/May 83		
				CANMET:	$ 76 331
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Coal	OTHER:	--
AUTHORITY:	M. Skubnik	TECHNOLOGY:	Slurry Transport	TOTAL:	$ 76 331

OBJECTIVES

Generate suitable data for the assessment of technical feasibility of centrifugal separation of coal and synthetic crude oil from long-distance pipeline slurries, and prepare coal-oil cake samples for additional oil recovery tests.

PROCEDURE

1. Preparation of slurries of Wabamun (WC), Vesta (VC) thermal, and McIntyre (MC) metallurgical coals in a synthetic crude oil, and simulation of long-distance pipeline transportation.

2. Slurry separation tests on a continuous screen bowl centrifuge 150 mm in diameter with feed rates ranging from 0.1 to 10 kg/min and at centrifugal force ratio ranging from 750 to 1500 G.

3. Determination of solids content and particle size distribution of all in- and out-coming streams.

4. Preparation of representative samples of cokes, and determination of the nature and degree of contamination of oil effluents.

RESULTS

1. The magnitude of G did not consistently affect the separation results.

2. Recoveries of coal and oil improved with increased feed rates from 70 to 87% or higher, but at the expense of higher oil effluent contamination and higher oil content in cake.

3. Oil in cake increased with feed rate from 5 to 10% and 6 to 8% for MC and WC, respectively, but was invariant at 9% for VC.

4. Coal residues of oil effluents, and correspondingly also BS and W sediment, MCR, and ash content increased considerably with feed rates particularly for MC and WC cases. Based on extrapolated data, the complete restoration of original synthetic crude oil properties would require a prohibitively high liquid residence time in the centrifuge pool ranging from 500 to 1000 seconds.

APPLICATION AND ONGOING WORK

Because of discouraging results, no continuation of this work is proposed.

SUPPORTING DOCUMENTS

"Experimental Studies on the Pipelining of Coal-In-Oil Slurries", SRC Report E 76-3, March 1976 (a brief outline of similar tests with conventional crude oil).

ENERGY TECHNOLOGY

RENEWABLE ENERGY

TITLE: PRE-HEATING OF WOOD CHIPS BY SIMULATED KRAFT RECOVERY BOILER FLUE GASES

CONTRACTOR:	University of British Columbia	FILE NUMBER:	2-9086	FUNDING	
		BEGIN/END:	Sept. 82/Aug. 84	CANMET:	$ 44 123
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	R. Braaten	TECHNOLOGY:	Biomass Heating Systems	TOTAL:	$ 44 123

OBJECTIVES

Provide necessary design parameters for the development of wood chip preheaters for kraft recovery boilers.

PROCEDURE

A laboratory-scale preheater using simulated flue gases is used to obtain necessary heat transfer and pressure drop data under a range of operating conditions.

RESULTS

Heat transfer and pressure drop charts were developed for a range of chip sizes.

APPLICATION AND ONGOING WORK

Results have application in the design of preheating systems for wood chips.

TITLE: SPECIFICATION OF EQUIPMENT AND METHODOLOGY FOR THE AUTOMATED CONDUCTIVITY TESTING OF CERAMICS

CONTRACTOR:	Queen's University	FILE NUMBER:	I-9096	FUNDING	
		BEGIN/END:	Nov. 81/Jan. 82		
				CANMET:	$ 4 100
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	T.A. Wheat	TECHNOLOGY:	Materials for Advanced Energy Conversions Systems	TOTAL:	$ 4 100

OBJECTIVES

Define the equipment and conditions for the computer-controlled characterization of dielectric materials. System must operate over a range of controlled temperatures (between room temperature and 500°C) and frequencies, log the data, and manipulate it to present the reduced data either graphically or in a tabular format.

RESULTS

Recommended system based on a Hewlett-Packard 9845B desk-top computer interfaced to a Solartron 1174 Frequency Response Analyzer and 1186 Electrochemical Interface.

System allows the real and imaginary impedance of a cell to be determined in the frequency range from 10 Hz to 300 kHz for any preset temperature, and for that data to be manipulated and presented either graphically or as tabulated data from which the grain and grain-boundary resistivity of a polycrystalline electrolyte can be obtained.

APPLICATION AND ONGOING WORK

System has been operating at CANMET since the fall of 1982.

