SUMMARIES OF CANMET MINERALS RESEARCH CONTRACTS 1984–1985

COMPILED BY T.P. LANZER

RESEARCH PROGRAM OFFICE
CANMET REPORT 86-2E

May 1986

Available in Canada through

Associated Bookstores
and other booksellers

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

Catalogue No. M38-13/86-2E
ISBN 0-660-12757-1

Canada: $32.00
Other Countries: $38.40

Price subject to change without notice

FOREWORD

This report summarizes minerals-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 minerals-related R & D that was contracted-out in 1984 and 1985 exceeded $2.6 million. Contracts administered by CANMET within the National Uranium Tailings Program are not included in this report. Minerals contracts completed prior to 1984 were summarized previously in CANMET Reports 78-1, 79-26, and 83-12.

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 des minéraux 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 2,6 millions de dollars. Les contrats administrés par le CANMET dans le cadre du Programme national de recherche sur les résidus d'uranium ne sont pas compris dans le présent rapport. Les contrats ayant trait aux minéraux achevés avant 1984 sont résumés dans les rapports du CANMET suivants 78-1, 79-26, et 83-12.

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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PERFORMANCE AND DURABILITY OF CONCRETE INCORPORATING WASTE MATERIALS

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MINERALS TECHNOLOGY

MINING

TITLE: DEVELOPMENT OF IMPROVED CIRCUITRY FOR MODEL BH-10 BOREHOLE LOCATOR

CONTRACTOR:	Richard Brancker Research Ltd.	FILE NUMBER:	8-9142	FUNDING	
		BEGIN/END:	June 79/Oct. 79	CANMET:	$ 4 436
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	R. Tervo	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 4 436

OBJECTIVES

1. Improve the borehole locator by providing two linear ranges with direct readout in feet, instead of the non-linear inverse cube ranges existing and shown on an analog millivoltmeter.

2. Provide the transmitter with a coded output to positively identify the signal from the probe.

3. Redesign receiver so that receiving coil orientation may be readily observed.

4. Provide solid state analog readout of distance using light-emitting diodes (LED).

5. Provide an indicator for low battery.

PROCEDURE

The transmitter and receiver circuits were redesigned to add the improved operating components.

Mechanical components of the receiver were redesigned to provide an external antenna.

RESULTS

The receiver, with linear output and LED indicators meeting the design criteria, was received at the Elliot Lake Laboratory and proved to be satisfactory. The unit was heavier than expected and the contractor has redesigned the aluminum case to overcome this minor problem.

Two of the new units (BH-20) have been purchased by Inco, who have been making their own borehole locators for many years.

APPLICATION AND ONGOING WORK

The units are now available for sale to mining and drilling companies.

SUPPORTING DOCUMENTS

Final report: "Bore Hole Locator Model BH-20".

The final report consists of operating instructions, technical description, and schematics.

TITLE: DATA LOGGING EQUIPMENT MODIFICATION AND PERFORMANCE EVALUATION

CONTRACTOR:	Heathwood Engineering Associates Ltd.	FILE NUMBER:	9-9055	FUNDING	
		BEGIN/END:	Oct. 79/March 80		
				CANMET:	$ 9 995
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	L. Geller	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 9 995

OBJECTIVES

Modify and rebuild the analog portion of data-logging instrumentation for diamond drills to improve the equipment's performance.

PROCEDURE

Redesign and rebuild analog portion of data logger, primarily one printed circuit board.

RESULTS

The equipment was duly rebuilt and field tested. It is now awaiting extensive field testing by the industry.

APPLICATION AND ONGOING WORK

No ongoing work on a contractual basis.

SUPPORTING DOCUMENTS

Final Report: "Data Logging Equipment Modification & A Performance Evaluation".

TITLE: SURVEY AND ASSESSMENT OF MINE RESCUE PROGRAMS

CONTRACTOR:	Norwest Resource Consultants Ltd.	FILE NUMBER:	2-9052	FUNDING	
		BEGIN/END:	Nov. 82/March 83		
				CANMET:	$ 73 790
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Dr. B. Stewart	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 73 790

OBJECTIVES

1. Summary of mine rescue programs in place in Canada.
2. Summary of mine rescue programs in selected foreign jurisdictions.
3. Comparison of foreign and domestic mine rescue programs.
4. Highlight recent developments in mine rescue.
5. Identify areas where a national focus could be desirable.

PROCEDURE

The contractor corresponded with and visited domestic and selected foreign jurisdictions, compiled descriptions of the mine rescue programs in place, compared foreign and domestic mine rescue programs, highlighted recent developments, and identified areas where a national mine rescue focus could be desirable.

RESULTS

Final report (plus Appendices) that meets all five objectives.

APPLICATION AND ONGOING WORK

The final report will be discussed with Provincial/Territorial Mine Inspectorates prior to public release. It is expected that public release will occur by the end of 1983.

SUPPORTING DOCUMENTS

"Proceedings of International Symposium on Crisis Management", October 19-21, 1982, Sydney, Nova Scotia.

TITLE: DEVELOPMENT, CONSTRUCTION AND TESTING OF A PROTOTYPE ELECTRO-HYDRAULIC MINI-SCALER

CONTRACTOR:	Teledyne Canada Limited	FILE NUMBER:	2-9173	FUNDING	
		BEGIN/END:	Jan. 83/March 85		
				CANMET:	$ 70 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	DSS:	105 450
AUTHORITY:	Dr. J. Pathak	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 175 450

OBJECTIVES

In keeping with the trend in the development of remote-controlled, electro-hydraulic underground hardrock mining equipment, a mini-scaler is an appropriate development. It is also one of the objectives of EMR to support development of mining equipment in Canada.

PROCEDURE

1. Conceptual development of remote-controlled electro-hydraulic mini-scaler.
2. Design and construction of a prototype.
3. Vigourous testing of it in an underground hardrock mine in Canada.

RESULTS

The product has been well received by the industry, although a few changes and further development will be required before full commercial potential is realized.

APPLICATION AND ONGOING WORK

The mini-scaler has application in underground mining and in the construction industry in Canada. Initial tests in an underground mine indicated that some modification of the prototype design will be required. Teledyne was looking for further funding to make these changes, but now they are funding some of the work themselves for some customers.

TITLE: A REVIEW OF MINE MAINTENANCE IN CANADA

CONTRACTOR: Queen's University	FILE NUMBER: 3-9094	FUNDING	
	BEGIN/END: Aug. 83/April 84		
		CANMET:	$ 35 730
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: R.J.R. Welwood	TECHNOLOGY: Mining Methods and Equipment	TOTAL:	$ 35 730

OBJECTIVES

Provide a full spectrum of methods and systems available to the mining industry in Canada for organizing its maintenance requirements.

PROCEDURE

1. Literature search.
2. Personal visits to maintenance and operations managers to check out maintenance systems being used.
3. Organization of data thus obtained into a report suitable for both researchers and operating personnel.

RESULTS

This report presents a state-of-the-art review of maintenance management as applied to the mining industry. It is based on a comprehensive literature review and field visits to twelve Canadian mining operations.

Effective management of the maintenance function requires a sound maintenance management program, designed to ensure optimum performance of equipment for the lowest possible cost and to provide for the supply of feedback data to demonstrate the achievement of these aims. Because of the diverse nature of mining activities, it is not possible to outline a simple "one-for-all" management program. Each operation must be considered individually.

This report is written as an aid to mine operations faced with the task of organizing a maintenance management program. It provides a step-by-step guide to what is involved in developing and implementing such a program. With this kind of information it is possible for a mine manager to develop a new program, evaluate an existing one or upgrade a weak one, and integrate the program into the overall mine organization to achieve a more economical operation.

APPLICATION AND ONGOING WORK

Workshop for senior executives being considered.

SUPPORTING DOCUMENTS

Final Report: "A Review of Mine Maintenance in Canada" and "A Bibliography of Mine Maintenance Systems" (Contract Report No. OSU83-00131).

TITLE: MAINTENANCE MANAGEMENT IN THE CANADIAN MINING INDUSTRY - AN EXECUTIVE SUMMARY

CONTRACTOR:	Queen's University	FILE NUMBER:	3-9094-1	FUNDING	
		BEGIN/END:	Aug. 84/Nov. 84		
				CANMET:	$ 12 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	L.B. Geller	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 12 000

OBJECTIVES

Over the past few decades, the cost of maintenance in mining operations has risen dramatically and currently represents the largest single cost category in most operating budgets. To facilitate improvements in this area, CANMET undertook a state-of-the-art review of maintenance in Canadian mines. Although both technical and managerial aspects were considered, it was clear early in the work that shortcomings existed in the management of maintenance systems. The report focusses on these shortcomings.

PROCEDURE

For the subject review, the total literature on maintenance was first examined in detail so as to develop a framework within which mine maintenance operations could be examined. Subsequently, twelve mining operations across Canada were selected to provide a representative sample of the industry on the basis of geography, scale, commodity, and type of operation. Each was visited or examined in some detail. In the process, both the framework devised for the analysis and the state of maintenance operations in the industry were evaluated.

The framework selected divided the numerous aspects of maintenance into two major categories: (1) Supporting elements, which improve the effectiveness of a maintenance system but are not essential to its operation, and (2) Essential elements, without which a rational system cannot exist. In addition, three supporting features that can contribute greatly to effectiveness were also considered: computing, analytic techniques, and system implementation.

RESULTS

The results of the review represent the industry's own view of its operations as seen in light of the overall framework that was developed. This framework, and the respective survey results, can be summarized as follows:

The conclusion is inescapable that the Canadian mining industry has considerable room for improvement of its maintenance operations, particularly as regards some of the management aspects.

Much of the improvement that could be suggested would deal with matters that are exclusively the responsibility of the individual companies, as opposed to systems and hardware-oriented improvements that could be purchased or injected by outsiders.

Moreover, the scope for improvement in mine maintenance systems does not include maintenance operations alone; changes are indicated at all levels from corporate offices to the maintenance job.

SUPPORTING DOCUMENTS

Final Report: "Maintenance Management in the Canadian Mining Industry - An Executive Summary" (Contract Report No. OST84-00260).

TITLE: ALTERNATIVES TO PRESENT POTASH MINING PRACTICES IN CANADA

CONTRACTOR:	Montreal Engineering Co. Ltd.	FILE NUMBER:	3-9124	FUNDING	
		BEGIN/END:	Nov. 83/Jan. 85		
				CANMET:	$ 53 864
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Dr. J. Pathak	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 53 864

OBJECTIVES

Carry out a study that will identify alternatives to methods used at present in Canada to mine potash or salt. Options that might provide lower cost mining or an improved extraction ratio need to be explored.

PROCEDURE

1. Review potash-mining practice around the world with descriptions of geological setting, overburden thickness and quantity, ground control concerns, production, productivity, and costs.

2. Identify major parameters for and against the use of alternate mining methods in Canada.

3. Outline geotechnical program for implementation of alternate methods.

RESULTS

The study indicates that the present potash mining methods in Saskatchewan could be changed from the room and pillar methods to shortwall mining, or possibly longwall mining methods incorporating backfill and/or yielding pillars.

Alternate mining methods could improve mining recovery, increase production and productivity, reduce costs, and improve safety.

APPLICATION AND ONGOING WORK

The report recommends detailed study of the following alternatives:

1. Shortwall Retreat Mining
   - with backfill
   - with yielding pillars
   - with backfill and yielding pillars.

2. Longwall Retreat Mining
   - with backfill
   - with caving.

SUPPORTING DOCUMENTS

Final Report: "Alternatives to Present Potash Mining Practice in Canada".

TITLE: COMPUTER BLAST DESIGN FOR LARGE DIAMETER BLASTHOLE STOPES UNDERGROUND

CONTRACTOR:	Mining Resource Engineering Limited	FILE NUMBER:	3-9186	FUNDING	
		BEGIN/END:	Nov. 83/Jan. 85		
				CANMET:	$ 50 751
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining Technology	OTHER:	--
AUTHORITY:	Dr. J. Pathak	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 50 751

OBJECTIVES

Current efforts in the development of new, higher productivity technology for underground hardrock mining are centered on large-diameter blasthole stoping.

The objective of the computer program was to minimize the effect of hole deviation and give better fragmentation at lower cost by optimizing blast design using computer simulation. The program will also generate reports, bill of materials, and plans and sections of drilled-off blocks that were previously done manually.

PROCEDURE

The procedure is based on modern theories of rock breakage by explosives, computer simulation, and graphics.

RESULTS

A program has been developed using modern theories on rock breakage by explosives. It simulates a blast for a particular blasthole drill pattern and explosive loading with appropriate delays. The graphics program gives the breakage pattern corresponding to the assumed blast design.

APPLICATION AND ONGOING WORK

The program has been developed based on theoretical work on blasting, but it has still to be tested underground. The program will be tested under a separate contract.

SUPPORTING DOCUMENTS

Final report: "Computer Blast Design for Large Diameter Blasthole Stopes Underground".

TITLE: INVESTIGATION OF COMPUTER SOFTWARE AND HARDWARE IN SURFACE AND UNDERGROUND MINING IN CANADA

				FUNDING	
CONTRACTOR:	H.A. Simons (International) Ltd.	FILE NUMBER:	3-9202		
		BEGIN/END:	March 84/April 85		
				CANMET:	$ 72 550
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	R. Boyle	TECHNOLOGY:	Mining Methods and	TOTAL:	$ 72 550
	V. Srajer		Equipment		

OBJECTIVES

1. Provide information on in-house computer software and hardware used in the Canadian mining industry.
2. Identify computer software available on the international market compatible with Canadian mining conditions.
3. Identify current R&D in computer software for underground and surface mining.
4. Identify short- and long-term needs for computer software development for underground and surface mining.

PROCEDURE

1. List of addresses of mining companies, R&D institutions (universities, government).
2. Design of a questionnaire to meet the contract objectives.
3. Compilation and analysis of received questionnaires.
4. Visits to certain participants.

RESULTS

One hundred and ninety-eight responses from 781 questionnaires are represented in various charts, figures, and tables providing information on software and hardware available and in use by Canadian mining industries.

APPLICATION AND ONGOING WORK

Presentation of results to the mining industries in certain Canadian cities.

TITLE: CANADIAN MINING INDUSTRY CAPITAL AND OPERATING COST INDICES (OPEN PIT AND UNDERGROUND)

CONTRACTOR:	Dynatec Mining Ltd.	FILE NUMBER:	4-9136	FUNDING	
		BEGIN/END:	Jan. 85/March 85		
				CANMET:	$ 33 796
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	R. Clarke	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 33 796

OBJECTIVES

The objective of this project was to develop an operating budget typical of a low- to medium-tonnage producing mine.

PROCEDURE

The contractor based his report on a feasibility study undertaken previously for a 2500 ton per day (2265 tonne/day) gold mine. The owners of the gold mine, currently being developed, agreed to the release of the basic data and reviewed the report. One other mining company also reviewed the report.

RESULTS

The contract resulted in a report containing operating costs for a producing mine, supported by the necessary detail cost and productivity elements. The report also contains a summarized listing of capital costs for mine plant, equipment, and development.

APPLICATION AND ONGOING WORK

The contract will be followed up by the design of a computer program, using data files provided by Dynatec, to evaluate various mine-operating scenarios.

TITLE: REVISION OF THE MONITORING CHAPTER OF THE PIT SLOPE MANUAL

				FUNDING	
CONTRACTOR:	Franklin Trow and Associates	FILE NUMBER:	8-9138		
		BEGIN/END:	June 79/March 80		
				CANMET:	$ 14 918
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	D.G.F. Hedley	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 14 918

OBJECTIVES

1. Review existing monitoring chapter.
2. Condense chapter to 1/3-1/2 of its present length, concentrating on those measuring systems in successful use in Canadian open pit mines.
3. Make specific recommendations on selection of measuring systems.
4. Include section of case histories.

PROCEDURE

1. Questionnaire sent to open pit mines to gather information on monitoring systems in use. Summaries compiled on each mine for inclusion in case histories section.
2. Review of recent literature to update information in present monitoring chapter.

RESULTS

The revised chapter includes sections on:

- Methods and Instruments
- Planning and Execution of the Monitoring Program
- Case Histories on:
  - 8 Canadian open pit mines
  - 3 Foreign open pit mines
- Selected Instrumentation for Monitoring in Open Pits

APPLICATION AND ONGOING WORK

Complements existing Monitoring chapter of the Pit Slope Manual. Both versions should be integrated in a new chapter.

SUPPORTING DOCUMENTS

Final report: "Pit Slope Manual", Chapter 8, Monitoring (Revised).

TITLE: REWRITE PERIMETER BLASTING CHAPTER, PIT SLOPE MANUAL

CONTRACTOR: Queen's University	FILE NUMBER: 0-9069	FUNDING	
	BEGIN/END: Sept. 80/Aug. 81		
		CANMET:	$ 20 835
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: G.E. Larocque	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 20 835

OBJECTIVES

Write a replacement chapter for Perimeter Blasting Chapter, Pit Slope Manual.

RESULTS

A draft chapter has been prepared and revised. The contract is essentially complete.

PROCEDURE

New material developed by Queen's is to be incorporated into a revised chapter.

TITLE: DEVELOPMENT OF A PORTABLE VIEWING SYSTEM FOR BOREHOLE LOGGING

CONTRACTOR: Diamond Canapower Ltd.	FILE NUMBER: 9-9025	FUNDING	
	BEGIN/END: Nov. 79/July 81		
		CANMET:	$ 29 093
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: G. Herget	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 29 093

OBJECTIVES

1. Improve borehole inspection and evaluation for roof and pillar assessment in underground excavations.

2. Design and produce a portable viewing system for borehole logging.

PROCEDURE

A small-diameter TV camera (Arvin Diamond ST-6 TV camera, O.D. 29 mm) with 800 lines resolution was fitted with a rotating right angle viewing attachment and was used for inspection of EX (38 mm) boreholes in the back of a slope.

RESULTS

Field evaluation proved very successful. The TV camera allowed, for the first time, the assessment of fracture location, frequency, and type in bolt holes of underground excavations.

The final report contains a description of equipment and first experiences from underground testing.

APPLICATION AND ONGOING WORK

The TV camera has been used at mine sites in Elliot Lake and Sudbury. Following CANMET's development, Ontario Hydro and University of Kentucky, Lexington have purchased similar equipment.

SUPPORTING DOCUMENTS

Final Report: "The ST-6 Borehole TV System", by G. Herget; Division Report MRP/MRL 81-122(TR); October 1981.

TITLE: ROCK PERMEABILITY OF ROOF STRATA IN TEST STOPES

CONTRACTOR: V. de Korompay	FILE NUMBER: 1-9093	FUNDING	
	BEGIN/END: Nov. 81/June 82		
		CANMET:	$ 24 275
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: D.G.F. Hedley	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 24 275

OBJECTIVES

1. Develop instrumentation and methodology to measure rock permeability.

2. Measure fracture location, width, and areal extent in roof strata and monitor the change as the roof bolt support system is removed.

PROCEDURE

1. A straddle packer and single packer system were developed to seal a borehole to which a vacuum was then applied. The air flow and pressure over time in the borehole were used to calculate rock permeability.

2. In two test stopes, the boreholes were surveyed using the straddle packer system. Vacuum was applied to sequential intervals of each borehole to determine location and width of open fractures. Areal extent was determined by applying a vacuum to one borehole and measuring any effects on surrounding boreholes.

3. Single packers were installed in each borehole prior to removing, in stages, the rock bolt supports.

RESULTS

1. In three underground openings, the first 1 m was fractured due to blasting.

2. The technique accurately locates open fractures 0.5 to 1.0 mm in width, 6 to 8 m in the rock mass. Boreholes were also surveyed with a TV camera with good correlation.

3. Fracture continuity was measured in boreholes 10 m apart.

4. In situ permeability as low as 0.002 m was measured.

5. During removal of the rock bolts, increased permeability and areal extent of open fractures was measured, although no large roof falls occurred.

SUPPORTING DOCUMENTS

Final Report: "Rock Permeability of Roof Strata" (CANMET Service Contract No. 1495893).

TITLE: INVESTIGATION OF THE SIZE AND STABILITY OF SURFACE CROWN PILLARS

CONTRACTOR: Roche Associés Ltée	FILE NUMBER: 3-9005	FUNDING	
	BEGIN/END: April 83/Feb. 84		
		CANMET:	--
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	DSS:	$ 116 629
AUTHORITY: M. Bétournay	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 116 629

OBJECTIVES

Report on the condition (particularly stability) of surface crown pillars existing in Canadian mines, prompted by the lack of information dealing with the stability aspects of surface crown pillars and the 1982 Belmoral mine accident.

PROCEDURE

1. Review the crown pillar subjects exposed in the published literature (particularly in regards to stability).

2. Prepare a set of cases representative of the type and condition of Canadian surface crown pillars, based on six mine visits.

3. Establish a classification system for surface crown pillars and general design guidelines based on existing classification systems and procedures used in the industry.

4. Define research requirements to develop improved guidelines for the design of surface crown pillars.

RESULTS

1. The bibliographic research has pointed out the limited published information on surface crown pillars and the absence of sources that could act as all encompassing references for design purposes.

2. The six mines visited (five in Quebec, one in Ontario) presented a very good cross-section of surface crown pillar types and existing conditions affecting them.

3. A breakdown of the nature and emphasis of work carried out on surface crown pillars at every site permitted a true evaluation of each site's program to design and evaluate the stability of the crown pillars.