TITLE: DEVELOPMENT OF CERAMIC PROTON CONDUCTORS

CONTRACTOR: Queen's University	FILE NUMBER: I-9105	FUNDING	
	BEGIN/END: Jan. 82/June 83		
		CANMET:	$ 38 500
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	--
AUTHORITY: T.A. Wheat	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 38 500

OBJECTIVES

Assess the candidate ceramic materials for their suitability in intermediate-temperature fuel cell and electrolyzer applications.

PROCEDURE

Literature survey to identify candidate materials, followed by synthesis or procurement of samples of suitable materials and their electrical characterization for ionic conductivity and activation energy between 25-300°C, using automatic scanning equipment controlled by a PET.

RESULTS

Data suggest that the most suitable material is based on a substituted beta-alumina as a two-dimensionally conducting material or on the doped silicates: "Zirpsios", "Gasicons", and "Yasicons" for the more desirable three-dimensional conductors.

Conductivities up to 10^{-3} $(ohm.cm)^{-1}$ at 300°C were obtained for ion-exchanged sodium-zirpsios.

APPLICATION AND ONGOING WORK

A study of the possible electrodes that can be used on these identified electrolytes has been initiated with the same contractor.

TITLE: DURABILITY OF CANMET-PRODUCED SOLID ELECTROLYTES

CONTRACTOR: McMaster University	FILE NUMBER: 3-9080	FUNDING	
	BEGIN/END: July 83/Dec. 83		
		CANMET:	$ 8 500
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	--
AUTHORITY: T.A. Wheat	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 8 500

OBJECTIVES

Verify the dubious claim made by others that the Na-zirpsios can be used successfully in place of beta-alumina in a sodium environment, i.e., in the sodium-sulphur battery or thermoelectric generator.

PROCEDURE

CANMET synthesized a range of compositions by both conventional and gel processing, and provided disc samples to the contractor. Two samples of each composition were sealed into the end of an alpha-alumina tube and used in a sodium-sodium concentration that was put on an automatic charge-discharge cycle pumping liquid sodium to and fro at 350°C.

RESULTS

All samples failed after a maximum of two weeks, the speed of failure being directly related to the amount of glass phase present in each disc.

Discs made from the glass composition, although highly conductive and hence not detected in impedance spectra, failed after about two days - further verifying the CANMET position that these materials are unsuitable for use in any sodium environment where a temperature excursion above 300°C (as in charging a battery) can be expected.

SUPPORTING DOCUMENTS

Final Report: "Evaluation of CANMET Nasicon Ceramics in Sodium/Sodium Cells".

TITLE: DEVELOPMENT OF NONDESTRUCTIVE TESTING TECHNIQUES TO EVALUATE THE INTEGRITY OF SINTERED SOLID-STATE ELECTROLYTES - PHASE 2

CONTRACTOR:	McMaster University	FILE NUMBER:	2-9065	FUNDING	
		BEGIN/END:	July 82/June 83		
				CANMET:	$ 28 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	T.A. Wheat	TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$ 28 000

OBJECTIVES

Development of methodology and instrumentation to determine, characterize, and map in 3D, sub-surface defects in sintered ceramic with a resolution of 5 μm, to a depth of 1 mm.

PROCEDURE

Essentially, the challenge is to obtain both resolution and penetration at the same time. At low frequency (25 MHz), adequate penetration occurs in these acoustically damped materials but with poor resolution. At high frequency (2 GHz), excellent resolution is obtained (less than 0.5 μm) but with poor penetration (2 few μm).

The compromise appears to be in the frequency range 100-300 MHz; this, in turn, means making the transducers since none are available commercially. For this purpose, transducers have been made using both thinned PZT and sputtered ZnO.

Automatic scanning equipment has been designed and built around a PDP-11. This allows an XY scan to be made of the surface, the coordinates of any defect being logged and displayed on a 3D-plot.

RESULTS

At the start of this work, the lower limit of detection with over 1-mm penetration was about 80 μm. The contractor can now detect about 25-μm defects (artificially introduced into glass). Because of the contamination in commercially available piezoelectric ceramic raw materials, which prevents satisfactory poling, the contractor has had to synthesize their own materials, sinter them to theoretical density, slice to 100 μm or less, pole, and incorporate into a transducer body prior to use.

The limitation of the technique remains the need to constantly scan in X&Y at the focal plane of the transducer for n values of Z in order to generate a 3D map. Modification of the signal beam shape should allow this information to be obtained in a single pass.

APPLICATION AND ONGOING WORK

Follow-up work pursuing the development of shaped transducers to give a 3D map in a single scan.

TITLE: NONDESTRUCTIVE TESTING OF SOLID ELECTROLYTES

CONTRACTOR: McMaster University	FILE NUMBER: 4-9175	FUNDING	
	BEGIN/END: Aug. 84/June 85	CANMET:	$ 44 004
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	--
AUTHORITY: T.A. Wheat	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 44 004

OBJECTIVES

Detect and characterize sub-surface defects in ceramic materials using nondestructive testing techniques.

PROCEDURE

Commercially available transducers are inadequate to detect and characterize defects in the 5-20 μm range. Therefore, materials for transducers were developed and incorporated into sensors used on an automatic X-Y-Z controlled stage for scanning the samples and logging the position of defects.

Initially, glass test samples having fine bubbles and solid inclusions were used so that the data could be correlated with that obtained by optical microscope.

RESULTS

Developed a series of materials and transducers that operate in the 25 to 80 MHz range (commercial transducers stop at 50 MHz) of fundamental resonance and that have a symmetrical signal output.

Transducers can detect sub-surface defects down to 20 μm, locate the position of the defect in space within the body, and give some idea of its nature (shape, void or inclusion, modulus higher or lower than that of the matrix).

This capability has demonstrated clearly that the ion-exchange process used to produce hydronium-conducting solid electrolytes is very destructive and introduces a high concentration of microcracks in the body. For that reason, the original process for the production of these electrolytes is being abandoned and a new series of bonded electrolytes is being developed.

APPLICATION AND ONGOING WORK

Widespread application of these devices in the testing of both metallic and non-metallic structural materials is evident. Commercial interest in the exploitation of this capability has been generated.

TITLE: PRODUCTION OF HIGH-STRENGTH, HIGH CONDUCTIVITY BETA-ALUMINA BY A SLIP-CASTING, LOW TEMPERATURE FIRING PROCESS - PHASE 2

CONTRACTOR:	McMaster University	FILE NUMBER:	7-9115	FUNDING	
		BEGIN/END:	Jan. 78/March 79		
				CANMET:	$ 20 000
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	Dr. T. Wheat	TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$ 20 000

OBJECTIVES

Determine the feasibility of producing high-quality solid electrolyte using a low-cost fabrication process.

PROCEDURE

1. Slip casting studies.
2. Sintering studies.
3. Glass impregnation studies.

RESULTS

Adequate slurries (slips) could be produced, but an undesirable textural feature occurred that suggested that casting was not the appropriate route to follow. The crystals aligned in a direction that gave the minimum conductivity through the tube wall, whereas a maximum was required.

APPLICATION AND ONGOING WORK

No further work in slip casting has been undertaken.

SUPPORTING DOCUMENTS

Final report: "A Study of the Production of High-Strength, High Conductivity β''-Al_2O_3 by a Slip-Casting, Low Temperature Firing Process".

TITLE: PRODUCTION OF SODIUM AND HYDROGEN-ION CONDUCTING SILICATES BY SPRAY DRYING - PHASE I

CONTRACTOR:	McMaster University	FILE NUMBER:	I-9104	FUNDING	
		BEGIN/END:	Dec. 81/Nov. 83		
				CANMET:	$ 48 551
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	T.A. Wheat	TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$ 48 551

OBJECTIVES

Development of an industrially acceptable process for the production of sintered solid electrolytes highly conductive to hydrogen or sodium for use in a hydrogen-air and high energy-density battery, respectively.

PROCEDURE

The work focussed on development of the synthesis, fabrication, sintering, and electrical and microstructural characterization of two materials known as "Gasicon" ($Na_5GdSi_4O_{12}$) and "Yasicon" ($Na_5YSi_4O_{12}$).

The powder synthesis was based on the spray-drying of a slurry of appropriate materials chosen to furnish a range of compositions based on the host gasicon/yasicon lattice.

By manipulation of the fabrication and sintering processes, it is possible to produce a wide range of microstructures/compositions having a range of properties.

RESULTS

It has been shown that high-density products can be readily produced using conventional equipment with some variations to conventional processing. The final materials are theoretically dense, three-dimensional (isotropic) conductors having an ionic conductivity of 10^{-13} $(ohm.cm)^{-1}$ or better to sodium and (separately) hydrogen at 400°K.