4. Roche also established a suggested procedure for the design of surface crown pillars.

APPLICATION AND ONGOING WORK

An extension of $8 000 to the contract will permit Roche to formulate a proposal for the following stage of work: a guide for the design of crown pillars for Canadian mines. Every member of the consulting committee realizes the necessity for such a guide.

SUPPORTING DOCUMENTS

Final Report: "Piliers de Surface" (Surface Crown Pillars).

TITLE: STUDY TO DEVELOP AND BUILD A BOREHOLE DILATOMETER

CONTRACTOR: University of Alberta	FILE NUMBER: O-9099	FUNDING	
	BEGIN/END: May 81/July 81		
		CANMET:	$ 8 394
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: Dr. G. Herget	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 8 394

OBJECTIVES

Determination of the strength and deformation characteristics of cured backfill is important for the assessment of the contribution of backfill to the stabilization of mined-out areas.

In the past, various attempts had been made to sample cured backfill to a depth of about 50 m with special drilling, Shelby tube, and split spoon sampling, but the rates of success were rather disappointing. In-the-hole testing appeared to be the only alternative and a borehole unit was developed that is based on the Ménard pressuremeter principle.

PROCEDURE

A prototype was built, based on previous experience with similar equipment, at the University of Alberta and tested with university personnel in Nordic tailings, Elliot Lake.

RESULTS

A 115-mm diameter borehole dilatometer was built to determine in situ deformation modulus and strength of backfill in mined stopes. The equipment is described and testing procedures are listed in the report.

APPLICATION AND ONGOING WORK

The equipment is being used for testing backfill in mines of Inco Metals Co., Coppercliff, Ontario.

SUPPORTING DOCUMENTS

Final Report: "Borehole Dilatometer for Backfill Studies", by G. Herget; Division Report MRP/MRL 82-2(TR); December 1981.

TITLE: BEHAVIOUR OF FROZEN BACKFILL IN UNDERGROUND MINES

CONTRACTOR:	Nantar Engineering Limited	FILE NUMBER:	2-9121	FUNDING	
		BEGIN/END:	Oct. 82/Aug. 83		
				CANMET:	$ 2 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M. Gyenge	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 2 000

OBJECTIVES

Conduct a series of laboratory measurements to determine important physical and mechanical properties pertaining to frozen tailings to be used as backfill material in underground mines, operating in cold environments where permafrost may be encountered.

PROCEDURE

1. Representative samples of tailings materials were obtained from: Chadbourne Mine, Matagami Mine, and Denison Mine.

2. The following properties of each tailings material were established:
   a) size distribution
   b) specific gravity of solids
   c) shape of particles
   d) bulk densities and porosity.

3. A series of tests with frozen tailings material were conducted in order to:
   a) determine the optimum water content versus strength of the frozen tailings
   b) establish the optimum balling conditions to pelletize the tailings material on a balling disk
   c) determine the uniaxial compressive strength of frozen pellet mass on specimens moulded under simulated conditions of self-weight compaction of pellets in a stope.

RESULTS

The results of this investigation indicate that frozen tailings exhibit remarkable strength properties. A mixture of 75% tailings and 25% (by water weight) has a uniaxial compressive strength nearly double that of non-frozen backfill at 5:1 sand-cement ratio. The frozen pelletized backfill that has been consolidated to 900 kPa exhibits higher uniaxial compressive strength than a non-frozen fill with a ratio of sand-cement of 10:1.

Based on the short-term strength of frozen tailings materials, it is realistic to envisage the use of such backfill materials in mines located in zones of permafrost. A scenario involving frozen pellets fabricated with mill tailings, in such a backfill operation, is given.

It is recommended, considering the encouraging results obtained with the completed short-term strength tests, investigating the time dependent deformation properties of frozen backfill. These data are essential to analyze the stability of backfill-free faces composed of frozen backfill.

APPLICATION AND ONGOING WORK

The Canadian North covers a very large territory and potentially contains a large number of mineral deposits. When compared with other areas of the world, the possibility of mining in permafrost zones is imminent. The understanding of concepts related to mining activities in sub-zero frozen ground materials is a matter of great importance.

Frozen tailings material has never been used to backfill underground openings in Canadian mines. The Polaris Mine situated on Little Cornwallis Island, N.W.T., is investigating the use of frozen backfill.

SUPPORTING DOCUMENTS

Final report: "The Behaviour of Frozen Backfill in Underground Mines".

TITLE: TIME DEPENDENT BEHAVIOUR OF FROZEN PELLETIZED TAILINGS IN UNDERGROUND MINES

CONTRACTOR: Nantar Engineering Ltd.	FILE NUMBER: 4-9129	FUNDING	
	BEGIN/END: July 84/July 85		
		CANMET:	$ 41 850
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: M. Gyenge	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 41 850

OBJECTIVES

Conduct a series of laboratory measurements to determine the long-term physical and mechanical properties of frozen pelletized tailings to be used as backfill material in underground mines, operating in cold environments where permafrost may be encountered.

PROCEDURE

1. (a) Procure mine tailings from three selected mines.

   (b) Measure physical properties of the materials.

2. Conduct tests to establish limiting strength conditions.

3. Conduct creep tests to determine the failure, and the strength and deformation behaviours, of both frozen slurry and frozen pelletized tailings.

4. Analyze the support capabilities of frozen fill.

5. Prepare final report.

RESULTS

The tailings materials were obtained from three Canadian gold and base metal mines. The initial characterization tests were followed by short-term strength tests. The instantaneous unconfined compression strength results indicate a much lower strength for frozen pelletized samples than for frozen slurried tailings.

The constant load tests (creep tests) were performed in two distinct phases in order to simulate mine conditions. In the first phase, samples were tested in confined conditions to simulate full stope confinement. Confined tests were continued until constant deformation-time rates were obtained. Then, in the second phase, confinement was released to simulate pillar extraction.

It is concluded that frozen pelletized mine tailings is not a competent backfill material if the recovery of pillars is contemplated. Frozen slurried tailings could remain exposed over heights reaching 75 m; however, the placement and in situ freezing of such material would present several technical difficulties.

APPLICATION AND ONGOING WORK

Mining in a permafrost environment poses numerous technical questions that cannot be answered due to lack of knowledge and experience. Consequently, related research is important for the future development of mining technology in the Canadian Arctic.

The results of this completed research work are disappointing.

SUPPORTING DOCUMENTS

Final report: "Time Dependent Behaviour of Frozen Pelletized Tailings in Underground Mines".

TITLE: ASSESSMENT OF POSSIBLE PROBLEMS IN REGIONAL MINE STABILITY WITH FUTURE MINING OF SASKATCHEWAN POTASH

CONTRACTOR:	Potash Corporation of Saskatchewan Mining Ltd.	FILE NUMBER:	3-9125	FUNDING	
		BEGIN/END:	Jan. 84/Jan. 85		
				CANMET:	$ 89 879
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M. Gyenge	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 89 879

OBJECTIVES

Establish the geotechnical database required to assess possible long-term regional stability problems in Saskatchewan potash mining and the potential benefits (higher extraction ratio, improved productivity) to be achieved using backfill or other options.

PROCEDURE

The participants in the contract, on a joint venture basis, were:

1. Earth Science Section; Engineering Department of PCS Mining.
2. The four potash mines operated by PCS Mining, namely: Allen Division, Cory Division, Lanigan Division, and Rocanville Division.
3. Central Canada Potash Division of Noranda Mines Ltd.
4. Noranda Research Centre.

The data available at each of the participating mines were obtained by a series of questionnaires and by direct interviews with the technical staff. The contract management was provided by a committee formed by representatives of the participating organizations.

Under the direction of the Project Leader, the data compilation and analysis were performed within the Engineering Department of PCS Mining and the Noranda Research Centre.

RESULTS

The project has been successful in achieving its objective within the limits imposed by the quantity and quality of the geotechnical data available. The project has identified specific areas where research and development are required to ensure long-term regional mine stability in the Saskatchewan potash mining industry. Areas where insufficient data are available to determine if a problem exists or may develop in the future have been identified, and the requirements for further research and development of instruments and techniques have been outlined.

The subsidence data were collected from five producing potash mines. The data indicate that subsidence tends to be time dependent. The plastic nature and low strength of the evaporites cause subsidence to occur in two stages: an initial contribution occurs at some time after first mining, followed by a constant subsidence rate. The functions relating initial and steady-state subsidence of a point overlying an excavation were found to correlate to extraction through an influence function. A computer program was developed to predict subsidence using a zone area method of influence function. The results show a reasonable correlation to field measurements.

APPLICATION AND ONGOING WORK

A two-year research program has been funded under START (Short Term Aid to Industry for Research and Technology). This contract was one of the eight contracts with the potash industry.

The results of the completed program are applicable to the entire potash industry. At present, technology transfer is taking place. A "Workshop on Subsidence Due to Mining of Soft Rock", organized by the industry, was held in November 1985, in Saskatoon.

SUPPORTING DOCUMENTS

Final report: "Assessment of Possible Problems in Regional Mine Stability with Future Mining of Saskatchewan Potash".

TITLE: EVALUATION AND LABORATORY TESTING OF LARGE EVAPORITE SAMPLES

CONTRACTOR:	Saskatchewan Research Council	FILE NUMBER:	3-9126	FUNDING	
		BEGIN/END:	Oct. 83/Nov. 84		
				CANMET:	$ 39 940
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	L. Geller	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 39 940

OBJECTIVES

Test, evaluate, and bring into full operation one of the ten existing large sample (200-mm diameter x 400-mm long) triaxial creep test pressure cells owned by the Saskatchewan Research Council, Saskatoon.

PROCEDURE

1. Refurbish one of the ten existing cells.
2. Prepare a 200-mm x 400-mm aluminum test piece.
3. Prepare a number of 200-mm x 400-mm evaporite test pieces.
4. Run pressure tests on the refurbished cell.
5. Run triaxial creep tests.

RESULTS

All major objectives have been satisfactorily achieved. One cell is now fully operational. The facility has also been evaluated as a practical and versatile research tool for resource-based industries, in particular, for coarsely crystalline rocks, coarsely granular tailings and fills, and fractured rocks and soils.

APPLICATION AND ONGOING WORK

The most obvious applications include:

1. Evaporate mines.
2. Mine tailings and backfill testing.
3. Open pit mines.
4. Heavy oil industry.

No ongoing work at present.

SUPPORTING DOCUMENTS

Final Report: "Creep Cell Evaluation and Laboratory Testing of Large Evaporite Samples".

TITLE: DETERMINATION OF ENGINEERING PROPERTIES OF WASTE SALT FOR BACKFILLING IN UNDERGROUND POTASH MINES

CONTRACTOR:	RE/SPEC Ltd.	FILE NUMBER:	3-9205	FUNDING	
		BEGIN/END:	Jan. 84/Sept. 84		
				CANMET:	$ 28 672
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M. Bétournay	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 28 672

OBJECTIVES

Establish waste salt characteristics (especially strength) applicable to the use of waste salt as underground backfill.

PROCEDURE

Review the documented research on crushed salt backfill. Using waste salt tailings, test samples of varying moisture content. Suject the samples to consolidation or creep tests, using loads from 0.035 MPa to 25 MPa. Post-test characterization of the specimens included uniaxial or triaxial testing, as well as density, porosity, and water content measurements. Mineralogy and particle characteristics were also examined.

RESULTS

1. Under quasi-static consolidation tests, the specimen's final density is not influenced by moisture content. No unconfined strength is produced.
2. Under creep tests, there is a rapid gain in strength, high permeability, and rapid loss of moisture. A void ratio of 12% exists after 28 days of loading.
3. Strength tests have shown that there is no significant development of strength unless samples have crept. The Mohr-Coulomb criterion applies only at low stress. After creeping, particle fusion allows strength to approach that of solid salt.

APPLICATION AND ONGOING WORK

Results valid to apply to in situ backfill testing. Further work could concentrate on a better failure criterion than Mohr's, for application to test results.

SUPPORTING DOCUMENTS

Final Report: "Determination of Engineering Properties of Waste Salt for Backfilling in Underground Potash Mines".

TITLE: COLLECTION AND EVALUATION OF FIELD DATA AROUND EXCAVATIONS IN POTASH TO EVALUATE EXCAVATION PERFORMANCE OR CONCEPTS FOR NEW MINING LAYOUTS

CONTRACTOR:	Cominco Ltd.	FILE NUMBER:	3-9206-2	FUNDING	
		BEGIN/END:	March 84/March 85		
				CANMET:	$ 31 441
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	51 441
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Dr. G. Herget	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 82 882

OBJECTIVES

Determine the absolute convergence and ground stress distribution around potash mine openings with time.

PROCEDURE

Installation of field instrumentation, monitoring, and analysis.

RESULTS

Twenty-one per cent of total room closure is due to roof subsidence.

At a depth of 100 m, abutment wall rock is instrumented to a depth of 61 m for stress monitoring, and yield pillars were instrumented throughout their total width. Excellent strain distribution patterns and total expansion records were obtained.

APPLICATION AND ONGOING WORK

The field data collected will be compared to results from numerical modelling and laboratory testing of evaporite strata. Additional work is being planned with the above contractor, subject to available funding.

TITLE: DEVELOPMENT OF A NUMERICAL MODELLING PACKAGE FOR DESIGNING UNDERGROUND OPENINGS IN POTASH

CONTRACTOR: RE/SPEC Ltd.	FILE NUMBER: 3-9155	FUNDING	
	BEGIN/END: Jan. 84/March 85		
		CANMET:	$ 52 094
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: Y.S. Yu	TECHNOLOGY: Rock Mechanics	TOTAL:	$ 52 094

OBJECTIVES

Develop a numerical modelling software package that can accurately model the visco-elastic behaviour of underground potash mines.

This software package would provide a tool for quantitative assessment of stability, and hence safety, of proposed new mining layouts. It shall be capable of modelling complex mine geometrics and mining sequences such as excavation and/or backfilling; identifying convergence, convergence rate, and ground stresses resulting from mining; and shall contain a suitable failure criterion.

PROCEDURE

1. Conduct a review of the failure criteria and constitutive laws that are used to describe the visco-elastic behaviour of potash/salt material and define the most appropriate ones.

2. Develop a numerical model based on the finite element technique and incorporate the most suitable constitutive relationship for the visco-elastic material.

3. Prepare users' manual including testing examples, verification of the program, and pre- and post-processors.

RESULTS

GEOROC is the software package resulting from this contract research. It is a large and sophisticated finite element stress analysis program that can analyze a wide range of potash and other underground mining problems.

Complex mining geometrics and varied excavation sequences can be modelled. Elastic and/or visco-elastic materials with complex geologic stratification can be simulated.

A mesh generator program (GEOMESH) and three post-processors (sub programs) are also included.

APPLICATION AND ONGOING WORK

GEOROC is a powerful and sophisticated stress analysis tool that has application not only in the potash industry but in a broad range of underground mining and engineering situations. It is recommended that continued evolution of GEOROC be implemented to increase its capabilities and improve its computational efficiency. It is also recommended that a detailed study of a Saskatchewan potash mine be undertaken in which GEOROC analyses are integrated with laboratory-derived material properties and with underground closure and stress data.

SUPPORTING DOCUMENTS

Final Report: "GEOROC: A Numerical Modelling Package for Designing Underground Openings in Potash".

TITLE: FEASIBILITY OF THE ACQUISITION AND DEVELOPMENT OF A CANADIAN MINES ATMOSPHERE MONITORING LABORATORY

CONTRACTOR: Professor J.H. Johnson	FILE NUMBER: 1-9004	FUNDING	
	BEGIN/END: June 81/March 82		
		CANMET:	$ 26 474
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: P. Mogan	TECHNOLOGY: Mine Environment	TOTAL:	$ 26 474

OBJECTIVES

Determine the feasibility of constructing and operating a Canadian Mines Atmosphere Monitoring Laboratory (MAML) similar to the facility funded by the U.S. Bureau of Mines, and operated by Professor Johnson at Michigan Technological University.

PROCEDURE

Contact Canadian mining companies, universities, government agencies, and equipment fabricators to determine the configuration and approximate cost of a MAML, and identify potential constructors and institutions with the appropriate infrastructure to support research with the MAML.

RESULTS

A trailer of maximum size 304 x 142 cm, 198 cm high was proposed. Eight gas sample lines and one particulate sample line would convey mine ambient air to the trailer from a variety of sites. Instrumental analyzers were recommended for carbon monoxide, carbon dioxide, nitrogen dioxide, nitric oxide, sulphur dioxide, and particulates in the ambient mine atmosphere. Sample sequencing, data acquisition and processing would be carried out by an on-board microcomputer.

Four Canadian constructors with the capability to build the MAML were located. One research organization and two universities with the capability to provide the infrastructure to operate the MAML were identified. The cost of the MAML was estimated at $230 000.

APPLICATION AND ONGOING WORK

A post-contract questionnaire to mining industry and provincial government sources ascertained that only three of seventeen respondents supported acquisition of a MAML at $230 000. Eleven respondents, however, endorsed the concept of a less elaborate "suitcase" underground monitoring package. This has proceeded under contract 2-9114, "Development of a Portable Underground Environment Air Quality Monitoring System". The "suitcase" system has now been scheduled for underground ambient monitoring in four Canadian mines.

SUPPORTING DOCUMENTS

Final Report: "The Feasibility of the Acquisition and Deployment of a Canadian Mines Atmosphere Monitoring Laboratory", by John H. Johnson and Mark Schimmelman.

TITLE: DEVELOPMENT OF A PORTABLE UNDERGROUND ENVIRONMENT AIR QUALITY MONITORING SYSTEM

CONTRACTOR: Prof. J. Johnson	FILE NUMBER: 2-9114	FUNDING	
	BEGIN/END: Oct. 82/March 83		
		CANMET:	$ 78 945
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: E.D. Dainty	TECHNOLOGY: Mine Environment	TOTAL:	$ 78 945

OBJECTIVES

Development of portable analytical instrumentation to determine the several toxic constituents of diesel exhaust in the underground environment in order to assess the Air Quality Index (AQI).

PROCEDURE

1. Survey existing analytical equipment of CO, CO_2, NO, NO_2, and particulate matter, and choose the best conditions.
2. Modify as necessary and adapt the successful candidates for portability.
3. Bench test the equipment to assure proper operation.
4. Deliver system to CANMET.

RESULTS

The instrumentation chosen is summarized as follows:

CO - Ecolyzer 2106
NO - Ecolyzer 7230
NO_2 - Ecolyzer 7230
CO_2 - Fuji ZFP5
Soot - Gravimetric dust-sampling system including 8 components, among which is a Perkin-Elmer AD-2B electronic micro-balance.

These and the accompanying equipment were bench performance tested as described in detail in the contract report. The instrumentation proved to be stable within the general limits for such analytical equipment.

APPLICATION AND ONGOING WORK

There is already considerable interest in the use of this package by the private sector to determine the AQI of dieselized headings underground. A collaborative CANMET/COMINCO project is slated to start in August of 1983. It is likely that this system will check the performance of a regenerating exhaust filter underground from December 1983 to February 1984, operating in the Inco Copper-cliff mine.

SUPPORTING DOCUMENTS

"Development of a Portable Underground Environment Air Quality System", by D.H. Carlson and J. Johnson of Michigan Technological University.

TITLE: IMPLICATIONS FOR UNDERGROUND MINING OF THE RECENT U.S. DIESEL HEALTH EFFECTS RESEARCH

CONTRACTOR:	Ian W. French & Associates Ltd.	FILE NUMBER:	1-9003/2-9062	FUNDING	
		BEGIN/END:	Sept. 82/March 84		
				CANMET:	$ 30 291
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 30 291

OBJECTIVES

In 1978-79, Ian French & Associates surveyed the literature on the health effects of diesel exhaust and assessed the relevance of their findings to the heavily dieselized Canadian underground mining industry. Because of the perceived impending dieselization of a significant portion of the U.S. passenger car fleet, a huge diesel health effects research program was begun in the U.S. This provided the opportunity for Ian French & Associates to assess the implications of this new work, and to revise the original recommendations accordingly.

PROCEDURE

Study the literature, attend symposia, contact research personnel, and visit laboratories engaged in the U.S. diesel automotive health effects research program. Analyze the information acquired for its relevance to Canadian underground dieselized mining, and revise the recommendations of Contract 6-90995 "Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions" accordingly.

RESULTS

The contractors have issued an updated version of the original study "Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions". As before, they have dealt with the health effects and exposure of each of the constituents of diesel exhaust, both alone, and in combination with other substances. They have provided a comprehensive synopsis of the new information that has become available since the previous contract, and analyzed the implications for dieselized underground mining. The information on diesel particulates emerging from the U.S. passenger car work, is the most dramatic new contribution, expanding from 20 pages in the original version to 170 in the new document.

Few actual diesel exposure studies were available prior to 1977, so the original recommendations were based primarily on indirect evidence. The extent to which these recommendations (including the formulation of a new diesel exposure criterion, the Air Quality Index, or AQI) are reinforced by the findings of the updated study, is a tribute to the thoroughness and expertise that the contractors applied to the 1977 study.

APPLICATION AND ONGOING WORK

Quantification of the effects of emission control strategies, underground environment assays, etc. carried out under several contracts (USBM/MOL/CANMET Collaborative Research Program, for example) has been made possible by the "Air Quality Index" developed with this contract. Two seminars to transfer the contractors' findings to the mining industry are planned. Also, the results of the USBM/NIOSH monkey exposure study (to coal dust and diesel exhaust) were not available in time for inclusion in the current document. The results of this extremely relevant study should thus be reviewed by the contractors to determine the implications for Canadian underground dieselized mining.

SUPPORTING DOCUMENTS

Final Report: "Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions", by Ian W. French & Associates Limited, April 1984 - 607 pages.

TITLE: TRANSFER OF THE FINDINGS OF THE DIESEL HEALTH EFFECTS PROJECT TO THE CANADIAN MINING INDUSTRY

CONTRACTOR:	Ian W. French & Associates Ltd.	FILE NUMBER:	4-9225	FUNDING	
		BEGIN/END:	Oct. 84/March 85		
				CANMET:	$ 12 744
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 12 744

OBJECTIVES

Transfer the findings of Contract No. 2-9062 (Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions - An Update) to the Canadian mining industry (mine operators, unions, provincial regulatory bodies, and mining associations).

PROCEDURE

One-day seminars were presented in Toronto and Vancouver.

RESULTS

Representatives of all of the mining companies with significant numbers of diesels underground, their unions, several Provincial mining associations, a number of American government agencies and private mining concerns, and the majority of Provincial regulatory agencies attended the seminars.

APPLICATION AND ONGOING WORK

The seminars provided the attendees with an understanding of the AQI/EQI concept. This concept is the basis for any cost savings accruing from the diesel emissions reduction program.

SUPPORTING DOCUMENTS

"Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions", by Ian W. French and Associates Limited (Contract No. 2-9062).

TITLE: METHODOLOGY DEVELOPMENT FOR AMES TESTING OF DIESEL EXHAUST PARTICULATES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	9-9178	FUNDING	
		BEGIN/END:	June 80/April 81		
				CANMET:	$ 12 408
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	DSS:	86 485
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 98 893

OBJECTIVES

Develop the appropriate sampling and assay procedure for determination of the mutagenic activity of extracts of diesel soot from engines and catalytic purifiers in common use in Canadian underground mines. Sampling procedures for the purifier-equipped engines are particularly critical because of potential sampling artifact formation.

PROCEDURE

Sample untreated, and PTX catalyst treated, diesel soot from a Deutz F6L-714 engine, using:

1. Undiluted exhaust on rapidly changed 47-mm pallflex filters to minimize the contact time of the collected soot with the exhaust gas and thereby minimize sampling artifacts.

2. Undiluted exhaust gas on 125-cm pallflex filters.

3. Diluted exhaust gas from a 10 cm dilution tube at 9:1, 13:1, and 16:1 dilution ratio, on 20 by 25 cm pallflex filters.

Determine appropriate extraction, storage, and assay procedures for a five-strain Ames Salmonella bioassay.

RESULTS

Unfortunately, too much organic soluble material (SOF) remained in the probe ahead of the 47-mm filters, so that baseline (minimal artifact) values for the specific mutagenicity could not be determined.

The standard extraction procedure with dichloromethane (DCM), followed by solvent exchange with dimethyl sulphoxide was found appropriate. Sulphate present on the filters from the catalytically treated exhaust was removed in iso-propyl alcohol after the DCM extraction to permit determination of the insoluble fraction.

Both catalytically treated and untreated soot extracts were found to be non-mutagenic with TA1535, somewhat mutagenic with TA1537, and most mutagenic with TA1538 and TA98. Non-treated soot exhibited increasing activity as the dilution ratio decreased, indicating that artifact activity was present at least up to the 16:1 dilution level. The catalytically treated soot, surprisingly, showed diminished activity as the dilution ratio decreased, suggesting that the sulphation reaction competes with the nitration reaction to produce non-mutagenic substitution products. This conjecture is consistent with the weak mutagenic response of TA100 found with only the 16:1 dilution. The results showed that further work with underground engines and catalysts should be confined to the TA98 strain, with at least 16:1 sample dilution. The toxic dose of extract appeared to occur around the 1500-µg level.

APPLICATION AND ONGOING WORK

The methodology developed here has been applied to the assay of soot samples from underground mines with similar diesel equipment, and to the determination of the effects of fuels and novel emission control strategies on mutagen levels.

SUPPORTING DOCUMENTS

Final Report: "A Study of the Sampling and Assay Methodology Necessary to Determine the Mutagenic Potential of Diesel Exhaust Particulate by Ames Salmonella Bioassay", by A. Lawson, H. Veergeer, W.A. Drummond, D.K. Smith, A.J. Horton, and N. Belson.

TITLE: QUANTITATIVE ASSESSMENT OF POLYNUCLEAR AROMATIC HYDROCARBON LEVELS IN UNDERGROUND MINES - PHASE 5

CONTRACTOR:	Laurentian University	FILE NUMBER:	1-9052	FUNDING	
		BEGIN/END:	July 81/March 82		
				CANMET:	$ 35 792
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 35 792

OBJECTIVES

Expand the database on the levels of polynuclear aromatic hydrocarbons (PAH) found in the ambient mine atmosphere in the vicinity of diesel machinery for both treated and untreated exhaust. In addition, establish the influence of other sources of PAH contamination such as oil mists and blasting fumes.

PROCEDURE

Collect particulate samples from the mine ambient air using standard high-volume samplers. Extract the soluble organics from the material collected on the 20 x 25 cm filters, and determine the concentration of polynuclear aromatics by means of the thin layer chromatographic techniques developed by Professor Katz of York University for urban air samples.

RESULTS

Levels of the ten polynuclear aromatics assayed were remarkably consistent for a variety of mines (nickel, uranium, and salt) and diesel engines (air-cooled indirect injection, water-cooled indirect injection, and two cycle). In general, PAH concentrations were found to vary from 4.5 to 0.2 times the levels found in the ambient winter air in Hamilton, Ontario.

The air-cooled engines appeared to produce the lowest levels of PAH's, while the water-cooled and two cycle were quite similar*. In contrast to the previous contract findings, exhaust treatment with pelletted catalytic purifiers did not seem to reduce ambient PAH levels*. Oil mists from drilling operations, and fumes from ammonium nitrate-fuel oil explosives were shown to produce high PAH levels in the ambient air*, and were thus potential sources of contamination for the diesel-sampling program.

APPLICATION AND ONGOING WORK

This work plus contracts 8-9129 and 9-9140 have defined the levels of underground PAH contamination relative to urban levels. It is planned to engage a medical researcher to examine the health risk resulting from exposure to these levels. Work to assess the impact of new diesel emission control strategies on PAH levels is continuing.

SUPPORTING DOCUMENTS

"A Quantitative Assessment of Mutagens and Polynuclear Aromatic Hydrocarbons in Dieselized Underground Mines", by K.C. Westaway and A.J. Faulds (contract report).

"Polynuclear Aromatic Hydrocarbons and Mutagens in the Air of Underground Dieselized Mines", by J.P. Mogan, K.C. Westaway, A.J. Horton, and E.D. Dainty. Proceedings of the 10th World Congress on the Prevention of Occupational Accidents and Disease.

*See companion mutagenic study: contract 1-9076.

TITLE: ASSESSMENT OF MUTAGEN LEVELS IN UNDERGROUND MINES

CONTRACTOR: Laurentian University	FILE NUMBER: 1-9076	FUNDING	
	BEGIN/END: Oct. 81/March 82		
		CANMET:	$ 8 689
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: P. Mogan	TECHNOLOGY: Mine Environment	TOTAL:	$ 8 689

OBJECTIVES

Expand the database on the levels of mutagenic substances in the ambient mine atmosphere in the vicinity of diesel machinery for both treated and untreated exhaust. In addition, establish the influence of other sources of mutagen contamination such as oil mists and blasting fumes.

PROCEDURE

Collect particulate samples from the mine ambient air using standard high-volume samplers. Extract the soluble organics from the material collected on the 20 x 25 cm filters, and determine the mutagen concentration by means of the Ames salmonella assay.

RESULTS

Concentration of revertants in the vicinity of diesel machines fitted with pelletted-type catalytic purifiers were found to be 75 to 500 times the average levels observed with no exhaust treatment. Revertant levels for water-cooled indirect-injection engines equipped with a monolithic catalytic purifier were found to be about double the levels observed with a similarly equipped air-cooled engine (itself about five times untreated levels). Oil mists and two-cycle engines exhibited negligible mutagenic activity, while blasting fume (ammonium nitrate-fuel oil) was strongly mutagenic.

APPLICATION AND ONGOING WORK

The mutagen levels detected here provided guidance to the mining industry for the selection of current generation emission control equipment. Further work to determine mutagen levels resulting from new emission control strategies is continuing.

SUPPORTING DOCUMENTS

"A Quantitative Assessment of Mutagens and Polynuclear Aromatic Hydrocarbons in Dieselized Underground Mines", by K.C. Westaway and A.J. Faulds (contract report).

"Diesel Emission Control Catalysts: Friend or Foe?", by J.P. Mogan and E.D. Dainty, Division Report MRP/MRL 84-3(OP).

TITLE: EFFECT OF CATALYST TYPES, ENGINES, AND LOAD CYCLES ON THE MUTAGENIC ACTIVITY OF DIESEL EXHAUST EXTRACTS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	I-9068	FUNDING	
		BEGIN/END:	Dec. 81/March 85		
				CANMET:	$ 163 905
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 163 905

OBJECTIVES

Compare the mutagenic response of extracts of diesel soot filtered from the dilute exhaust of a variety of diesel engines, operating at a variety of speeds and loads, and equipped with a variety of emission control hardware. While assay of mutagenic activity does not provide an actual measurement of cancer risk, it has been accepted as providing an accurate basis of comparison of relative risk for similar sources. This work thus permits a comparison of underground engines and operating practices with the large inventory of studies of cancer risk now available for light duty automobile engines. Furthermore, the work also permits an evaluation of relative cancer risk attributable to a variety of existing and novel emission control hardware.

PROCEDURE

Test, by means of multiple strain salmonella typhimurium Ames bioassay, the mutagenic activity of extracts of diesel soot from:

1. Untreated exhaust of the Deutz engines, during both steady-state and cyclic operation.

2. Untreated exhaust of the Caterpillar and Detroit Diesel (DADD) engines.

3. Catalytically treated exhaust from a Deutz engine, for a variety of catalytic devices in current or projected use underground.

RESULTS

Deutz engine soot extract exhibited mutagenic activities of 0.94 to 0.38 revertants per microgram when tested with the TA98 strain. Surprisingly, lug-down operation yielded a lower value (0.42) than 7/8 load at rated speed, suggesting that nitration (NO_x concentration is a maximum at 7/8 load) has more impact on mutagenic activity than the reduced combustion efficiency expected at lug-down. This was confirmed by the results of the tests with the nitrosensitive strains: a 44% reduction for TA98NR, 83% for TA98/1,8DNP$_6$, and 91% for TA98/NR/1,8DNP$_6$ as compared to TA98 activity.

These measured activities were much lower than light-duty engine values reported in the literature, suggesting that exposure to Deutz exhaust presents less risk than exposure to equal quantities of light-duty engine exhaust. The mutagenic activity of the soot extract from the exhaust of a Caterpillar 3304NA engine was slightly higher than the Deutz at 1.35 revertants per microgram, while the Detroit Diesel did not exhibit any activity over a similar range of concentrations.

A PTX monolith catalytic purifier fitted to a Deutz engine increased the specific activity of the soot extract to 3.8 revertants per microgram; a Diesler III pelletted catalytic purifier exhibited levels from 0.4 to 51 revertants per microgram; and a Johnson Matthey CTO yielded 0.24 revertants per microgram for a calculated cycle that included a regeneration phase.

APPLICATION AND ONGOING WORK

This study has achieved its goal of establishing the relationship between diesel fume exposure in Canadian underground mines and the massive U.S. light-duty diesel health effects research program. Further, it has established the effect of existing and new catalytic devices on the mutagenic activity of diesel soot extract. The values obtained have correlated well with underground tests of similar engines and emission control hardware - Contracts 9-9140, 1-9076, 2-9117, and 3-9175.

SUPPORTING DOCUMENTS

Final Report: "Evaluation of the Effect of Catalyst Types, Engines, and Load Cycles on the Mutagenic Activity of Diesel Exhaust Extracts" (Contract Report No. OSQ81-00146).

"A Comparison of Laboratory and Underground Mutagen Levels for Treated and Untreated Diesel Exhaust", by J.P. Mogan, A.J. Horton, H.C. Vergeer, and K.C. Westaway; Division Report M&ET/MRL 86-10(OP-J).

TITLE: ASSESSMENT OF THE SULPHURIC ACID AEROSOLS, HYDROCARBONS, AND RESPIRABLE COMBUSTIBLE DUST IN THE UNDERGROUND ENVIRONMENT

CONTRACTOR:	Laurentian University	FILE NUMBER:	2-9068	FUNDING	
		BEGIN/END:	Jan. 81/Jan. 84		
				CANMET:	$ 54 397
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 54 397

OBJECTIVES

1. Confirm the sampling and analysis methodologies developed during the several contract phases.
2. Determine whether the sulphate ion was present as sulphuric acid (toxic) or as a sulphate salt (relatively non-toxic).
3. Define the composition of respirable combustible dust (RCD) samples collected in underground mines.

PROCEDURE

1. Select appropriate filters to heat sample (a) the RCD, (b) the sulphate ion concentration for H_2SO_4 measurement, and (c) the SO_2 concentration.
2. Determine the effects of ammonia compounds in the muck pile, derived from ammonium nitrate/diesel fuel explosives, on the airborne sulphuric acid concentrations, by a combination of sulphate ion, ammonium ion, and pH analysis of the material on the sample filters.
3. By appropriately sampling the work places and applying developed methodology, assess the levels of sulphuric acid in mine environments and gauge the relative effects of catalytic purifiers, fume diluters, total exhaust filters, and fuel grade.
4. As in (3) for respirable combustible dust (RCD).

RESULTS

1. Of the four types examined, silver membrane filters proved clearly superior. Inco "Maskery Badge" filters were chosen for SO_2 determination.
2. Where ammonium nitrate/diesel fuel explosives leave ammonia compounds in the muck, the airborne levels of both acid and ammonia are well below their respective TLVs.
3. Extensive measurements (4 mines, 15 locations) indicate only 2.5% of the material on sample filters is volatile acid relative to that expected by total conversion of fuel sulphur to acid, regardless of the type of exhaust treatment. Dynamometer predictions of conversion for catalysts range from 15 to 30% for LHD service. Therefore, conversion of H_2SO_4 to neutral sulphates must occur between tail pipe and sampling point. This process needs definition regarding the agents (ammonia, ore dust, etc.) and the dynamics.
4. About 30% of the RCD has been identified; RCD forms 55% of total respirable dust. RCD values averaged 0.60 mg/m^3 or 0.92 maximum (TLV = 2 mg/m^3) for an average ventilation of 170 cfm/bhp. Corning filters reduced RCD about 50% instead of the expected 80 to 90%. These facts suggest the need to characterize the undefined portion of the RCD. Slight evidence suggests that high sulphur (0.5%) 1990 fuels may produce significantly larger volatile acid components in the RCD.

APPLICATION AND ONGOING WORK

This work, though extensive, did not result in definitive RCD characterization; rather, it helped define the major problems. The approximately 30% undefined portion of the RCD needs characterization, as do the dynamics and responsible agents for the conversion of H_2SO_4 to neutral sulphate before sampling. Acid measurements in a very dry salt mine might define the role of humidity in acid disappearance. Finally, the possible change of respirable sulphide ore to sulphate forms on heating filter samples to obtain the RCD, should be investigated.

SUPPORTING DOCUMENTS

1. Final Report: 2-9068 "An Assessment of the Sulphuric Acid Aerosols, Hydrocarbons and Respirable Combustible Dust in the Underground Mine Environment", by L.A. Baldisera and K.C. Westaway.

2. Final Report: 0-9165 "A Quantitative Assessment of Diesel Generated Acidic Aerosols in Underground Mines", by K.C. Westaway.

TITLE: ASSESSMENT OF THE DIESEL EMISSIONS ENVIRONMENT IN AN UNDERGROUND POTASH MINE

CONTRACTOR: John H. Johnson	FILE NUMBER: 4-9128	FUNDING	
	BEGIN/END: Oct. 84/March 85		
		CANMET:	$ 34 645
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: M.K. Gangal	TECHNOLOGY: Mine Environment	TOTAL:	$ 34 645

OBJECTIVES

Determine the air quality index (AQI) and assess the effects of diesel emissions on air quality in an underground potash mine.

PROCEDURE

1. The Lanigan Mine of Potash Corporation of Saskatchewan (PCS) was visited to select a suitable location for field work.

2. Ambient measurements for CO, CO_2, NO, NO_2 and particulate matter were made over a five-day period at four locations, including one on a diesel truck.

3. Particulate samples and Palmes' passive samplers for NO_2, and NO_x were taken and analyzed in the laboratory.

4. The field data were analyzed by computer to calculate the AQI and various other parameters, and a final report was written.

RESULTS

The experimental data were tabulated in the contract report. The baseline diesel pollutant measurement data for the "drive location development" operation were developed. The pollutant characteristic curves and AQI were prepared. All the diesel pollutants in order from least to most critical were listed. NO_2 is considered to be the diesel pollutant of major concern in this particular study.

APPLICATION AND ONGOING WORK

The advanced monitoring and control methodology will be used to assess the AQI in other Canadian mines by in-house research. This study provides a scientific measurement method to assess air quality and can be applied to control the diesel pollutants of most concern in the Lanigan Mine.

SUPPORTING DOCUMENTS

Final Report: "A Study to Assess the Effects of Diesel Emissions on Air Quality in the PCS Mining Lanigan Division Underground Potash Mine", by John H. Johnson and David H. Carlson (Contract Report No. OSQ84-00228).

TITLE: DIESEL EXHAUST PARTICULATES AND RESPIRABLE DUST

CONTRACTOR: Metrex Instruments Ltd.	FILE NUMBER: 3-9091	FUNDING	
	BEGIN/END: Oct. 83/May 84		
		CANMET:	$ 15 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	DSS:	65 000
AUTHORITY: G. Knight	TECHNOLOGY: Mine Environment	TOTAL:	$ 80 000

OBJECTIVES

Development of a sensor capable of separately estimating the components of airborne dust originating from the two major sources - mineral handling and diesel exhausts - in the presence of each other.

PROCEDURE

The two dust sources are distinguished by their differing but overlapping size distributions using two light-scattering units with different scattering angles to distinguish the two components. The two signals are processed using a microcomputer to compute the most likely concentrations of respirable mineral dust and diesel exhaust particulate.

RESULTS

Preliminary tests show that the instrument performs satisfactorily in the normal range of dust concentrations found in mines.

Full calibration and assessment of separation ability is yet to be carried out.

APPLICATION AND ONGOING WORK

The instrument is to be used for continuous monitoring of the underground airborne environment. Its efficacy and value will be assessed in future studies.

SUPPORTING DOCUMENTS

Final Report: "Diesel/Mineral Sensor".

TITLE: DEVELOPMENT AND CONSTRUCTION OF A PROTOTYPE HIGH ENERGY SCRUBBING SYSTEM

CONTRACTOR:	Jarvis Clark Ltd.	FILE NUMBER:	9-9071/9-9096	FUNDING	
		BEGIN/END:	Jan. 80/June 81		
				CANMET:	$ 21 200
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Paul Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 21 200

OBJECTIVES

Design and construct a prototype high-energy (venturi) water scrubbing system for the exhaust of a Jarvis Clark five yard Load-Haul-Dump (LHD) diesel unit according to venturi design principles developed in-house at CANMET laboratories.

PROCEDURE

1. Study the feasibility of fitting the requisite water tanks, pump, venturi, and mist eliminator within the confines of the Jarvis Clark five-yard LHD.

2. Fabricate the high-energy water scrubbing system.

RESULTS

A prototype design fitting two 90 gallon (409 L) water tanks to the fender skirts, and combining the exhaust from each bank of the Vee engine for treatment in a single stainless steel venturi supplied with 1.5 gpm (6.82 L/min) of scrubbing water, was developed and constructed.

APPLICATION AND ONGOING WORK

The prototype venturi system was supplied under contract 9-9096. It will be tested in the laboratory for cyclic operation and ultimately in underground trials as part of the USBM/MOL/CANMET collaborative research program.

SUPPORTING DOCUMENTS

Final Report: "Development of a Prototype High Energy Diesel Exhaust Scrubber System".

TITLE: DEVELOPMENT OF A WATER RECYCLING SYSTEM FOR A VENTURI WATER SCRUBBER

CONTRACTOR:	Jarvis Clark Company Ltd.	FILE NUMBER:	0-9164	FUNDING	
		BEGIN/END:	July 81/March 84		
				CANMET:	$ 9 299
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 9 299

OBJECTIVES

The underground diesel venturi scrubbing system designed and fabricated for contracts 9-9096 and 9-9071 requires a water flow of about three times the volume needed for evaporation cooling of the exhaust to attain efficient soot capture. Filtration and recycling of this non-evaporated water will permit longer operating cycles before the underground diesel machine must return to a service area to refill the water tanks. It also removes the uncertainty as to the final disposition of the diesel soot, which could result from discharge of the contaminated water onto the mine floor.

PROCEDURE

Design and fabricate a water-recycling system. It should include a transfer device to push about 4 L per minute of contaminated water from the mist eliminator through a suitable mine-worthy filter, and deliver filtered water to the on-vehicle water supply tanks.