The combination of insolubility, high conductivity, and relatively high upper temperature stability limit (at least double that reported elsewhere) suggests that the hydrogen conductors are appropriate for exploitation in a fuel cell.

Patent action on behalf of the Crown to cover the processes by which these hydrogen conductors are produced is underway.

APPLICATION AND ONGOING WORK

Further work is planned to examine the durability of these materials in a fuel cell environment.

TITLE: SYNTHESIS OF NGS, NYS, AND BETA-ALUMINA - CONTINUATION

CONTRACTOR:	McMaster University	FILE NUMBER:	3-9051	FUNDING	
		BEGIN/END:	June 83/March 84		
				CANMET:	$ 43 500
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	A.K. Kuriakose	TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$ 43 500

OBJECTIVES

Produce, characterize, and supply single-phase high-density NGS ($Na_5GdSi_4O_{12}$), NYS ($Na_5YSi_4O_{12}$), and Na-K beta"-alumina suitable for the preparation of hydronium ion conducting solid electrolytes.

PROCEDURE

Used an industrially acceptable spray-drying process instead of the expensive freeze drying to produce the reactive powders; calcined, pressed, and sintered the various products; subjected some of the products to hydronium ion exchange after a potassium exchange in a molten potassium salt bath; characterized the various products by density, X-ray, and ultra sound velocity measurements.

RESULTS

NGS and NYS in single-phase form with densities in the range of 93 to 100% of theoretical were obtained. Na-K beta"-alumina containing up to 70% beta", with densities in the range of 93-99% of theoretical were produced. After a potassium ion exchange, part of the alkali metal ions in the materials could be substituted by hydronium ions by field-assisted ion exchange. Young's modulus in the range of 80-145 GPa was obtained on the samples.

APPLICATION AND ONGOING WORK

Potential precursors for membranes in hydrogen-air fuel cells. Work is continuing under Contracts 4-9114 and 4-9203.

TITLE: CHARACTERIZATION OF SOLID ELECTROLYTES

CONTRACTOR: McMaster University	FILE NUMBER: 4-9114	FUNDING	
	BEGIN/END: Aug. 84/June 85		
		CANMET:	$ 49 180
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	--
AUTHORITY: A.K. Kuriakose	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 49 180

OBJECTIVES

Characterize microstructurally, sodium/potassium beta/beta"-alumina and the Nasicons - sodium yttrium silicate (NYS) and sodium gadolinium silicate (NGS); and detect glassy phases, if any, in these systems.

Supply to CANMET, thin foils of the above materials together with their respective scanning transmission electron micrographs (STEMs).

PROCEDURE

Synthesize and sinter sodium/potassium beta/beta"-alumina, NYS, and NGS; ion exchange these into the potassium form by interaction with molten potassium salt bath; prepare thin foils of these for transmission electron microscopy; and examine the various foils by STEM for general microstructure and phase assemblage.

RESULTS

The sodium and potassium compounds were too sensitive to electron beam bombardment during the STEM analysis due to the high mobility of the alkali metal ions. Hence, the materials had to be first converted into a more stable form by ion exchange with calcium and strontium.

The microstructure of sodium/potassium beta/beta"-alumina consisted of individual grains of pure beta and beta" alumina and intergrowths of beta and beta" aluminas. No grain boundary phases were detected.

The NYS and NGS showed the presence of glassy phases in the systems. These glassy phases contained more silicon than in the bulk material.

APPLICATION AND ONGOING WORK

The sodium/potassium beta/beta"-alumina appears to be suitable for conversion into the hydronium form. The NYS and NGS systems in the sintered form do not appear attractive for the fabrication of high grade hydronium conductors due to the presence of the glassy phases in them.

There is no ongoing work with the contractor at the present time.

TITLE: SYNTHESIS OF HYDROGEN-CONDUCTING SOLID ELECTROLYTES

CONTRACTOR:	McMaster University	FILE NUMBER:	4-9203	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 15 990
CANMET		ENERGY TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Renewable Energy	OTHER:	--
AUTHORITY:	A.K. Kuriakose	TECHNOLOGY:	Materials for Advanced Energy Conversion Systems	TOTAL:	$ 15 990

OBJECTIVES

Produce and supply to CANMET, discs of hydronium ion-conducting Yasicon (HNYS) in diameters of 1.0 and 2.5 cm. Supply discs of potassium Yasicon.

PROCEDURE

Prepare sodium Yasicon powder by spray-drying; heat-treat and sinter to high density; ion exchange to potassium form in NaCl/KCl molten salt bath; ion exchange to hydronium form by field-assisted ion exchange; and run samples in a steam electrolysis cell to complete the hydronium ion exchange.

RESULTS

Fabricated and supplied hydronium ion-conducting Yasicon (HNYS) in disc form in diameters of 1.0 and 2.5 cm. These will be tested at CANMET as membranes in a hydrogen-air fuel cell.

Fabricated and supplied potassium-exchanged Yasicon samples.

APPLICATION AND ONGOING WORK

Potential application in hydrogen-air fuel cells; high-temperature steam electrolysis cells; and in hydrogen, deuterium, and tritium sensors, separators, and pumps. Ongoing work at CANMET in-house.

TITLE: REVIEW OF SOLID-STATE ELECTROLYTES

CONTRACTOR: ASCOR	FILE NUMBER: 1-9051	FUNDING	
	BEGIN/END: Oct. 81/July 83		
		CANMET:	$ 27 592
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	--
AUTHORITY: T.A. Wheat	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 27 592

OBJECTIVES

Assemble a master script for a CANMET-produced book entitled "Progress in Solid Electrolytes" with contributions from internationally recognized experts in the field.

PROCEDURE

Twenty-one contributions were obtained from the following countries: Canada, China, Denmark, France, Germany, Italy, Japan, India, U.K., and U.S.A.

RESULTS

This volume brings together comprehensive state-of-the-art papers on recent developments in understanding and using solid electrolytes. Internationally recognized experts were invited by CANMET to contribute papers on selected topics in this rapidly expanding field. To expedite publication, this volume has been printed directly from the manuscripts as received from the authors and hence they are responsible for the opinions expressed.

SUPPORTING DOCUMENTS

Final Report: "Progress in Solid Electrolytes", by T.A. Wheat, A. Ahmad, and A.K. Kuriakose, 1983. (Contract Report No. OSQ81-00102).

The final report is also published as Division Report ERP/MSL 83-94(TR).

TITLE: PREPARATION AND DEVELOPMENT OF EPITACTIC GaAs FILMS

CONTRACTOR: McGill University	FILE NUMBER: I-9112	FUNDING	
	BEGIN/END: Oct. 81/Oct. 83	CANMET:	$ 11 700
CANMET	ENERGY TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Renewable Energy	OTHER:	15 000
AUTHORITY: S.M. Ahmed	TECHNOLOGY: Materials for Advanced Energy Conversion Systems	TOTAL:	$ 26 700

OBJECTIVES

Prepare single crystal, n- and p-type GaAs films for use as photoanodes and photocathodes, respectively, in the photoelectrochemical cells for solar energy conversion.

PROCEDURE

Single crystal epitactic GaAs films were prepared by metal-organic vapour phase epitaxy on semi-insulating GaAs substrates with <100> orientation, in an induction furnace at 625°C, at 0.3 Torr pressure. Chemical reactions consist of reducing trimethyl gallium by hydrogen to CH_4 and Ga, the latter then reacting with AsH_3 to give GaAs, at controlled temperature and pressures. The films are suitably doped to give n- and p-type GaAs. Information on carrier concentration, mobility, and resistivity for each sample was obtained by Hall-coefficient measurements. The film thickness was measured. Samples of n- and p-type GaAs films were provided with information on the electrical properties.

RESULTS

Single crystal, epitactic GaAs films of high quality and high purity with low resistance were obtained by the MOVPE method. The film thickness ranged from 1.5 to 10.4 μm. Only four of the n-type and three of the p-type samples were provided. With the exception of two samples, the carrier concentration was rather high ($\sim 10^{18}$). Lower carrier concentration, and thicker films are preferred for the photoelectrochemical (PEC) work, in any future extension of the contract. Preliminary tests indicated that the films have excellent PEC properties. Further work is being planned.

APPLICATION AND ONGOING WORK

Photocorrosion of GaAs in the PEC cells is posing a serious problem. Work is now underway to prevent photocorrosion. The films will then be tested in greater detail, for application in the PEC cells.