RESULTS

A cycling system with solenoids was selected to move slugs of contaminated water by air pressure from the mist eliminator sump to the filter. A large (30 cm diameter by 20 cm high) cylindrical pleated filter was designed to fit into a cylindrical chamber fitted into one of the tanks, thereby eliminating any requirement for additional space on the machine. The filter has been shown (in in-house tests at CANMET) to be effective in removing diesel soot from the water, and shows promise that the collected soot may be able to be back-washed out so that the filter may be re-used.

APPLICATION AND ONGOING WORK

The prototype recirculation system will be tested in the laboratory for cyclic operation and ultimately in underground trials as part of the USBM/MOL/CANMET collaborative research program.

SUPPORTING DOCUMENTS

"Installation Manual for CANMET Venturi Exhaust System", by Anthony Branje.

TITLE: DEVELOPMENT OF A COMBINED DIESEL EXHAUST COOLER/SCRUBBER FOR USE IN UNDERGROUND OPERATIONS

CONTRACTOR: Hovey & Associates Ltd.	FILE NUMBER: 2-9180	FUNDING	
	BEGIN/END: April 83/March 84		
		CANMET:	$ 41 084
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: E.D. Dainty	TECHNOLOGY: Mine Environment	TOTAL:	$ 41 084

OBJECTIVES

Design, construction, and delivery of a combined diesel exhaust cooler/scrubber for underground vehicle application.

The unit so developed is to minimize water evaporation into the mine environment and thus reduce the need for constant refilling, and at the same time make it possible to install a "hot flame trap" to reduce maintenance associated with this item used in coal mines.

PROCEDURE

1. A series of typical diesel engine sizes in common use will be chosen and representative exhaust gas volumes and other characteristics established.

2. Water consumption, and estimated scrubber volume, weight, and costs will be derived for an uncooled design and for designs with various degrees of pre-cooling of the exhaust gases. Optimum degrees of cooling will be determined by balancing cooler size and cost against savings in scrubber size, cost, and water consumption.

3. A prototype cooler/scrubber will be designed and fabricated for an engine size that appears, from this analysis, to benefit significantly from this approach.

4. A final report will be prepared describing the work carried out on the project and will be submitted by March 31, 1984.

RESULTS

1. Seven commercial engines were studied and the performance estimated.

2. Because of the unavailability of other engines studied, it was decided to design the cooler/scrubber to match the requirements of the Ford 330 engine (97hp at 2200 rpm) in the CANMET/MRL/CEAL Laboratory.

3. The study indicated that a 40% reduction in exhaust gas temperature would reduce the water consumption by approximately 50%. The cooler/scrubber was designed to provide these benefits.

4. The scrubber, specially fitted for in-house CEAL performance checks, was delivered with appropriate testing equipment during May of 1984.

APPLICATION AND ONGOING WORK

This type of exhaust treatment for diesel engines provides a simple, reduced maintenance approach for both mineral and coal mines, while at the same time reducing the toxicity of the emissions by 40% as measured by the AQI. The performance of the unit will be assessed in the CEAL facilities. It will be marketed by Hovey.

SUPPORTING DOCUMENTS

Final report: "Development of a Combined Diesel Exhaust Cooler/Scrubber for use in Underground Operations".

TITLE: UNDERGROUND EVALUATION OF CERAMIC PARTICULATE TRAPS FOR DIESEL ENGINES

				FUNDING	
CONTRACTOR:	Michigan Technological University	FILE NUMBER:	2-9115		
		BEGIN/END:	April 83/March 84		
				CANMET:	$ 29 766
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 29 766

OBJECTIVES

This study was one aspect of a collaborative diesel emissions reduction program involving CANMET, the Ministry of Labour of Ontario, and the United States Bureau of Mines, and was undertaken in connection with a total diesel exhaust, ceramic filter field durability test in cooperation with Inco Metals Ltd. in the Sudbury Basin. The essential objectives of the study were:

1. Assess the effects of the application of ceramic total exhaust filters on LHD operator exposure and on mine air quality, with respect to the concentration of CO, NO, NO_2, RCD, SO_2, and SO_4.

2. Provide CANMET personnel with the first 'real world' opportunity to become familiar with the use of an array of equipment necessary to accomplish the assessment.

PROCEDURE

This research included daily simultaneous time-weighted-average concentration measurements for CO_2, CO, NO, NO_2, particulate matter (RCD and total), and SO_2 (or SO_4). Four locations on the 1400-foot level of Little Stobie Mine were monitored. The first was upstream of the study area in the ventilation system, the second was on-board the LHD near the operator, the third was in the stope (or heading) near where the LHD was mucking, and the fourth was in the return downstream from the study area in the ventilation system.

One week of measurements involved the normal Inco LHD dual-exhaust system, which contained a PTX catalytic convertor on each bank. For the other week of measurements, each catalytic convertor was replaced by a ceramic filter trap.

RESULTS

1. The averaged daily ambient pollutant data showed that both the baseline week (catalytic convertors) and the week with the ceramic traps installed met all the standards, TLVs, and assumed limits. The measured pollutant concentrations and the characteristic curve slopes relative to CO_2 were similar to past data gathered by the contractor in other mines.

2. The comparison of the respirable combustible dust (RCD) plus SO_4 characteristic curve slopes for the two weeks showed that a reduction of 43% occurred during the week the traps were used. This reduction may be attributed to the traps and to a simultaneous reduction in drill oil mist. The AQI was reduced by 31% with the traps if the fuel sulphur level is assumed to be equal for both weeks at 0.19%. Limited data suggest a 31% particulate reduction in the environment exclusive of the complicating factor of oil mist.

3. The data show that the Air Quality Index (AQI) is the most stringent criterion and the RCD at a limit of 2 mg/m^3 is the next most stringent for determining air flow requirements in these circumstances.

4. In general, the equipment employed performed well. However, there was an unexplained discrepancy in the two methods of measuring NO and NO_2, which will require further attention.

APPLICATION AND ONGOING WORK

This study was the first involving in-house CANMET effort to assess the AQI in various types of dieselized mine workings in Canada. Ultimately, it is intended that this function will be privatized by the transfer of the assessment technology to the industry and the inspectorates.

SUPPORTING DOCUMENTS

Final report: "A Study of Diesel Pollutants in an Underground Production Metal Mine Using an Advanced Monitoring and Data Analysis Methodology".

TITLE: PERFORMANCE OF THE JOHNSON MATTHEY CATALYTIC TRAP IN THE TREATMENT OF EXHAUST FROM UNDERGROUND ENGINES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9174	FUNDING	
		BEGIN/END:	March 84/June 84		
				CANMET:	$ 24 960
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 24 960

OBJECTIVES

Determine, by dynamometer simulation of an underground load-haul-dump (LHD) cycle, the capacity of the Johnson Matthey/Engine Control Systems catalytic-trap-oxidizer (CTO) to reduce the levels of a number of toxic contaminants in the exhaust of a typical underground diesel engine. The study was intended as a companion study to underground trials of a similar device (Contract No. 3-9175).

PROCEDURE

An 8-cylinder air-cooled diesel engine, typical of those used in 5 m^3 underground LHD units, was cycled through a typical (light) LHD operating cycle by means of a computer-controlled dynamometer. Levels of carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, particulates, aldehydes, and mutagens were measured in the untreated and CTO-treated exhaust using a double dilution (tunnel) emissions' monitoring system.

RESULTS

The CTO was found to accumulate soot during the LHD (light) cycle, such that back pressure increased from 35 to 60 cm of water in a two-hour period. It was thus necessary to regenerate the traps by running the engine at rated speed and load for fifteen minutes after each two hours of cyclic loading. An exhaust temperature of 365°C was sufficient to initiate soot burnoff.

During the cycle operation, the CTO oxidized 94% of the carbon monoxide, 83% of the total hydrocarbons, and 74% of the total aldehydes. Soot removal efficiency was 85.6% overall (97.1% of the soluble fraction, 60.1% of the insolubles). Total sulphur oxides (SO_2 and $SO_4^=$) were 33% lower in the treated exhaust, but this was shown to be a storage phenomenon as SO_x output reached 140% of input during burnoff, with a greatly increased proportion of $SO_4^=$ (11% during the cycles, 39% during burnoff). Mutagenic material was greatly reduced by the CTO (95%), but reached double the cycle values during regeneration. Oxides of nitrogen were slightly lower after CTO treatment. Carbon monoxide and hydrocarbon levels remained below raw exhaust cycle levels during burnoff, as did the aldehydes. Overall, it appears that the CTO achieved significant reduction of most of the noxious constituents of diesel exhaust. The health implications of a significant oxidation of SO_2 to $SO_4^=$ remain a concern; however, it can apparently only be addressed at this stage of development by the use of a low-sulphur content fuel.

APPLICATION AND ONGOING WORK

This study, and the companion underground study, Contract No. 3-9175, will assist the mining industry in the selection of state-of-the-art emission control options.

SUPPORTING DOCUMENTS

Final Report: "Emissions Assessment of Johnson Matthey Catalyzed Wire Mesh Traps".

TITLE: UTILIZATION OF METHANOL FUEL AS A TRANSPORTATION FUEL IN MINING OPERATIONS

CONTRACTOR: Inco Limited	FILE NUMBER: 0-9087	FUNDING	
	BEGIN/END: Feb. 81/May 85		
		CANMET:	$ 226 773
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	DSS:	105 250
AUTHORITY: P. Mogan	TECHNOLOGY: Mine Environment	TOTAL:	$ 332 023

OBJECTIVES

Substitute methanol for a portion of the diesel fuel requirement in a constrained environment - the underground diesel fleet in the Sudbury basin. Other studies (Contract No. 6-9086-8, [OSQ76-00162]) indicated that significant reductions in underground pollutant burdens would be an additional supplementary benefit.

PROCEDURE

1. Extend the application of the "Hydroshear" emulsifier system (Contract 6-9086-8) to the current generation of underground mining engines.

2. Develop a "mine worthy" package (including "safe" fuel containment).

3. Assess emission levels for representative mining conditions via dynamometer tests.

4. Demonstrate the system in a working mine environment.

RESULTS

Contract 6-9086-8, the basis for this contract, investigated the effect of methanol emulsions on the operation of the then current 714 series Deutz diesel engines. The 714 series is now obsolete, so work under this contract was carried out with the replacement 413 series. Unfortunately, preliminary studies showed that the combustion characteristics of the new engine were less tolerant of the emulsion than the previous model. Brake specific fuel consumption, peak combustion pressures, and rate of pressure rise reached unacceptable levels, and could not be satisfactorily reduced by a full range of engine adjustments. The addition of octyl nitrate cetane improver achieved satisfactory operating characteristics, so emission testing was carried out on a 30-volume percent emulsion (15% energy replacement) containing 2.4 volume percent of octyl nitrate. Insoluble soot was reduced by an impressive 61%, but the soluble fraction by only 9%, for an overall reduction of 25%. Carbon monoxide increased by an insignificant 11% and total hydrocarbon emissions were unaffected. Nitric oxide was reduced 23%, but decomposition of octyl nitrate evidently increased the small quantity of nitrogen dioxide in the baseline exhaust several fold, thus limiting the NO_x reduction to 17%. Aldehydes were also reduced, with the exception of acetone, which slightly increased. There was some scaling or metal transfer on the head and top surface of the piston at the end of the 300-hour program.

APPLICATION AND ONGOING WORK

The high cost of the cetane improver necessary to achieve normal engine operation resulted in a reasonably severe economic penalty at current methanol and diesel fuel costs. Thus, the mine demonstration portion of this contract was cancelled. The technology developed, however, is being applied to the investigation of the benefit of a 100% methanol engine as an underground power source, Contract No. 4-9166.

SUPPORTING DOCUMENTS

Final Report: "Utilization of Methanol Fuel as a Transportation Fuel in Mining Operations".

TITLE: EFFECT OF FUEL COMPOSITION ON THE ATMOSPHERE OF UNDERGROUND DIESELIZED MINES

CONTRACTOR: Laurentian University	FILE NUMBER: 2-9117	FUNDING	
	BEGIN/END: Dec. 82/March 83		
		CANMET:	$ 36 971
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: P. Mogan	TECHNOLOGY: Mine Environment	TOTAL:	$ 36 971

OBJECTIVES

Determine the effect of a wide variety of diesel fuels (spanning the range of properties from jet fuel to the "1990's" for sand fuel) on the hydrocarbon portion of diesel soot collected in underground dieselized mine workings.

PROCEDURE

Sample, on 20 x 25-cm filters in high-volume samplers, the ambient particulates in a mine heading where a 5 m^3 Load Haul Dump (LHD) diesel machine is working. Samples were collected during simulated operating cycles (loading and dumping on piles rather than an ore pass) while fueling the diesel engine on Jet A-1, the regular fuel used in the mine, and the "1990" tar-sand-derived fuel.

Polynuclear aromatic hydrocarbons (PAH's) and the levels of mutagenic activity were determined for the extractable fraction of the collected soot.

RESULTS

The concentrations of the twelve polynuclear aromatic hydrocarbons measured for the two extremes of fuel properties, Jet A-1 and "1990", were within the range measured for the regular fuel with the exception of pyrene (which was not greatly different). Thus, concentrations of the same twelve PAH's varying from 235 ppb (Jet A-1) to 16 441 ppb ("1990") in the raw fuel had little effect on the PAH content of the exhaust products.

The mutagenic activity (TA98) of the soot extract was virtually identical for the two lighter fuels, at 0.25 revertants per microgram, but was doubled for the "1990" fuel.

Although the ambient levels of the exhaust products (CO, CO_2, NO, NO_2, soot) showed little variation with fuel properties, the operators reported some increase in irritant level with the Jet A-1, and significant eye and throat irritation when the "1990" fuel was used.

APPLICATION AND ONGOING WORK

Although the measured parameters indicated little degradation in the mine environment, the subjective observations strongly suggested that the road fuel that might be supplied in the 1990's is unsuitable for use in dieselized underground mining operations at present ventilation levels.

SUPPORTING DOCUMENTS

Final Report: "An Assessment of the Effect of the Fuel Composition on the Atmosphere of Dieselized Underground Mines", by L.A. Baldisera, A.J. Faulds, and K.C. Westaway.

TITLE: ASSESSMENT OF AUTO-REGENERATION OF DIESEL PARTICULATE FILTERS BY FUEL ADDITIVES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9128	FUNDING	
		BEGIN/END:	Sept. 83/March 84		
				CANMET:	$ 50 943
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 50 943

OBJECTIVES

1. Select most appropriate fuel additive for use with diesel fuel.
2. Assess the performance of that additive on the basis of reduction of particulate ignition temperature, and backpressure build-up for steady-state operation.
3. Assess the emissions impact of additive use in conjunction with the ceramic wall-flow filter for MTU/LHD load cycle.
4. Assess the Ames mutagenic activity of the regenerating filter for the MTU/LHD cycle.
5. Measure the thermal gradients inside the regenerating filter to assess the extent of thermal stresses so generated.

PROCEDURE

1. Consult with suppliers and automotive companies to obtain direction from their experience.
2. Run steady-state dynamometer tests with step increases in load to achieve higher temperature, noting the temperature(s) at which backpressure does not further increase. Note spectrum of emissions at each load.
3. Run dynamic MTU/LHD cycles noting emissions and backpressure buildup rate, and take Ames mutagenic samples to indicate potential cancer concern. Also, monitor the various internal filter temperatures for evidence of excessive exothermic temperature gradients during cycle operation.

RESULTS

1. An additive composed of 80 mg Mn + 20 mg Cu per litre of fuel was chosen.
2. Steady state tests indicated that the additive caused:
   a) a reduction in apparent soot ignition temperature from over 482°C (900°F) to approximately 350°C (660°F).
   b) regeneration of the soot at this 350°C level as evidenced by a cessation of pressure buildup.
   c) no significant increases in the emissions of CO, THC, NO, SO_2/SO_4, and aldehydes. An increase in NO_2 was not thought to be additive-related.
3. Dynamic MTU/LHD cycle tests indicated that the additive caused:
   a) regeneration of the filter at the average cycle exhaust temperature of 350°C (660°F).
   b) no significant changes in gaseous emissions including SO_2 to SO_4 conversion and aldehydes. NO_2 was entirely absent, and particulates remained very low due to filtration.
   c) a reduction in Ames mutagenic activity from approximately 8000 revertants/m^3 of exhaust with no filter or additive, to 3000 with both.
   d) no appreciable exothermic temperature gradients.

APPLICATION AND ONGOING WORK

The above results are entirely positive. This means that the application of filter plus additives to circumstances where the average exhaust temperature is in excess of 350°C (a substantial

proportion of production vehicles) is likely to be for long maintenance-free periods. The AQI reduction is approximately 40 to 50%, suggesting a corresponding improvement in the environment or a proportional reduction in expensive ventilation. This option will be tested underground at MTU as part of the collaborative USBM/CANMET/MOL program in 1985/86.

SUPPORTING DOCUMENTS

Final Report: "Assessment of Auto-Regeneration of Diesel Particulate Filters by Fuel Additives", by H.C. Vergeer and W. Drummond.

TITLE: COMPLETION OF PRE-TRIAL PHASE OF DIESEL EMISSIONS REDUCTION OPTION DEVELOPMENT - PHASE I

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9169	FUNDING	
		BEGIN/END:	Oct. 83/March 84		
				CANMET:	$ 74 394
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 74 394

OBJECTIVES

This study was part of a collaborative diesel emissions reduction program involving CANMET, the Ministry of Labour on Ontario, and the United States Bureau of Mines. The major objectives of this study were:

1. Development of a methodology and the subsequent determination of the amount of hydrocarbons that pass through the standard hi-vol sample filter paper.

2. Confirmation of the method of Corning filter regeneration by electrical face heater induced combustion of the deposited soot developed at CANMET.

3. Determination of the mutagenic activity of the filter exit gases during the above artificially induced regeneration.

PROCEDURE

1. By means of Poly Urethane Foam (PUF) backup plugs and an XAD_2 absorber, capture the substances that pass through the standard hi-vol sample filter during the artificially induced regenerations and assess their character.

2. By means of a 4.2 kW face heater connected to two 12 volt industrial batteries in series and a flow of 8.4 m^3/h (5 cfm), initiate regeneration in filters preloaded with soot to a level commensurate with a backpressure of 5 kPa (20 in. H_2O), and sample gaseous concentrations, soot levels, temperatures, and mutagens.

3. Repeat item (2) three additional times.

RESULTS

1. Operating a Deutz F6L-714 engine at 2200 rpm and at 7/8 full load on No. 1 fuel, and collecting samples on hi-vol filters, PUFs, and XAD_2 absorber in a 16:1 dilution tunnel, produced the following results:
   a) Corning traps collected 90+% of total particulates and PAHs.
   b) With no trap installed, 4.6% insoluble and 18.9% soluble particulates passed through the hi-vol sample filter; 15.6 BaP passed through.
   c) With the trap installed, 42.2% insoluble and 48.6% soluble particulates passed through the hi-vol sample filter; 22.0% BaP passed through.
   d) Ames mutagenicity was reduced from 27 338 revertants/m^3 to 3660 using the Corning filter, and 6.5% of the mutagenic material passed through the hi-vol filter.

2. The electric face heater, in conjunction with a 8.4 m^3/h (5 cfm) flow, is effective for regeneration requiring between 30 and 50 minutes for completion. Maximum emissions at the low flow were: CO_2-7.0%, NO-122 ppm, NO_2-52 ppm, and CO-30 000 ppm estimated. The CO level requires that the regeneration be done in a heading with 85 m^3/min (3000 cfm) airflow and that a special effort be made to rapidly dilute the exit gases from the filter. The particulate level ranged from 9 to 57 mg/m^3.

3. The Ames mutagenic activity in raw engine exhaust is 14 000 revertants/m^3; the regeneration products produce a mutagenic activity of 1700 revertants/m^3.

APPLICATION AND ONGOING WORK

This positive result means that a relatively simple system has been developed with the potential of permitting application of filters to a wide range of underground mining vehicles.

This system is being further developed for application to an LHD vehicle slated for testing underground at Michigan Technological University during 1985 as part of the three government collaboration.

The passage of the combustion "wave" through the ceramic generates thermal stresses that need to be studied to assess the thermal fatigue effects on ceramic life. Such assessments are being undertaken by Corning Glass scientists.

SUPPORTING DOCUMENTS

1. Progress Report: "Completion of Pre-Trial Phase of Diesel Emissions Reduction Option Development - Phase I", by H. Vergeer and M. Szabo. This report outlines the development of the "by-pass" or "pass-through" methodology.

2. Final Report of the same name by B. Manicon, W. Robinson, and H. Vergeer. This report describes the performance tests on electric heater regeneration.

TITLE: COMPLETION OF PRE-TRIAL PHASE OF DIESEL EMISSIONS REDUCTION OPTION DEVELOPMENT - PHASE 2

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	4-9025	FUNDING	
		BEGIN/END:	June 84/May 85		
				CANMET:	$ 177 057
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 177 057

OBJECTIVES

In general, complete six development and assessment tasks relating to the collaborative USBM/MOL/CANMET diesel emissions reduction program. In particular:

1. Assess the performance of an exhaust filter pressure drop indicating system.
2. Confirm the electric face heater concept for exhaust filter regeneration.
3. Assess EGR/additive/filter combination performance.
4. Perform a post-underground test examination of four Inco Ltd. ceramic exhaust filters.
5. Confirm the performance of a non-recirculating venturi scrubber system.
6. Assist in adapting these and other emissions reduction options to the Jarvis Clark LHD destined for MTU environment trials.

PROCEDURE

Tasks 1 to 5 involved assembling the necessary equipment in the ORF dynamometer cell and undertaking the various specified tests to determine the performance of the various options from the point(s) of view of:

1. Functional control
2. Emissions' reduction
3. Equipment condition.

Task 6 was a consultative function.

RESULTS

Task 1:

An orange Research DP Sensor model No. 1516DGS-4A-4.5L-13 was found suitable for monitoring backpressure and signalling pressures in excess of 40 cm of H_2O to the driver, indicating action against fouling is required.

Task 2:

The electric face heater regeneration of ceramic exhaust filters was demonstrated and found to be practical, particularly from the point of view of mutagen generation.

Task 3:

The combined EQI reduction relative to the baseline value, using filter/EGR/additive strategies in concert, was 66%. EGR alone does not significantly impact EQI values, but is useful in circumstances where NO conversion to NO_2 is a problem.

Task 4:

The Inco 850 hour filters were dynamometer checked and found suitable for continued operation.

Task 5:

The venturi scrubber reduced the MTU cycle EQI by 45%, the Ames mutagenic activity was reduced 44%, and the sulphate and particulate removal efficiencies were 35 and 73%, respectively. The backpressure was higher than anticipated.

Task 6:

Consulting services were provided to Jarvis Clark regarding installation of equipment on the JC/MTU machine for environmental impact assessment.

APPLICATION AND ONGOING WORK

This work completes a major part of the dynamometer testing aspect of the collaborative USBM/MOL/CANMET emissions reduction program.

Phase 3 continues this work to completion in 1985/86 and involves: (1) assessment of the ceramic filtration efficiency of additive metals, and (2) performance assessment of Degussa noble and non-noble catalyzed ceramic filters.

SUPPORTING DOCUMENTS

Final Report: "Completion of Pre-Trial Phase of Diesel Emission Reduction Option Development - Phase 2".

TITLE: ATMOSPHERIC FOGGING IN UNDERGROUND MINES

CONTRACTOR:	Golder Associates Limited	FILE NUMBER:	2-9046	FUNDING	
		BEGIN/END:	Aug. 82/June 83		
				CANMET:	$ 24 100
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M.K. Gangal	TECHNOLOGY:	Mine Environment	TOTAL:	$ 24 100

OBJECTIVES

Investigation of control techniques to reduce the atmospheric fogging in underground mines, which leads to a loss in visibility and production efficiency.

PROCEDURE

1. Study and detail the mechanism of fog formation in mines.
2. Conduct a survey on the occurrence of fog in underground Canadian mines.
3. Review the existing techniques for controlling fog.
4. Analyze in detail the fogging problem and its control in four or five underground Canadian mines.
5. Estimate the capital and operating costs associated with the system for the control of fog in mines.

RESULTS

The techniques available for fog control are: good ventilation planning, direct air heating, fan compression, cooler/reheater, absorbant drying, mixing of air with dryer air, mixing of air with compressed air, and vertical airway water settling.

Every effort must be made to improve visibility in foggy areas. The imposition of safe limits and the provision of control traffic lights should be used.

Specific recommendations are made for the mines that were visited. Also, general recommendations for future work are indicated.

APPLICATION AND ONGOING WORK

Some mines are planning to use these techniques to control fog problems in their mines.

SUPPORTING DOCUMENTS

1. Final Report: "Study to Investigate the Problem of Atmospheric Fogging in Underground Mines".
2. "Atmospheric Fogging in Canadian Mines", by A.E. Hall, M.K. Gangal, and S.B.V. Stewart; presented at the Annual Technical Sessions, Mines Accident Prevention Association of Ontario, Toronto, May 25-27, 1983.

TITLE: DETERMINATION OF FRICTION FACTORS OF MINE AIRWAYS

CONTRACTOR: Queen's University	FILE NUMBER: 4-9130	FUNDING	
	BEGIN/END: Aug. 84/March 85		
		CANMET:	$ 50 607
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: Dr. M.K. Gangal	TECHNOLOGY: Mine Environment	TOTAL:	$ 50 607

OBJECTIVES

Determine airway friction factors characteristic of a broad cross-section of Canadian mines, and applicable to modern mine openings.

PROCEDURE

A program of field measurement work was carried out in 11 Canadian mines. The work was confined to reasonably straight, unobstructed airways. Standard techniques were used for airflow and pressure drop measurements, and a photoprofiling method was used to characterize the airways. A table of friction factors was produced and a final report was written.

RESULTS

Friction factors were determined in 11 Canadian mines including nickel, copper, zinc, silver, gold, uranium, asbestos, potash, and coal-mining operations. The friction factors were shown to be generally lower than the standard published values, reflecting the larger size and smoother surface conditions of modern airways. An attempt was made to correlate the measured friction factors with the standard hydraulic friction factors based on relative surface roughness.

APPLICATION AND ONGOING WORK

It is expected that these friction factors for modern mine openings will be useful in planning ventilation systems for mines.

SUPPORTING DOCUMENTS

Final Report: "A Study to Determine Friction Factors of Mine Airways".

TITLE: DUST SAMPLING SLIDESHOW

CONTRACTOR:	National Film Board	FILE NUMBER:	9-9051	FUNDING	
		BEGIN/END:	Aug. 79/Aug. 80		
				CANMET:	$ 14 427
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mine Environment	TOTAL:	$.14 427

OBJECTIVES

Disseminate CANMET research on personal gravimetric dust sampling to industry. Intended audience: managers and staff, specified technicians, union safety and health shop stewards.

PROCEDURE

Select slides from stock, write script, take extra photographs. Prepare sound track in both English and French.

RESULTS

Successfully completed.

APPLICATION AND ONGOING WORK

Part of dust-sampling method and program development.

SUPPORTING DOCUMENTS

1. CANMET Report 78-7: Mine Dust Sampling System - CAMPEDS, by G. Knight.
2. "Personal Dust Sampling in Mines - Statistical Analysis", by G. Knight; Second International Mine Ventilation Congress, 1979; Society of Mining Engineers, New York; 1980.

TITLE: SURVEY OF CANADIAN RESEARCH AND DEVELOPMENT INTO ASBESTOS FIBRE MEASUREMENT, MONITORING METHODS AND INSTRUMENTATION

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	O-9074/O-9137	FUNDING	
		BEGIN/END:	Oct. 80/Dec. 80		
				CANMET:	$ 12 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mine Environment	TOTAL:	$ 12 000

OBJECTIVES

Survey Canadian research and development into asbestos fibre measurement, monitoring methods and instrumentation.

PROCEDURE

A cross-Canada survey was made to determine past, present, and future areas of interest in asbestos measurement, monitoring methods, and instrumentation.

RESULTS

The survey contains lists of individuals, organizations, and activities in asbestos fibre measurement and research.

The conclusions of the technical paper are as follows:

There are many problems involved with studying asbestos in the workplace. It is still not known what properties of asbestos give rise to the health risks involved. This in turn causes problems in the monitoring and measurement of the fibre levels present in a workplace. If the harmful properties of asbestos could be recognized, work could begin on a method for monitoring fibres that have only those properties. Once the harmful concentration levels are deduced, the controversy surrounding the definition of a workplace could be cleared up in cases where the concentration falls below the critical value. An international method of analysis could be formulated to allow statistical analyses to be correlated from different studies. Analytical labs could be accredited by qualified personnel to ensure uniform analytical procedures.

APPLICATION AND ONGOING WORK

To further Canada-EEC cooperation in the asbestos measurement field.

SUPPORTING DOCUMENTS

The final report for Contract No. O-9074 contains the individual responses to the survey (Contract Report No. OSQ80-00105).

The final report for Contract No. O-9137 is a technical paper entitled: "Asbestos: Definitions, Monitoring and Measurement in the Workplace" (Contract Report No. OSQ80-00192).

TITLE: VIBRATION SOURCES AFFECTING MINE WORKERS

CONTRACTOR:	University of British Columbia	FILE NUMBER:	I-9133	FUNDING	
		BEGIN/END:	June 82/July 83		
				CANMET:	$ 29 273
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M.U. Savich	TECHNOLOGY:	Mine Environment	TOTAL:	$ 29 273

OBJECTIVES

1. Determine representative vibration records that characterize the levels of hand-transmitted vibration that rock drillers are exposed to. These measurements were to be conducted in a mine environment.

2. Conduct preliminary studies on how the vibration loads produced by rock drills may be reduced.

3. Consider how existing instrumentation may be modified to provide and transfer data to a computer, and evaluate the effectiveness of such instrumentation to the rest of the mining industry.

PROCEDURE

1. Site visits were conducted at two large underground mines in British Columbia, and vibration measurements were recorded on a large sample of drills in underground operating conditions.

2. Laboratory tests were conducted on mechanical isolation devices to assess their effectiveness in reducing vibration levels.

3. Existing instrumentation was tested in field and laboratory tests, and analysis of the digital interface conducted in the laboratories at U.B.C.

RESULTS

1. The most comprehensive set of field data gathered to date in North America was obtained. The data provided representative details of the dynamic characteristics of drills commonly in use. These data are important in assessing the effect of vibration upon VWFD and in considering what design changes may result in decreased vibration levels.

2. Test results showed that significant reductions in vibration levels can be obtained using vibration isolation systems. Details of such systems were presented.

3. A digital interface and appropriate software were developed for the transfer of vibration data from an existing Bruel and Kjaer data storer to a computer. Such a development removes the necessity of purchasing a relatively expensive data logger and plotter.

APPLICATION AND ONGOING WORK

Proposal entitled: "The Development of Computer Compatible Vibration Instrumentation for the Mining Industry" was submitted to CANMET in July, 1983.

SUPPORTING DOCUMENTS

Final Report: "A Study of Vibration Sources Affecting Mine Workers" (Contract Report No. OSU82-00117).

Publications resulting from contract work:

"Vibration Effects on Mine Workers", by S.G. Hutton and R. Brubaker; CIM Bulletin, February 1982.

"Vibration Characteristics of Rock Drills", by S.G. Hutton; CIM Bulletin (submitted for publication).

TITLE: DEVELOPMENT OF COMPUTER SOFTWARE PROGRAM FOR DETAILED STATISTICAL ANALYSIS OF DIGITAL DATA RELATED TO NOISE IN THE WORK PLACE

CONTRACTOR: Leq Measurements Limited	FILE NUMBER: 3-9207	FUNDING	
	BEGIN/END: Dec. 83/May 84		
		CANMET:	$ 6 750
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mining	OTHER:	--
AUTHORITY: M.U. Savich	TECHNOLOGY: Mine Environment	TOTAL:	$ 6 750

OBJECTIVES

Provide professional services necessary to develop a computer software program for detailed statistical analysis of digital data related to noise in the work place. The software program will be written to be acceptable on Apple II, Commodore Business Machines, and TRS microcomputers.

PROCEDURE

1. Visit Falconbridge Nickel Mines to determine work in progress and type of information to be processed.

2. Study reproduction of manually produced data and determine the characteristics of a computer program to speed up production of aggregated data from several individual noise level exposure data series.

3. Write up a program to aggregate the noise level exposure data mentioned in (2) and display the results. The program will be converted in formats compatible with Apple, Commodore Business Machines, and TRS microcomputers.

RESULTS

A program was designed to sort data files on individuals by job category from data previously collected and stored on data discs. The printout from a microcomputer will be both numerical and graphical.

The program is compatible with the Apple II computer but not with the Commodore or TRS 80 machines.

APPLICATION AND ONGOING WORK

There have been many difficulties with this contract. The program should be improved and made fully applicable.

SUPPORTING DOCUMENTS

Final report: "Job Category Software Program".

The final report contains a printout of the program.

MINERALS TECHNOLOGY

RESOURCE ASSESSMENT

TITLE: CHARACTERISTICS OF CANADIAN NIOBIUM ORES AND AMENABILITY TO CONCENTRATION

CONTRACTOR: H. Noblitt	FILE NUMBER: 8-9026	FUNDING	
	BEGIN/END: June 78/Aug. 78		
		CANMET:	$ 5 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Resource Assessment	OTHER:	--
AUTHORITY: D. Raicevic	TECHNOLOGY: Commodity Background Studies	TOTAL:	$ 5 000

OBJECTIVES

Tantalum and niobium, or columbium, are becoming important metals in industrialized countries because of their unique properties. At present, Canada ranks second to Brazil in the production of niobium and tantalum concentrates in the non-Communist world. Most of the Canadian production is exported to the United States where it is processed. The objectives of this report are to present a description of resources and production statistics of these two metals, both domestic and foreign, and to summarize ore-dressing research carried out at CANMET. In the case of niobium, research activities conducted elsewhere are also included.

PROCEDURE

The tantalum sections were compiled by D. Raicevic, and those on niobium by H.L. Noblitt.

RESULTS

A summary of each investigation contains the following information:

- number and title of investigation
- mineralogy and analysis of ore samples tested
- purpose of investigation
- methods of concentration
- results and conclusions.

APPLICATION AND ONGOING WORK

Information on the mineralogy of the ores and their amenability to beneficiation will be helpful in evaluating resources and will also serve as a guide for future ore-dressing investigations, indicating how new or improved beneficiation methods would be required to help bring promising deposits into production.

SUPPORTING DOCUMENTS

1. "Characteristics of Canadian Niobium Ores and Amenability to Concentration"; by H. Noblitt.

2. The above paper was merged with another by D. Raicevic and published as CANMET Report 79-1: "Tantalum and Niobium Ore Dressing Investigations at CANMET".

TITLE: LEVEL OF RESEARCH IN CANADA IN CONSTRUCTION MATERIALS, AGGREGATES, CEMENT AND CONCRETE AND THE ADEQUACY OF CANMET'S CONTRACTING-OUT PROGRAMS

CONTRACTOR:	Dr. A.M. Neville	FILE NUMBER:	0-9078	FUNDING	
		BEGIN/END:	Sept. 80/March 81		
				CANMET:	$ 18 260
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Resource Assessment	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Commodity Background Studies	TOTAL:	$ 18 260

OBJECTIVES

The objective of this contract was to develop an overview of long-term applied research in the areas of aggregates, cement, and concrete in Federal Government Agencies, Provincial Government Agencies, Universities, and Industry in Canada, and consider this research in relation to work done at CANMET.

PROCEDURE

The contractor travelled extensively across Canada and interviewed a number of people in Government, the private sector, and in industry. The results of these interviews were compiled in a report and recommendations were made to CANMET management.

RESULTS

As a result of his travels and visits, the Contractor concluded:

1. A comparison of long-term applied research in Canada with that in other industrialized countries indicates that the Canadian effort is relatively low.

2. In order to encourage development of local facilities, it is desirable for CANMET to expand its contracting activities.

3. The work done at CANMET does not overlap with work done elsewhere.

SUPPORTING DOCUMENTS

Final Report: "Long-Term Applied Research in Construction Materials of Mineral Origin in Canada with Particular Reference to CANMET". (Contract Report No. 2556272)

TITLE: AGGREGATE, CEMENT AND CONCRETE RESEARCH IN CANADA - 1980

CONTRACTOR: Dr. A.M. Neville	FILE NUMBER: 1-9040	FUNDING	
	BEGIN/END: April 81/Oct. 81		
		CANMET:	$ 2 040
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Resource Assessment	OTHER:	--
AUTHORITY: V.M. Malhotra	TECHNOLOGY: Commodity Background Studies	TOTAL:	$ 2 040

OBJECTIVES

Write a report on aggregate, cement, and concrete research in Canada.

PROCEDURE

The contractor had previously prepared a report on cement and concrete research in Canada with special reference to CANMET (Contract No. 0-9078). This report is a summary of the above report with reference to CANMET deleted and prepared in a more general fashion.

RESULTS

The report is a self-contained document and lists details of research work being carried out in Canada by Federal and Provincial governments, industrial and university research organizations and laboratories.

SUPPORTING DOCUMENTS

Final Report: "Aggregate, Cement and Concrete Research in Canada - 1980" (Contract Report No. OSQ81-00074).

TITLE: SURVEY ON THE AVAILABILITY OF MARGINAL AND SHALY AGGREGATES IN THE METROPOLITAN MONTREAL AREA AND THEIR POTENTIAL USE IN CONCRETE

				FUNDING	
CONTRACTOR:	Centre de Recherche et de Contrôle Appliqué à la Construction	FILE NUMBER:	1-9089		
		BEGIN/END:	Nov. 81/March 82	CANMET:	$ 5 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Resource Assessment	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Commodity Background Studies	TOTAL:	$ 5 000

OBJECTIVES

1. Identify available sources of marginal and shaly aggregates in the metropolitan Montreal area for their potential use in concrete.
2. Identify known methods and research needs regarding the evaluation of shale aggregate for use in concrete.

PROCEDURE

1. Study of existing sources of conventional aggregates and factors that will influence their development.
2. Study of the availability of shale and shale aggregates in relation to their exploitability in the area of Montreal.
3. An international survey on existing test methods to evaluate marginal aggregates.

RESULTS

1. Areas where marginal aggregates are most likely to be exploited in the future were located; the principal sources identified include shale limestone and dolostone, and shale of the Utica and Lorraine formations.
2. A number of test methods were identified for the evaluation of marginal aggregates, and research needs were outlined.

SUPPORTING DOCUMENTS

Final Report: "Utilisation de Schistes et de Matériaux Schisteux dans le Béton" (Contract Report No. OSQ81-00125).

TITLE: SYMPOSIUM ON MINERAL FILLERS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	I-9056	FUNDING	
		BEGIN/END:	April 81/Dec. 81		
				CANMET:	$ 5 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Resource Assessment	OTHER:	--
AUTHORITY:	R.K. Collings	TECHNOLOGY:	Commodity Background Studies	TOTAL:	$ 5 000

OBJECTIVES

In cooperation with CANMET staff, organize and conduct a two-day symposium on mineral fillers.

PROCEDURE

The program for the meeting was developed during several meetings between ORF and CANMET staff. Tentative papers/authors were suggested and the program firmed-up based on consultation with selected authors. Announcements of the symposium were placed in appropriate journals, and invitations to attend the symposium forwarded to interested individuals in government and industry by ORF. Following the meeting, papers were bound into a symposium volume and distributed by ORF to symposium delegates.

RESULTS

ORF circulated a questionnaire to symposium delegates following completion of the meeting to ascertain an expression of opinion. Everyone thought the conference to be very worthwhile. All delegates expressed interest in future meetings of this nature - with timing ranging from two meetings per year to one every two to three years. Following completion of the symposium and distribution of symposium volume, a number of requests have been received for copies of the volume - these have been redirected to ORF. Tentative discussions have been held with ORF concerning a second conference on mineral fillers, but there is nothing concrete to date.

SUPPORTING DOCUMENTS

Final Report: "Mineral Fillers - Applications, Specifications, Traditional and Substitute Materials"; Symposium volume; October 20 & 21, 1981.

TITLE: DEMAND PATTERNS FOR MINERAL BASED COMMODITIES IN THE HIGH TECHNOLOGY INDUSTRIES

				FUNDING	
CONTRACTOR:	Arthur D. Little of Canada Limited	FILE NUMBER:	3-9105		
		BEGIN/END:	Jan. 84/June 84		
				CANMET:	$ 30 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Resource Assessment	OTHER:	--
AUTHORITY:	M.C. Campbell	TECHNOLOGY:	Commodity Background Studies	TOTAL:	$ 30 000

OBJECTIVES

Identify mineral commodities (elements) that could experience very rapid growth in demand during this decade and into the 1990's in the emerging or new technologies.

PROCEDURE

The contractor reviewed a number of emerging and new technologies; i.e., catalysis, semiconductors, energy conversion, and sensors. The initial review was a literature review that helped identify possible new applications. This was followed by in-depth discussions with various experts in a number of technologies. Areas of greatest increase in demand and performance were analyzed.

RESULTS

Three elements were identified as having high demand growth potential (10 to 20% per year) over the next 10 years:

1. Gallium (as GaAs), in semiconductors and solar cells.

2. Lithium metal, in batteries and alloys.

3. Neodymium, in magnets and TV faceplates.

Other elements with a good demand growth potential (5 to 10% per year) were identified as yttrium, selected lanthanides, germanium, tellurium and indium, beryllium, and rhodium.

APPLICATION AND ONGOING WORK

The information has been useful in confirming the current R&D directions within CANMET. Furthermore, the report is of considerable interest to a number of Canadian mineral companies in their corporate planning.

For the immediate purposes of CANMET's R&D planning, no follow-up work is proposed. However, it may be that more marketing and manufacturing-oriented agencies would be interested in pursuing the supply capability for these commodities for possible business opportunities.

SUPPORTING DOCUMENTS

Final Report: "Study of Demand Patterns for Mineral Based Commodities in the 'High Technology' Industries".

TITLE: NOVA SCOTIA SILICA STUDY

				FUNDING	
CONTRACTOR:	Fenco Shawinigan Engineering Ltd.	FILE NUMBER:	5-9061		
		BEGIN/END:	July 85/Sept. 85		
				CANMET:	$ 20 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Resource Assessment	OTHER:	--
AUTHORITY:	R.K. Collings	TECHNOLOGY:	Commodity Background Studies	TOTAL:	$ 20 000

OBJECTIVES

Make a detailed study of Nova Scotia silica resources, encompassing deposits, required beneficiation procedures, current activity and interest of producers/would-be producers. Determine the potential of these producers/would-be producers to gain entry into current and developing markets for silica, particularly in eastern Canada and north-eastern United States, with recommendations for such further research as might be indicated.

PROCEDURE

1. Visit the Nova Scotia Dept. of Mines and Energy, discuss Provincial silica resources, and acquire and review information and reports on Nova Scotia occurrences.

2. Visit producers and discuss deposits, processing, beneficiation, product specifications, and applications. Visit the more promising of the Province's silica resources, and obtain samples from these for shipment to CANMET laboratories in Ottawa.

3. Review the acquired information, and prepare a comprehensive report of the results of the study.

RESULTS

The report summarizes the results of the study and, in particular, treats 5 of the more promising deposits under the following headings:

a) ownership
b) location and access
c) site description
d) development history
e) silica quality
f) reserves
g) production, treatment
h) products, markets
i) recommendations.

Included also is a section on silica uses, glass sand beneficiation procedures, and production and consumption.

The report recommends further beneficiation studies if warranted on the basis of a study of silica markets in Atlantic Canada. This study is being carried out by another contractor.

APPLICATION AND ONGOING WORK

The samples provided are being evaluated by CANMET as part of a 3-year project on the evaluation of Canadian silica resources.

TITLE: DEVELOPMENT OF R&D PROJECT DESCRIPTIONS FOR GOLD AND METALLIC MINERALS PROCESSING IN NOVA SCOTIA

CONTRACTOR: P.D.R. Maltby, P. Eng	FILE NUMBER: 5-9098	FUNDING	
	BEGIN/END: July 85/Oct. 85	CANMET:	$ 16 873
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Resource Assessment	OTHER:	--
AUTHORITY: M. Stefanski	TECHNOLOGY: Commodity Background Studies	TOTAL:	$ 16 873

OBJECTIVES

Develop R&D project descriptions to benefit the establishment of a viable Nova Scotia gold industry.

PROCEDURE

1. Review the historical data of Nova Scotia gold processing in the quartz veins contained in the Meguma Group.
2. Discuss the background and aims of the Canada/Nova Scotia Mineral Development Agreement with personnel from CANMET, GSC, and MPS with reference to gold activity in Nova Scotia.
3. Meet with personnel presently active in the gold extraction industry in Nova Scotia. These include Nova Scotia Mines and Energy personnel as well as mining executives, engineers, and geologists.
4. Visit Nova Scotia research facilities and gold-processing plants to determine present physical plant resources.
5. Visit research facilities and personnel with experience in the areas of the proposed R&D projects.
6. Prepare a report describing the justification, benefits, and workplans for selected R&D topics on gold and metallic minerals in Nova Scotia.

RESULTS

Six specific R&D projects related to Nova Scotia gold processing have been suggested and tentatively prepared for bids. Low cost, environmentally acceptable methods are recommended for primary concentration. The recommended R&D processes would also meet strict environmental safety requirements, provided certain conditions relative to marketing or disposing of the by-products are met.

APPLICATION AND ONGOING WORK

In the framework of the Canada/Nova Scotia Mineral Development Agreement, studies on recovery of gold from selected gravity tailings in Nova Scotia and from low-grade gold developments will be undertaken to assess the economic exploitability of these resources.

This project is a first step for these studies.

SUPPORTING DOCUMENTS

Final Report: "Development of R&D Project Descriptions Related to Nova Scotia Gold Deposits".

MINERALS TECHNOLOGY

MINERAL PROCESSING

TITLE: COMMINUTION BIBLIOGRAPHY

CONTRACTOR: D. Vandenhoff	FILE NUMBER: 2-9142	FUNDING	
	BEGIN/END: Oct. 82/March 83		
		CANMET:	$ 4 197
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	OTHER:	--
AUTHORITY: L.L. Sirois	TECHNOLOGY: Beneficiation	TOTAL:	$ 4 197

OBJECTIVES

Complete three quarterly comminution bibliographies for 1980 and four quarterly comminution bibliographies each for 1981 and 1982.

PROCEDURE

This work consisted of literature searching, collecting and reviewing papers, and compiling the entries in the standard bibliographic format for CANMET publications.

RESULTS

Three quarterly bibliographies for 1980.

Four quarterly bibliographies for 1981.

Four quarterly bibliographies for 1982.

SUPPORTING DOCUMENTS

Final Report: "Crushing and Grinding Bibliography", by D.G. Vandenhoff; Division Report MRP/MSL 83-21(LS); Dec. 1982.

TITLE: COMPUTER MODELLING FOR MINERAL INDUSTRY-ORE CHARACTERIZATION FOR GRINDING MILL MODELLING

CONTRACTOR: Noranda Research Centre	FILE NUMBER: 0-9136	FUNDING	
	BEGIN/END: July 81/March 82		
		CANMET:	$ 20 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	OTHER:	--
AUTHORITY: R. Pilgrim	TECHNOLOGY: Beneficiation	TOTAL:	$ 20 000

OBJECTIVES

1. Produce a methodology to get data for ball mill model calibration.
2. Produce FORTRAN routines to help in calibrating ball mill models using already published mathematical theories.
3. Follow methodology (item 1) to produce data sets from Brenda Mines' plant and ore.
4. Apply FORTRAN routines for demonstration purposes on data sets.

PROCEDURE

1. Laval University was subcontracted to act as a consultant on methodology and mathematical theories.
2. Batch tests were performed at Laval University laboratories on Brenda ore to get data for breakage matrix calculation.
3. Two sampling campaigns were performed at Brenda Mines' plant for further residence time distribution (RTD) calculation.
4. One sampling campaign was performed at the same location for further selection function calculation. The program BILMAT, from the SPOC project, was used to adjust the data from a mass balance point of view.
5. FORTRAN routines were written, compiled, and tested on the EMR computer from the Noranda Research Centre (Montreal) using the DATAPAC network.
6. Routines were tested on data sets obtained under the contract, and results compared with those from Laval University APL routines.
7. Other data sets were used for demonstration purposes.

RESULTS

Three programs are available.

1. RTD uses three different mathematical tools to compute RTD.
2. MIXERS uses a fourth method to compute RTD.

   The four methods cover all known possibilities for RTD calculations.

3. FINDBS: According to a menu, several combinations of parameters may be used to get the best calibration of a given ball mill.

All programs are interactive and work well. Several publications have already been produced based on this work.

Two reports are now available:
- one relative to B and S calibration (specific to ball mill modelling).
- the other one relative to RTD calculation (general use).

APPLICATION AND ONGOING WORK

This contract has produced improved data sets for ball mill modelling as well as a greater understanding of ball mill modelling.

SUPPORTING DOCUMENTS

*NOTE: Parts 1 and 2 of this contract were combined in Oct. 1981. Part 1 had a closing date of Nov. 30, 1982; Part 2's closing date was March 31, 1983. This summary sheet covers the work done in Part 1 only.

TITLE: PREPARATION OF COMMINUTION TECHNOLOGY SOFTWARE

				FUNDING	
CONTRACTOR:	E.E. Berry & Associates Ltd.	FILE NUMBER:	I-9116		
		BEGIN/END:	Dec. 81/March 82		
				CANMET:	$ 7 560
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	D. Laguitton	TECHNOLOGY:	Beneficiation	TOTAL:	$ 7 560

OBJECTIVES

1. Implement non-linear optimization programs for model parameterization.
2. Conduct a comparative study of these programs on test problems.
3. Complete documentation of MATBAL3.
4. Assess utility of SPARPACK software.

PROCEDURE

1. Individual testing of 5 programs.
2. Selection of optimization problems with 3, 11, and 23 variables.
3. Determination of best search strategy for each program.
4. Comparison of performances of programs in test problems.
5. Analysis of results.
6. Investigation of the potential of the SPARPACK software in the SPOC project.

RESULTS

1. The documentation of the MATBAL3 program has been completed and constitutes one chapter of the SPOC manual.
2. Five optimization programs have been tested and compared and are directly accessible in the SPOC libraries.
3. The matrices used in the MATBAL algorithm are not sparse enough or large enough to justify using the SPARPACK software.

APPLICATION AND ONGOING WORK

The results obtained in this study have contributed to the non-linear optimization capacity of the SPOC software. The MATBAL3 program is now routinely distributed.

SUPPORTING DOCUMENTS

Contract reports relating to the SPOC Project are continually being updated. In order to ensure that the public does not purchase redundant material, updated reports are available only through Dr. D. Laguitton of CANMET's Mineral Sciences Laboratories - Phone (613) 996-7953.

TITLE: PREPARATION OF A SOFTWARE MODULE COMPATIBLE WITH THE SPOC SYSTEM FOR SIMULATING OPERATION OF A MOGENSEN SIZER

CONTRACTOR:	University of Western Ontario	FILE NUMBER:	3-9156	FUNDING	
		BEGIN/END:	Nov. 83/June 84		
				CANMET:	$ 4 192
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	D. Laguitton	TECHNOLOGY:	Beneficiation	TOTAL:	$ 4 192

OBJECTIVES

Preparation of a software module compatible with the SPOC system for simulating operation of a Mogensen Sizer.

PROCEDURE

1. Report the effect of:
   a) Screen mesh size
   b) Screen inclination
   c) Feed
   d) Line content
   e) Vibrating amplitude and frequency

   of the Mogensen Sizer on its performance. This report will constitute the model description section of the program users' guide.

2. Code in FORTRAN 4 a mathematical model of the Mogensen Sizer in which the above parameters are user-controlled variables.

3. Enter the program on the EMR Cyber computer by remote access or by shipment of a card deck or tape.

4. Verify the proper functioning of the program on the EMR computer.

5. Document the simulator in the standard format used in Chapters 5A and 5B of the SPOC Manual as a final report. This report must include an executive summary in English and French.

RESULTS

The following programs were installed on the EMR computer:

1. A main program called EXMOGS; four subroutines: MOGS, MG2OUT, MGNOUT, DETOUT; and a data set for executing these programs.

2. The programs simulate a Mogensen Sizer as observed in experiments where the following variables were varied: feed rate, angle of inclination, screen aperture size, vibration frequency and amplitude, and material specific gravity.

APPLICATION AND ONGOING WORK

Programs to be used in a coal plant simulator.

SUPPORTING DOCUMENTS

"Performance Characteristics of a Probability Screening Machine", by J.M. Beeckmans, E. Hu, R. Germain, and A. McIntyre, submitted to Powder Technology.

TITLE: EVALUATION OF NEW DEPRESSANTS FOR THE SELECTIVE FLOTATION OF MASSIVE SULPHIDE ORES

CONTRACTOR:	Lakefield Research of Canada Ltd.	FILE NUMBER:	2-9130	FUNDING	
		BEGIN/END:	Oct. 82/Oct. 83		
				CANMET:	$ 30 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		DSS:	37 500
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	DOE:	2 500
AUTHORITY:	A.I. Stemerowicz	TECHNOLOGY:	Beneficiation	TOTAL:	$ 70 000

OBJECTIVES

The objective of the test program was to compare the effectiveness of newly developed organic depressant mixtures for the selective flotation of base-metal sulphides with the standard inorganic depressants currently in use: cyanide, zinc sulphate, sulphur dioxide, and lime. The basic ingredient in all these mixtures was high molecular weight lignin sulphonate. Other substances added to make various two- and three-component mixtures were starch, guar, zinc sulphate, and sulphur dioxide.

An important consideration was that the new depressants will have much less of an impact on the environment because they will eliminate or reduce the use of toxic cyanide.

PROCEDURE

A total of 167 bench-scale flotation tests were carried out on the following Canadian sulphide ores:

1. Noranda-Geco Division copper-zinc
2. Kidd Creek Mines copper-zinc
3. Kidd Creek Mines copper-lead-zinc
4. Brunswick Mining (BMS) copper-lead-zinc
5. Cyprus Anvil lead-zinc.

In each case, results for standard tests based on current plant practice that employs standard depressants were compared to test results obtained with various organic depressant mixtures.

RESULTS

For all ores except BMS, the addition of the organic depressant mixtures resulted in improved selectivity, i.e., more pyrite and sphalerite was depressed in the initial flotation step. This was accompanied by complete elimination of the need for cyanide on the GECO ore and a 50% reduction in cyanide required for the Cyprus Anvil ore. In the case of the Kidd Creek ore, it was found that the amounts of sulphur dioxide and lime normally required could be reduced when the depressant mixtures were used. On the BMS ore, there were no clear-cut differences obtained with organic depressant mixtures when compared to the standard procedure.

APPLICATION AND ONGOING WORK

The depressant mixtures tested could be employed on practically all types of sulphide ores. No further work along these lines is planned. Copies of the report have been sent to the mines submitting the samples.

TITLE: ADAPTABILITY OF THE KNELSON CONCENTRATOR TO ORE BENEFICIATION

CONTRACTOR: Lee-Mar Industries Ltd.	FILE NUMBER: 4-9180	FUNDING	
	BEGIN/END: Nov. 84/March 85		
		CANMET:	$ 7 215
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	OTHER:	--
AUTHORITY: Marius A. Cristovici	TECHNOLOGY: Beneficiation	TOTAL:	$ 7 215

OBJECTIVES

1. Evaluate the technological characteristics and performance of the Knelson Concentrator.

2. Investigate the possibility of upgrading a gold ore sample (Forest Hill tailings) using the Knelson Concentrator.

PROCEDURE

1. Tests to determine the influence of various operating conditions (feed rate, water back-pressure rate) on concentrating performance of the equipment.

2. Tests to improve the results by retreating the concentrate, or by regrinding the ore.

3. Demonstration test in a placer to evaluate and examine the equipment performance in a commercial application.

RESULTS

The Knelson Concentrator is a centrifugal separator that uses high gravitational forces to concentrate mineral values.

Upgrading of Forest Hill tailings was unsuccessful. It is believed that liberation of gold minerals was not sufficient to obtain a significant concentration by this type of equipment.

Good results were, however, obtained with placer ore. After removing the waste rock in the field, the rougher concentrate was upgraded in a smaller unit from 4.7 to 45.9 g/t Au for a gold recovery of 98.4% related to the retreatment stage.

APPLICATION AND ONGOING WORK

The Knelson Concentrator can be used to upgrade gold and other types of ore where there is a significant difference between the specific gravities of the constituents.

A proposal will follow to purchase a laboratory unit for research to beneficiate various types of ores.

SUPPORTING DOCUMENTS

Final Report: "Investigation of Adaptability of the Knelson Concentrator to Ore Beneficiation".

TITLE: SURFACE TENSION DETERMINATIONS OF LEAD PRODUCING SALT ELECTROLYTES

CONTRACTOR: University of Toronto	FILE NUMBER: I-9064	FUNDING	
	BEGIN/END: Sept. 81/Sept. 83		
		CANMET:	$ 55 972
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	OTHER:	--
AUTHORITY: K. Bartels	TECHNOLOGY: Metal Extraction	TOTAL:	$55 972

OBJECTIVES

Provide basic engineering data for use in the fused salt electrolytic production of lead, specifically the surface tensions of $PbCl_2$-KCl-LiCl and $PbCl_2$-KCl-NaCl systems.

PROCEDURE

1. Measure the surface tensions and densities of these systems for a series of temperatures ranging from the liquidus to 600°C, using the maximum bubble pressure method.

2. Determine associated "wetting" characteristics of the fused salt systems by measuring contact angles using X-ray fluoroscopy.

RESULTS

1. The techniques for surface tension measurements were reviewed. Based on this review, the maximum bubble pressure technique was recommended for the aforementioned high-temperature $PbCl_2$ systems. Surface tensions in the ternary systems were estimated based on the reviewed binary systems.

2. The contact angles formed between liquid $PbCl_2$-alkali chloride mixtures and graphite, alumina, quartz, zirconium oxide, boron nitride, and inconel were measured. Alumina, quartz, and inconel were completely wetted by all the salt mixtures used in this study, while the contact angles on graphite were between 120° to 140° when an argon atmosphere was used. Introduction of dry chlorine gas did not affect the contact angle on graphite, while the introduction of air or dry air lead to a rapid decrease in the contact angle on both graphite and amorphous carbon. The surface tension was measured for two ternary mixtures containing 40 mol % $PbCl_2$.

3. The maximum bubble pressure method was used to determine the surface tension and density of melts within the $PbCl_2$-KCl-NaCl system. The temperature range of this study was from 450 to 800°C. In all cases, the surface tension was found to decrease with increasing temperature. At constant molar ratio of KCl to NaCl, a minimum in the surface tension was observed at approximately 40 mole % $PbCl_2$. The ternary surface tension values were found to obey the simple additivity expression of the binary surface tensions of $PbCl_2$-KCl and $PbCl_2$-NaCl. Based on these findings, constant surface tension contours have been drawn. In a similar manner, the surface tension in the ternary $PbCl_2$-KCl-LiCl system has been estimated.

APPLICATION AND ONGOING WORK

Surface tension data are essential when considering construction of crucible materials and optimum melt compositions for lead recovery by fused salt electrolysis. A further study on the viscosity of these systems is now underway.

SUPPORTING DOCUMENTS

There are three final reports:

1. "Surface Tension Measurement as Applied to Fused Salt Systems and a Literature Review of Surface Tensions in the Systems $PbCl_2$-KCl-NaCl and $PbCl_2$-KCl-LiCl", by T. Fujisawa and J.M. Toguri.

2. "Wetting Behaviour of Molten $PbCl_2$-Alkali Chloride Mixtures", by T.A. Utigard.

3. "Surface Tension and Density of the Molten $PbCl_2$-KCl-NaCl Ternary System", by T. Fujisawa, T.A. Utigard, and J.M. Toguri.

[Contract Report No. OSU81-00274 for all three reports].

TITLE: DETERMINATION OF HYDRONIUM ION IN JAROSITE-TYPE COMPOUNDS

CONTRACTOR: Carleton University	FILE NUMBER: 2-9076	FUNDING	
	BEGIN/END: Aug. 82/March 83		
		CANMET:	$ 9 937
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	OTHER:	--
AUTHORITY: J.E. Dutrizac	TECHNOLOGY: Metal Extraction	TOTAL:	$ 9 937

OBJECTIVES

1. Confirm the existence of hydronium ion in jarosite-type compounds.

2. Quantify the amounts of this ion in hydronium-sodium jarosite solid solutions.

The detection of hydronium will be done principally with low-temperature IR spectroscopy, but laser Raman spectroscopy will also be tried.

PROCEDURE

1. The Scientific Authority synthesized both end-member hydronium jarosite and hydronium-sodium jarosite solid solution series. These were well characterized at CANMET.

2. The contractor prepared various H_3O^+ standards.

3. Low-temperature infrared spectroscopy was used to try to confirm the existence of H_3O^+ in jarosite-type compounds, and to quantify its concentration.

4. A few exploratory tests were done using laser Raman spectroscopy to see if this is a useful tool for H_3O^+ characterization.

RESULTS

1. Laser Raman spectroscopy was not a useful tool for H_3O^+ characterization because of in situ sample heating.

2. Several low-temperature IR spectra were obtained and these were analyzed with a computer subroutine.

3. The results confirm a three-band model of the H_3O^+-H_2O IR spectral region. Although the results are not unequivocal, the existence of H_3O^+ is suggested.

4. A quantitative analysis of H_3O^+ was not successful since high H_2O levels are indicated. This likely results from different local H_3O^+ and H_2O environments in the jarosite-type structures relative to the standards used.

APPLICATION AND ONGOING WORK

This work is continuing at NRC where NMR spectroscopy is being used to confirm the existence of H_3O^+.

TITLE: FERRIC CHLORIDE LEACHING OF SULPHIDE MINERAL CONCENTRATES - PHASE I

CONTRACTOR:	Acres Davy McKee Engineering Inc.	FILE NUMBER:	3-9083	FUNDING	
		BEGIN/END:	Nov. 83/March 85		
				CANMET:	$ 45 700
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	B.H. Lucas	TECHNOLOGY:	Metal Extraction	TOTAL:	$ 45 700

OBJECTIVES

1. Review of open literature and CANMET literature.
2. Assessment of CANMET work.
3. $FeCl_3$ flowsheet design.
4. Pilot plant design.
5. Pilot plant capital cost estimate.

The objective is to fully assess the process and the progress to date and, on that basis, to develop a plan to extend CANMET work.

PROCEDURE

1. Conduct computer literature search.
2. Evaluation of CANMET work.
3. Consultation with engineering companies with chloride experience.
4. Assessment of data.
5. Flowsheet development.
6. Cost estimation.
7. Final report.

RESULTS

1. The literature search did not provide a relevant reference in which silver, lead, zinc, and copper can be recovered in a single flowsheet based upon ferric chloride leaching of complex base metal sulphide concentrates. Information, however, was available on the extractions of individual metals, and other combinations of metals, from the ferric chloride medium.
2. The assessment of CANMET test work revealed that it had progressed to a stage where a potential flowsheet had been identified. However, in this flowsheet only certain sections had been tested sufficiently to enable the determination of adequate design criteria.
3. A preferred flowsheet has been developed based upon the two-stage ferric chloride leaching flowsheet proposed by CANMET, supplemented by information obtained from the literature search.
4. Design criteria have been developed and a preliminary design for a pilot plant has been produced. Bench-scale testing, to be carried out during Phase 2 of the program, will be required to more clearly define the design criteria for certain sections of the pilot plant.
5. Capital cost of the pilot plant has been estimated at $764 800.

The pilot plant is unique in that silver, lead, zinc, and copper are extracted in one integrated flowsheet. Several other plants have successfully extracted individual metals, or combinations of metals, but none have been used to extract the silver/lead/zinc/copper combination.

APPLICATION AND ONGOING WORK

This contract exposed the deficiencies of our flowsheet development to date, i.e., selection of process elements to be made; bench work to complete prior to final definition of a flowsheet for pilot plant testing.

TITLE: FERRIC CHLORIDE LEACHING OF SULPHIDE MINERAL CONCENTRATES - PHASE 2

CONTRACTOR:	Bacon, Donaldson & Associates Ltd.	FILE NUMBER:	4-9202	FUNDING	
		BEGIN/END:	Nov. 84/April 85		
				CANMET:	$ 247 496
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	B.H. Lucas	TECHNOLOGY:	Metal Extraction	TOTAL:	$ 247 496

OBJECTIVES

1. Confirm parameters for certain unit operations.
2. Develop parameters for certain other unit operations.
3. Select suitable equipment size, select material of construction, and cost equipment for a 10 kg concentrate per hour continuous pilot plant.

PROCEDURE

1. Perform bench testwork on various unit operations.
2. Develop and select parameters for pilot-plant design.
3. Do a mass balance and select equipment of proper size and material plus auxiliary equipment.
4. Estimate the capital cost for a pilot plant.

RESULTS

1. Developed new 3-stage leach procedure.
2. Did not confirm Pb concentration unit operation.
3. Developed conditions for lead chloride production.
4. Did not improve on zinc solvent extraction.
5. Determined conditions for $FeCl_2$ oxidation.
6. Determined conditions for $FeCl_2$ chlorination.
7. Sized and costed pilot plant.

APPLICATION AND ONGOING WORK

This contract was pursued while CANMET personnel performed similar tests. CANMET is finalizing the parameters for the $FeCl_3$ leach process and this contract supplemented our work.

SUPPORTING DOCUMENTS

Final Report: "Ferric Chloride Leaching of Sulphide Mineral Concentrates - Phase 2".

Appendix B: "Laboratory Testwork Details" (Contract Report No. OSQ84-00290 for both volumes).

TITLE: STATE-OF-THE-ART REVIEW ON THE USES OF MICROORGANISMS IN MINERAL BENEFICIATION AND ORE PROCESSING

				FUNDING	
CONTRACTOR:	Beacon Research Associates Limited	FILE NUMBER:	4-9182		
		BEGIN/END:	Oct. 84/March 85		
				CANMET:	$ 30 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	H.W. Parsons	TECHNOLOGY:	Metal Extraction	TOTAL:	$ 30 000

OBJECTIVES

The objective of the contract is to provide the mining industry with a comprehensive document that will enable the assessment of (a) the potential of the use of microorganisms in mineral beneficiation and ore processing; and (b) the need for further R&D prior to use by industry.

PROCEDURE

The contractor shall prepare a comprehensive and critical review on the use of microorganisms in mineral beneficiation and ore processing.

In this critical state-of-the-art review the contractor shall:

1. Identify the various operations in which microorganisms could be, or are, used and describe the characteristics of the organisms utilized.

2. Delineate areas of needed research prior to the practical application of these microorganisms in industry.

No testwork is to be conducted under the terms of this contract.

RESULTS

Although the contractor issued a massive 234-page report, only about 6 or 7 pages were devoted to applications (such as flocculation, precipitation, chelation, etc.) other than bioleaching and bioadsorption. The contractor sidetracked himself into discussing bioleaching and bioadsorption, and seemed to lose sight of his objective.

Thus, the contractor fulfilled the legal requirements of the contract, but did not fulfill the spirit or intention of the literature review.

APPLICATION AND ONGOING WORK

Because of the lack of references to applications other than bioleaching and bioadsorption, there is practically no follow-up of this work.

TITLE: COMPARISON OF SULPHURIC ACID AND CARO'S ACID LEACHING WITH HYDROCHLORIC ACID LEACHING OF ELLIOT LAKE AND SASKATCHEWAN URANIUM ORES WITH RESPECT TO THE MINERALOGY OF THE ORES AND LEACHING BEHAVIOUR

CONTRACTOR:	Queen's University	FILE NUMBER:	4-9168	FUNDING	
		BEGIN/END:	Sept. 84/March 85		
				CANMET:	$ 10 370
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	G. Ritcey	TECHNOLOGY:	Uranium Extraction	TOTAL:	$ 10 370

OBJECTIVES

Examine leached and unleached Saskatchewan complex ores to determine the reasons for minerals being left unattached during the leaching process.

PROCEDURE

Ores subjected to mineral identification by optical techniques and semi-quantitative electron microprobe analysis.

RESULTS

Low-intensity radioactivity is distributed uniformly throughout the ore and residues of the HCl, H_2SO_4, HNO_3, and Cl_2 leaches. The most effective lixiviants for dissolution of minerals containing uranium (pitchblende and coffinite) were identified as $FeCl_3$ and H_2SO_4.

APPLICATION AND ONGOING WORK

The information provides valuable data for continuing investigations on improving uranium recovery.

SUPPORTING DOCUMENTS

Final Report: "Identification of Residual Phases in Leached Midwest Lake Uranium Ore".

TITLE: EVALUATION OF BIOMASS FOR URANIUM RECOVERY FROM PROCESS STREAMS

CONTRACTOR:	Senes Consultants Ltd.	FILE NUMBER:	4-9172	FUNDING	
		BEGIN/END:	Nov. 84/Sept. 85		
				CANMET:	$ 59 985
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	V. Sanmugasunderam	TECHNOLOGY:	Uranium Extraction	TOTAL:	$ 59 985

OBJECTIVES

Rank the biosorption capacities of the following types of biomass:

1. Fungal mycellum.
2. Microbial derivatives.
3. Mixed microbial cultures.
4. Yeasts.
5. Algae.

PROCEDURE

The specific growth rates and biomass yields of actinomycete, fungal, and yeast biomass were evaluated in continuously operating fermentors (chemostat) and the algal biomass in fed-batch growth vessels.

Uranium adsorption, equilibrium distribution, and desorption studies were performed on the various types of biomass.

RESULTS

The study confirmed that the fungus Rhizopus arrhizus and the bacteria Streptomyces levoris are simple to cultivate and are effective biomass for adsorption of uranium. The capacity to biosorb is a strong function of pH and the presence of other ionics species reduces the amount of U adsorbed. Sodium bicarbonate ($NaHCO_3$) is a simple and effective stripping agent for desorption of uranium from biomass.

Production costs were estimated to be $30-$35/kg of U_3O_8 produced. The contractor recommends further work on a pilot-plant scale and further studies on the development of robust immobilized biomass.

The contractor has produced an excellent document of the results and recommendations.

APPLICATION AND ONGOING WORK

Two RFP's - one for further biosorption studies with fungi isolated from Denison Mines, and another to compare ion exchange - reverse osmosis and biosorption. Further work in this regard will depend on the outcome of these studies.

TITLE: LOW TEMPERATURE FLUXES IN METALLURGY

CONTRACTOR: Scintrex Limited	FILE NUMBER: 3-9062	FUNDING	
	BEGIN/END: June 83/March 84		
		CANMET:	$ 7 322
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Mineral Processing	DSS:	30 000
AUTHORITY: A.H. Webster	TECHNOLOGY: By-Product Recovery	TOTAL:	$ 37 322

OBJECTIVES

Investigate the dissolution of titania slag (from QIT - Fer et Titane Inc.) and the minerals chalcopyrite and pyrochlore in low-temperature fluxes recently developed by Scintrex Limited, and study methods for recovering the valuable constituents after flux treatment. Also consider the possibility of recycling or regenerating the flux.

The fluxes, consisting of a strong oxidizing agent (potassium persulphate) and a halide component (sodium chloride), had been found to solubilize many metals and geological materials. Scintrex Limited, in an unsolicited proposal, suggested investigations to determine possible applications of the fluxes in extractive metallurgy.

PROCEDURE

The characteristics of the flux were studied. Thermal analysis was used to determine freezing points in the $NaCl-K_2S_2O_8$ system. Gases evolved from the molten flux were examined, and the cooled, solidified flux was analyzed to determine any changes in composition.

Chalcopyrite ($CuFeS_2$), titania slag (from smelting ilmenite) and pyrochlore [$(Ca_{0.47}Na_{0.7})Nb_2O_5.4F_{0.8}$] were treated with fluxes with compositions covering the whole range from $K_2S_2O_8$ to NaCl. The quantities of Cu and Ti released by the flux treatment were determined by leaching the cooled fluxes with dilute acid and analyzing the solution obtained. In the case of pyrochlore, difficulties were encountered due to precipitation of a niobium compound on leaching. The effects of temperature and duration of flux treatment were investigated for each material.

Under a sub-contract with Hatch Associates Ltd., a preliminary comparison was made between the economics of a flux process and conventional processing. The possibilities for recycling or disposal of spent solution were examined.

RESULTS

A tentative phase diagram for the system $NaCl-K_2S_2O_8$ showed a eutectic at 420°C for 25% NaCl. After fusion and cooling, the sulphate content of the flux was lower than expected, but only minor quantities of chloride were lost.

The maximum solubilization of copper from chalcopyrite was about 3.5% Cu in a flux with 90% $K_2S_2O_8$. Solubilization of Cu increased with temperature (420° to 800°C), but was independent of time. The titania slag underwent maximum attack by a flux containing only $K_2S_2O_8$; about 8.7% Ti was taken up into the flux. The solubilization of Ti was independent of temperature and time. The fine precipitate formed on leaching a flux after attack on pyrochlore could be separated from residual pyrochlore by screening. This precipitate, after purification and ignition, gave Nb_2O_5. The best flux composition, 90% $K_2S_2O_8$, dissolved 27% of its weight of pyrochlore. If, instead of water, oxalic acid solution was used for leaching the cooled flux, a soluble niobium complex was formed.

It was concluded, on the basis of the quantities of flux required, that the costs of $K_2S_2O_8$ reagent would be greater than present conventional processing costs, thus rendering the flux process uneconomic. Recycling potassium to make $K_2S_2O_8$ would decrease costs, but not sufficiently to make the process attractive.

APPLICATION AND ONGOING WORK

The fluxes may have application in analytical chemistry for attacking mineral samples that are resistant to dissolution by other methods.

SUPPORTING DOCUMENTS

Final Report: "Low Temperature Fluxes in Metallurgy".

TITLE: DEVELOPMENT OF A FLOTATION PROCESS FOR THE RECOVERY OF SILVER FROM ZINC PLANT RESIDUES

CONTRACTOR:	Noranda Inc.	FILE NUMBER:	3-9078	FUNDING	
		BEGIN/END:	Aug. 83/Jan. 85		
				CANMET:	$ 59 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	A.I. Stemerowicz	TECHNOLOGY:	By-Product Recovery	TOTAL:	$ 59 000

OBJECTIVES

Investigate the flotation behaviour of silver-bearing minerals commonly found in Canadian electrolytic zinc plant residues with the view to developing techniques for the recovery of silver from these residues.

PROCEDURE

A literature and patent search on silver mineral flotation and recovery of silver from acid leach residues was carried out. Bench-scale flotation studies were then conducted with both natural and synthetic silver-bearing minerals: native silver, cerargyrite, argentite, tetrahedrite, silver jarosite, precipitated silver sulphide and silver chloride, and silver-doped pyrite and sphalerite. Flotation feed consisted of an appropriate amount of silver mineral mixed with finely ground sand. In some tests with cerargyrite and silver jarosite, slimes in the form of hematite, goethite, or ammonium jarosite were added to the feed. Test variables investigated were: collector type, pH, sulphidization, and the use of slime depressants. Finally, batch flotation tests were conducted on four different types of zinc plant acid leach residues applying the knowledge gained in the work on silver minerals. Also, several of the flotation processes used in offshore zinc plants were tried on the residues.

RESULTS

It was found that both natural and synthetic silver minerals, with the exception of silver jarosite, could be floated readily with sulphide collectors in an acid media. The range of recoveries obtained was 92 to 99%. Chemically precipitated silver jarosite did not respond to this flotation technique, but equally high recoveries could be obtained using oleic acid or petroleum sulphonate in a mildly alkaline pulp. However, the inclusion of slimes in the feed resulted in a sharp drop in recovery of the silver jarosite. Flotation tests under acidic conditions with zinc plant acid leach residues give silver recoveries ranging from 8 to 80%, with freshly prepared neutral leach residue giving the highest and hematite residue the lowest silver recoveries, respectively. The results, together with the demonstrated ready floatability of silver compounds believed to occur in zinc plant acid leach residues, indicate that the successful flotation of silver from residue requires that the leach conditions be controlled to maintain silver in a liberated and floatable form.

APPLICATION AND ONGOING WORK

The techniques are applicable to any type of silver-bearing acid leach residue. Further work is warranted on the flotation of silver-bearing jarosites, and on studies of leach conditions that would result in the formation of floatable silver compounds.

MINERALS TECHNOLOGY

ENVIRONMENTAL TECHNOLOGY

TITLE: VEGETATION OF URANIUM MILL TAILINGS AT ELLIOT LAKE, ONTARIO

CONTRACTOR: Erocon Limited	FILE NUMBER: 8-9136	FUNDING	
	BEGIN/END: May 79/Aug. 79		
		CANMET:	$ 20 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: D. Murray	TECHNOLOGY: Tailings	TOTAL:	$ 20 000

OBJECTIVES

Complete the annual maintenance and seeding required for a large-scale vegetation trial on uranium mill tailings at Elliot Lake.

PROCEDURE

1. Adjust drainage contours to permit free drainage of all surface water.
2. Apply soil amendments of limestone and fertilizer.
3. Incorporate amendments into the top 15 cm of tailings.
4. Seed the unvegetated areas.
5. Apply maintenance fertilizer to previously vegetated areas.

RESULTS

The work was satisfactorily completed on the vegetated areas, but grading and preparation of the unvegetated areas was extremely difficult. Poor weather conditions and limited gradient drop resulted in high soil moisture and poor planting conditions. A large part of this area still remains barren.

APPLICATION AND ONGOING WORK

Maintenance work of fertilization will continue. This was year 2 of a 5-year stabilization program. Proposals are being prepared on how to handle the barren area.

SUPPORTING DOCUMENTS

1. The final report is in the form of a letter from Erocon Ltd. outlining the work done.
2. The full report of the work done under this contract is in Division Report MRP/MRL 80-12 (TR) - "Surface Stabilization: Waste Management Demonstration Study; Progress Report 1978/79"; by D.R. Murray; February 1980.

TITLE: EFFECT OF SURFACE TREATMENT OF TAILINGS AREAS ON QUANTITY AND QUALITY OF EFFLUENT

CONTRACTOR: Rio Algom Limited	FILE NUMBER: 8-9133	FUNDING	
	BEGIN/END: April 79/March 80		
		CANMET:	$ 7 294
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	7 294
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: D.R. Murray	TECHNOLOGY: Tailings	TOTAL:	$ 14 588

OBJECTIVES

Prepare, in conjunction with CANMET, a report to describe the effect of surface treatment of tailings on the quantity and quality of effluent. Include the level of confidence that can be placed on the conclusions and if a continuation of the study would be of any significant value.

PROCEDURE

1. The surface treatment of 1976 will be maintained in good order.

2. The effluent from six pits, both surface runoff and seepage, will be collected and sampled on a bi-weekly basis and analyzed for the following: pH; total dissolved solids; Ra-226; sulphate; acidity/alkalinity; selected heavy metals Fe, Cu, Al (totals); nitrate; ammonia; electrical conductivity.

3. The total quantity of effluent will be monitored on a daily basis along with a daily record of rainfall. Snowfall accumulation will be determined.

RESULTS

The pits were maintained and samples taken as required. The report of the data was examined by CANMET and Rio Algom personnel in preparation of the final report, which was published as indicated below under supporting documents.

There were a number of mechanical reservations about the pit functions, yet there appeared to be no benefit per se in the long run from the use of different surface treatments to control water quality within environmentally acceptable limits.

APPLICATION AND ONGOING WORK

The data collected over the past five years have provided a database making educated interpretation of the problems with tailings surface treatment possible. The data are being examined closely because of their important relationship to other hydrological and geochemical studies planned for the field and the laboratory. New direction will likely result from this study to extend the waste management technology.

SUPPORTING DOCUMENTS

Final Report: "Effect of Surface Treatment of Tailings on Effluent Quality", by D.R. Murray and D. Okuhara. (Contract Report No. OSQ79-00033).

The final report is a paper that was published in Reclamation Review, Volume 3, Number 3, 1980, on pages 169-177.

TITLE: ASSESSMENT OF THE FUNCTIONAL CAPABILITIES OF TEST PIT SURFACE

CONTRACTOR: Rio Algom Limited	FILE NUMBER: 2-9009	FUNDING	
	BEGIN/END: June 82/March 83		
		CANMET:	$ 4 755
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: D. Murray	TECHNOLOGY: Tailings	TOTAL:	$ 4 755

OBJECTIVES

A study to investigate the impact of surface treatment on tailing seepage water was initiated in 1975. After five years of operation, the results were published in 1980. The report highlighted several mechanical irregularities which could not be explained at that time, one of which was the reduction in seepage flow. Some exploratory excavation would shed light on the problem and make corrective measures possible.

PROCEDURE

1. Excavate the effluent collection lines at the base of the vegetated test pit with supports to hold up pit liner and material.

2. Cut the drainage tile effluent line to permit access to the drainage tile from outside.

3. Assess the condition of the tile and blockages that may be occurring to explain the limited flow from the tile line.

4. Perform other excavation as necessary to verify with other pits or material.

RESULTS

The surface test pits at Rio Algom's Quirke Mine site were examined for their functional capabilities by cutting open the tile drainage lines. The lines were found to be plugged with tailings and iron precipitates. All lines were cleaned, flushed, and restored to their designed functions. Flushing lines were installed to facilitate cleaning if required. The results have indicated the need for oxygen interceptors to minimize chemical precipitates plugging the lines again.

APPLICATION AND ONGOING WORK

Application to the installation of future surface test pits and their design criteria.

SUPPORTING DOCUMENTS

Final Report: "Evaluation of Surface Treatment Test Pits", by D.R. Murray and H. Willett; Division Report MRP/MRL 82-148(TR); November 1982 (Contract Report No. OSQ82-00037).

TITLE: BENCH-SCALE EVALUATION OF THE DEWATERING CHARACTERISTICS OF $Ba/RaSO_4$

				FUNDING	
CONTRACTOR:	International Environmental Consultants Ltd.	FILE NUMBER:	9-9030		
		BEGIN/END:	July 79/Oct. 79		
				CANMET:	$ 4 588
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	DOE:	$ 4 588
AUTHORITY:	Dr. J.M. Skeaff	TECHNOLOGY:	Tailings	TOTAL:	$ 9 176

OBJECTIVES

Conduct a bench-scale evaluation of the dewatering characteristics of $Ba/RaSO_4$ sludge.

The purpose of the work is to generate data.

PROCEDURE

Tests conducted were:

1. Physical characterization.
2. Gravity thickening.
3. Capillary suction time.
4. Specific resistance.
5. Centrifugation.
6. Vacuum filtration.
7. Freeze-thaw.

RESULTS

The $Ba/RaSO_4$ sludge is difficult to filter. Polymer additions would probably be needed to increase filtration rates.

APPLICATION AND ONGOING WORK

Results form a database for a study of methods for recovery and dewatering of $Ba/RaSO_4$ sludges (8-9032).

SUPPORTING DOCUMENTS

Final Report: "Physical-Chemical Properties of $Ba/RaSO_4$ Sludges". The final report contains lab data only.

The results are evaluated in Division Report MRP/MSL 80-7(TR).

TITLE: RECOVERY OF CONTINUOUS DRILL CORE SAMPLES FOR MICROBIOLOGICAL PROFILES FROM THE NORDIC TAILINGS DEPOSIT, ELLIOT LAKE, ONTARIO

CONTRACTOR:	Site Investigation Services Ltd.	FILE NUMBER:	1-9142	FUNDING	
		BEGIN/END:	May 82/Aug. 82		
				CANMET:	$ 20 400
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	Dr. M. Silver	TECHNOLOGY:	Tailings	TOTAL:	$ 20 400

OBJECTIVES

1. Obtain continuous drill core samples of the Nordic tailings deposit from the surface to the underlying peat layer.

2. Recover, contain, and transport drill core samples to a designated sample recovery area adjacent to the tailings deposit.

PROCEDURE

Using a truck-mounted power auger drill equipped with a 10.8 cm (4.25 in.) hollow stem auger, 4 core samples were obtained from the Nordic tailings by advancing a 7.6 cm (3 in.) diameter thin-wall aluminium tubing by light tapping with a 63.5 kg (140-lb) drop hammer. The aluminium tubing was withdrawn and cut into 15-cm segments.

RESULTS

All 4 core samples were successfully obtained, cut into 15-cm segments, and delivered to Dr. M. Silver.

APPLICATION AND ONGOING WORK

Assessment of bacterial populations in the Nordic uranium tailings.

SUPPORTING DOCUMENTS

Final Report: "Recovery of Continuous Drill Core Samples for Microbiological Profiles from the Nordic Tailings Deposit, Elliot Lake, Ontario".

TITLE: CONTINUOUS CORE SAMPLING OF THE NORDIC MAIN TAILINGS AREA, ELLIOT LAKE, ONTARIO

CONTRACTOR:	Site Investigation Services Ltd.	FILE NUMBER:	3-9021	FUNDING	
		BEGIN/END:	June 82/Aug. 83		
				CANMET:	$ 8 630
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	T.P. Lim	TECHNOLOGY:	Tailings	TOTAL:	$ 8 630

OBJECTIVES

In order to develop an overall balance of the radionuclides in an abandoned uranium tailings area, as well as determine their distribution with depth, it is necessary to obtain drill core samples of the tailings solids for analysis. This is a continuation of the previous year's project to complete the mass balance study.

PROCEDURE AND RESULTS

1. Continuous core samples from three locations on the Nordic Main tailings area were taken from the surface to the base of the tailings (a maximum depth of 30 ft) plus a continuous core sample of the peat at each location.

2. To prevent cross contamination, no drilling mud was used.

3. The contractor cut the samples into 1 foot lengths, placed each sample in a watertight polyethylene wide-mouth container and capped it to preserve the original sample moisture content. Samples were labelled and delivered to the Scientific Authority.

APPLICATION AND ONGOING WORK

This technique can be used elsewhere in Canadian soft tailings deposits for similar investigations as outlined in the objectives.

SUPPORTING DOCUMENTS

Final Report: "Report on Sampling Techniques; Nordic Mines Tailings Deposit, Elliot Lake, Ontario".

TITLE: ANALYSIS OF URANIUM TAILINGS SAMPLES FOR RADIONUCLIDES

CONTRACTOR: Various	FILE NUMBER: 0-9059-1/0-9059-2	FUNDING	
	BEGIN/END: Jan. 81/March 82		
		CANMET:	$ 49 600
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: R. Lim	TECHNOLOGY: Tailings	TOTAL:	$ 49 600

OBJECTIVES

Perform radionuclides and chemical analysis of solid samples of uranium mine and mill tailings.

PROCEDURE

Prepared samples were sent in batches. Each batch was randomized and contained 20% replication samples for precision test.

RESULTS

Since the samples were sent in random order, the results can be trusted and the precision test indicates an excellent quality of work.

The expected standard deviation for heterogeneous tailings samples is 20% and most of the results are below this limit.

APPLICATION AND ONGOING WORK

The data will be fitted into the field information for the chemical and radioisotopes balance study on the old abandoned uranium tailings.

TITLE: CHEMICAL ANALYSIS OF URANIUM TAILINGS

CONTRACTOR: Chemex Labs Ltd.	FILE NUMBER: 0-9060	FUNDING	
	BEGIN/END: Nov. 80/March 81		
		CANMET:	$ 39 845
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: D.R. Murray	TECHNOLOGY: Tailings	TOTAL:	$ 39 845

OBJECTIVES

Perform chemical analysis of uranium tailings samples evaluating the extent of soil profile development under vegetation.

PROCEDURE

Dried samples were provided to Chemex Labs Ltd. for specified analyses. A list of some 29 possible analyses were previously negotiated on a standing offer basis. Assays depended on sample and results of previous samples.

RESULTS

The results of the requested analyses were evaluated and used in describing the extent of soil development with depth and age of vegetation cover.

APPLICATION AND ONGOING WORK

The long-term stability of vegetation cover on uranium tailings requires a suitable rooting medium. The vegetation program over 10 years was designed to develop the tailings into a more suitable soil medium. This study showed that various treatments and time limits have different effects on profile development. Work is progressing satisfactorily.

SUPPORTING DOCUMENTS

Interpreted results are included in the report: "Soil Profile Development in Vegetated Uranium Tailings", by D.R. Murray; Division Report MRP/MRL 81-126(J); Sept. 81.

TITLE: RADIOISOTOPE ANALYSIS OF SOLID AND SOLUTION SAMPLES FROM URANIUM TAILINGS

CONTRACTOR:	Monenco Consultants Ltd.	FILE NUMBER:	1-9097/2-9006	FUNDING	
		BEGIN/END:	June 82/March 83		
				CANMET:	$ 50 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	N.K. Dave	TECHNOLOGY:	Tailings	TOTAL:	$ 50 000

OBJECTIVES

Perform radioisotope analysis of solid and solution samples from uranium tailings. The radioisotopes to be analyzed were: Ra-228, Ra-226, Th-232, Th-230, Th-228, and Pb-210.

PROCEDURE

Solid core samples were dried, ground, and homogenized. All solid and liquid samples were randomized and sent in batches for analysis. An average of 10% replicate samples were sent for precision test. Radioisotopes Ra-228, Ra-226, Th-232, Th-230, and Th-228 were analyzed using alpha spectrometric techniques, and Pb-210 using Bi-210 decay beta counting.

RESULTS

The results were forwarded in the form of an analysis report. The replicate samples showed good precision. The expected standard deviation for heterogeneous tailings samples was 20% and most of the results were below this limit.

APPLICATION AND ONGOING WORK

This is a continuation of a study on radioisotope and chemical constituent profiles in a pyritic uranium tailings basin. The data will be used in modelling the migration of contaminants.

TITLE: CHEMICAL ANALYSIS OF SOLID SAMPLES FROM URANIUM TAILINGS FOR MAJOR IONS AND ANIONS

CONTRACTOR:	Guelph Chemical Laboratories Ltd.	FILE NUMBER:	1-9126/2-9007	FUNDING	
		BEGIN/END:	Feb. 82/March 83		
				CANMET:	$ 54 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	T.P. Lim	TECHNOLOGY:	Tailings	TOTAL:	$ 54 000

OBJECTIVES

A detailed investigation of the solid phase distribution profiles of radioisotope and chemical constituents of the pyritic uranium tailings piles at the Nordic Mine tailings site in Elliot Lake is underway. Part of the tailings core samples have been analyzed for their radioisotope constituents and a definite distribution profile has been observed. To understand the observed trends, information on the distribution of major chemical constituents is required to evaluate the role played by the various geohydrochemical interactions in the tailings formation material contributing to the observed phenomenon.

PROCEDURE

1. Perform chemical analysis on solid samples provided by the Scientific Authority as follows:
   a) Measure sample pH.
   b) Analyze for Fe, Ca, Al, Pb, Mg, K, S, and total SO_4 down to mg/g range.
   c) Analyze for U and Th down to µg/g range.
   d) Perform silica analysis only on selected samples as specified by the Scientific Authority.
2. Prepared homogeneous samples were sent in batches. Each batch was randomized and contained 20% replication samples for precision test. An analytical report shall be forwarded to the Scientific Authority upon completion of each batch of analyses.
3. Proposal should submit the methods, attainable precision on each element or compound, description of equipment, turn-around time, and cost per sample for 0-100 and 101-300 samples.

RESULTS

Overall, the results were very satisfactory. The results were tested for precision and accuracy and compared with some results obtained from random samples of the same batch, analyzed by CANMET-MRL, Elliot Lake Laboratory. The expected standard deviation for heterogeneous tailings samples is 20% and most of the results are below this limit.

APPLICATION AND ONGOING WORK

This is part of the chemical analysis done in conjunction with the project on "Methods of Treating Tailings to Minimize Environmental Impact".

TITLE: MONITORING OF PILOT PLANT TAILINGS - PHASES I TO 3

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	I-9140	FUNDING	
		BEGIN/END:	March 82/March 83		
				CANMET:	$ 190 012
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC AUTHORITY:	G.M. Ritcey B.A. Chomyn	SUB-ACTIVITY:	Environmental Technology	OTHER:	--
		TECHNOLOGY:	Tailings	TOTAL:	$ 190 012

OBJECTIVES

Develop a methodology to predict the migration of radionuclides and other contaminants through uranium tailings based on simulated weathering in a lysimeter. The influence of the type of disposal technology on the quality and quantity of the seepage and runoff streams are to be determined. Correlation of chemistry, biogeochemistry, geochemistry, and physical measurements are to be determined.

PROCEDURE

Eleven tonnes of uranium tailings from the acid leaching of a complex uranium-nickel-arsenic ore were deposited in a specially constructed box or lysimeter using the layering technique of Knight and Piesold for disposal. Simulated weathering on a 5-fold acceleration of the normal acid rainfall of Northern Saskatchewan was applied, as well as cyclic periods of heat, darkness, and freeze-thaw. Effluent samples were taken periodically for chemical, radionuclide, and bacteria analyses, as were core samples of the tailings for analyses of mineralogy changes, chemical changes and composition, and porosity and permeability measurements.

RESULTS

1. Seepage greater than runoff.

2. Runoff pH 7.4.
   Seepage pH 6.7.

3. As, Ni, U, Ra-226 increased in seepage.

4. U, Ra, Fe, Ca, Mg, K, Na depleted in cores with time but not as pronounced in freeze-thaw.

5. CO_3 concentrates at depth in cores.

6. Increase in permeability with time; freeze-thaw destroys impervious nature.

7. No thiobacillus ferrooxidans detected.

8. The beach end of the bed contained a considerably higher fraction of fine material (minus 74 micron). Ra-226 concentrations strongly correlate with the proportion of fine material.

9. Radon flux: 5 $pCi/m^2/s$ while the bed was frozen; 316 $pCi/m^2/s$ on the same area after thawing out. Thus, freezing significantly reduces the radon emanations.

APPLICATION AND ONGOING WORK

The work to date has provided for a simulated 10-year period of weathering. Samples of solution, effluents, and cores have been taken and are still being analyzed and data are under assessment. A few months of further sampling followed by completion of the analyses of samples is expected in 1984 before a final report will be written. The tailings lysimeter will be dismantled during 1984 and the tailings transferred to Elliot Lake for disposal.

SUPPORTING DOCUMENTS

Final Report: "Long Term Monitoring of High Grade Uranium Mill Tailings" (Contract Report No. OSQ81-00211).

TITLE: MONITORING OF PILOT PLANT TAILINGS - PHASE 4

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	3-9004	FUNDING	
		BEGIN/END:	April 83/Sept. 83		
				CANMET:	$ 29 950
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	G. Ritcey	TECHNOLOGY:	Tailings	TOTAL:	$ 29 950

OBJECTIVES

Monitor the weathering taking place in a simulated tailings lysimeter by measuring and determining the changes in composition of the effluent, and the changes in the surface properties of the solids with respect to mineralogy, chemistry, and biology.

PROCEDURE

A simulated tailings area of 11 tonnes was sampled and monitored in an accelerated weathering cycle. The bacteria growth or support was studied, physical properties (porosity, permeability) were measured, clay sorption qualities and surface chemistry of solids were studied, and effluent and runoff quality and quantity were determined.

RESULTS

The data have provided information for the ongoing tailings program. Some observations include:

1. Radium concentration at depth and in fines at beach end.
2. No evidence of thiobacillus ferrooxidans present.
3. Porosity increased with freeze-thaw cycle.
4. Efflorescence salts of Ni, U, SO_4 on surface.
5. Runoff exceeded seepage.
6. Presence of high amount of clays affecting sorption.

APPLICATION AND ONGOING WORK

Data directly applicable to ongoing work in progress.

SUPPORTING DOCUMENTS

Final report: "Long Term Monitoring of High Grade Uranium Mill Tailings" (Contract Report No. OSQ82-00264).

TITLE: HYDROGEOCHEMICAL STUDIES ON WTC URANIUM TAILINGS LYSIMETERS

CONTRACTOR:	IEC Beak Consultants Limited	FILE NUMBER:	2-9170	FUNDING	
		BEGIN/END:	Jan. 83/March 83		
				CANMET:	$ 25 389
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	J.M. Skeaff	TECHNOLOGY:	Tailings	TOTAL:	$ 25 389

OBJECTIVES

Provide hydrogeochemical data and expertise that will enable the completion of the Wastewater Technology Centre (WTC), Environment Canada, uranium tailings lysimeter study.

PROCEDURE

Interpretation of available and sub-contracted analyses of leachates and tailings solids.

RESULTS

As a result of the contractor's hydrogeochemical interpretation of the data, a WTC-IEC Beak report has been written that describes a conceptual model of tailings leaching processes and accounts for gypsum and Ra-226 dissolution and pyrite oxidation.

APPLICATION AND ONGOING WORK

It is expected that this report will be valuable in developing a long-term disposal strategy for uranium tailings.

TITLE: MEASUREMENT OF ANISOTROPIC MAGNETIC SUSCEPTIBILITY OF TAILINGS CORES OBTAINED FROM THE ONTARIO RESEARCH FOUNDATION LYSIMETER EXPERIMENT

CONTRACTOR: Morris Magnetics Inc.	FILE NUMBER: 5-9064	FUNDING	
	BEGIN/END: June 85/Aug. 85		
		CANMET:	$ 3 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: G.M. Ritcey	TECHNOLOGY: Tailings	TOTAL:	$ 3 000

OBJECTIVES

Measure the anisotropic magnetic susceptibility (AMS) of five cores from a simulated tailings weathering experiment.

In the AMS technique we investigate the bulk geometry of oxide particles in a specimen. Magnetite crystals exhibit the property of shape anisotropy. Magnetite forms crystals in the cubic system, hence a pure single crystal will always have the same magnetic susceptibility along all axes of the crystal. However, magnetite may occur naturally as elongate multigrains, or as a string of aligned single grains. In each of these cases, susceptibility along the elongate axis of the crystal(s) will be much greater than across the short axis. Hematite in contrast is a hexagonal mineral, which exhibits a crystalline anisotropy in the basal plane of the hematite rhombs.

Crystal alignment is closely related to the fluid transport pattern at the time of deposition, and to the effects of chemical redeposition. Therefore, subsequent measurement of the magnetic fabric (AMS) of a specimen should give some information about the planar and linear fabric elements present in certain sections of the tailings.

PROCEDURE

All measurements of magnetic susceptibility were made on a Sapphire Instruments S.I.-1 susceptibility bridge. For each measurement an integrating time constant of 4 seconds was used. Eight measurements were obtained on each of the XY, YZ, and XZ planes of each specimen. Each set of eight measurements was processed by a Fast Fourier Transform algorithm to isolate the $\sin 2\theta$ components from all other components. (When rotating a specimen in any plane, any susceptibility anisotropy present in that plane must by definition exhibit a $\sin 2\theta$ variation.) After correcting each of the three sets of eight measurements for each specimen, the orientation of the susceptibility axes of that specimen was calculated using a diagonalized matrix routine.

RESULTS

Anisotropic magnetic susceptibility measurements are reported for 72 specimens taken from 5 cores removed from the ORF lysimeter tailings experiment. A Fast Fourier filter routine was developed to isolate only those components that are contributing to the anisotropic susceptibility. Foliation fabrics, recognized by a concentration of minimum susceptibility axes and Q values less than 0.67, are mostly shallow dipping. Lineation fabrics are recognized by a concentration of maximum susceptibility axes and Q values greater than 0.67. Cores 30 and 29 define relative northwesterly trending lineations, while cores 7, 26, and 32 have more southwesterly trending lineations. These lineations are similar to the trends of the alteration zone boundaries defined by bulk susceptibility measurements.

This survey has shown that:

1. It is possible to use the anisotropic magnetic susceptibility technique to identify the presence of foliation planes and lineations in complexly deposited tailings.

2. It is possible to use magnetic fabrics in conjunction with bulk magnetic susceptibility studies to obtain information on the migration of fluids in tailings.

For future studies it is recommended that:

1. All furthur studies be performed on fully oriented cores.

2. Some effort be expended in developing a technique for a mathematically exact decomposition of multiple fabrics.

TITLE: REMOVAL OF PYRITE FROM URANIUM TAILINGS

CONTRACTOR:	Simon-Carves of Canada Ltd.	FILE NUMBER:	2-9189	FUNDING	
		BEGIN/END:	Feb. 83/March 83		
				CANMET:	$ 15 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	W.J.S. Craigen	TECHNOLOGY:	Tailings	TOTAL:	$ 15 000

OBJECTIVES

Determine the economics of acid production from pyrite concentrate at Elliot Lake, Ontario. The pyrite concentrate was obtained from the uranium ore.

PROCEDURE

The study covered the following points:

1. A process description, specifying feed materials, operating factors, storage requirements, and production facilities and equipment including flotation, roaster, and acid plants.
2. Mass balances for the flotation, roasting, and acid plant facilities.
3. Heat balances to support the process designs being compared.
4. Options for disposal of waste materials (sludge, excess pyrite).
5. Estimation of capital and operating costs and proposals for the use of excess pyrite that will include: other markets for sulphuric acid, production of by-product gypsum, and disposal in a separate tailings pond.

RESULTS

The study examined three alternatives but focussed primarily on fluid-bed roasting and subsequent production of sulphuric acid from 95% of the pyrite in the Elliot Lake uranium operation's current tailings production. Pyrite is not recovered at present but is pumped to tailings, resulting in acid generation and dissolution of radioactive elements.

The major advantages of the primary scheme proposed in the report are summarized as follows:

1. Establishment of a stable and economic source of sulphuric acid at Elliot Lake.
2. Production of large quantities of steam (by oxidation of the pyrite) for use in milling operations and elsewhere.
3. Conversion of acid-forming pyrite to inert iron oxide in the tailings pond, thereby minimizing danger to the environment due to dissolution of radioactive elements.

SUPPORTING DOCUMENTS

Final Report: "Study of Facilities Relative to Stabilization of Uranium Mill Tailings at Elliot Lake, Ontario".

TITLE: DEVELOPMENT AND GENERATION OF A PROTOTYPE URANIUM TAILINGS DATABASE

CONTRACTOR: Systemhouse Limited	FILE NUMBER: 2-9143	FUNDING	
	BEGIN/END: Oct. 82/March 83		
		CANMET:	$ 48 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: P. Sutterlin	TECHNOLOGY: Tailings	TOTAL:	$ 48 000

OBJECTIVES

In March of 1982, Systemhouse Limited prepared a preliminary design for the organization and content of a database for uranium tailings data. The study and preliminary design were limited in scope to the tailings containment facility and its content. The report contained seven major recommendations related to implementation and nine recommendations related to usage of the data and database. It is now proposed to proceed with the consolidation and conversion of existing data into a common format, and the implementation of a prototype database to be used in modelling contaminant dispersion and release from uranium mine tailings sites.

PROCEDURE

The requirements were completed in two main phases.

1. Development of data and coding standards.
2. Conversion of machine readable data into the prototype System 2000 database.

RESULTS

A prototype Canadian Uranium Tailings database (CANUT) was developed and implemented on EMR's in-house computer system using the System 2000 database management software package. The database design and implementation were done by Systemhouse Limited with guidance from an ad hoc advisory committee established by the National Uranium Tailings Program (NUTP).

APPLICATION AND ONGOING WORK

A workshop was held by Systemhouse Limited to demonstrate the capabilities of the CANUT database and provide potential users an opportunity to become familiar with the database by hands-on experience.

SUPPORTING DOCUMENTS

Final report: ""National Uranium Tailings Program - Data Standard Manual" and "CANUT Users' Manual".

TITLE: REVIEW OF STATE-OF-THE-ART OF DYNAMIC MODELLING OF URANIUM TAILINGS

CONTRACTOR:	Atomic Energy of Canada Limited	FILE NUMBER:	2-9148	FUNDING	
		BEGIN/END:	Oct. 82/March 83		
				CANMET:	$ 40 825
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	G.M. Ritcey	TECHNOLOGY:	Tailings	TOTAL:	$ 40 825

OBJECTIVES

1. Review the current state-of-the-art for dynamic modelling of the long-term behaviour and environmental impact of uranium mine tailings.

2. Recommend a number of possible models for each part of the pathways analysis.

PROCEDURE

1. The mathematical modelling literature relevant to each aspect of the pathways analysis was reviewed.

2. Discussions were held with a number of consultants who have attempted to model similar behaviour.

RESULTS

A report was prepared summarizing the literature and recommending a number of candidate models for each area of interest.

APPLICATION AND ONGOING WORK

This work is continuing as part of the National Uranium Tailings Program.

SUPPORTING DOCUMENTS

Final Report: "A Review of Computer Models for Assessment of the Long-Term Behaviour of Uranium Tailings".

TITLE: PROGRAM PLAN FOR THE NATIONAL URANIUM MINE TAILINGS OFFICE

CONTRACTOR:	IEC Beak Consultants Ltd.	FILE NUMBER:	2-9195	FUNDING	
		BEGIN/END:	March 83		
				CANMET:	$ 40 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	V.A. Haw	TECHNOLOGY:	Tailings	TOTAL:	$ 40 000

OBJECTIVES

Prepare the main elements of the five-year National Uranium Tailings Program that would serve as a basis for detailed planning by the staff of the National Uranium Tailings Program Office.

PROCEDURE

The contractor was to use as a basis for his report, the report of the National Uranium Tailings Planning Group that was chaired by Phillip Lapp. He was also to draw upon his own experience in planning and scheduling project activities. The contractor used the three main program components identified by the Planning Group's report: Modelling, Measurement, and Disposal Technology. The predictive modelling activity was the controlling theme for the scheduling of events, and emphasized the development of assistance models that would simulate the behaviour and migration of source contaminants from the tailings into the environment. Other activities related to the Measurement and Disposal Technology were controlled by the timing of model development.

RESULTS

The contractor produced a report that outlined the program objectives, produced a conceptual program plan, a technical program plan, and an outline of the consultant's proposed plan for program management. The heart of the report was a planning schedule that described individual activities for each of the three main program components, showing the interrelationships one with the other and also how the program structure related to the management functions, including the Technical Advisory Committee and the Senior Review Board. Each of the program activities shown on the program schedule are individually described.

APPLICATION AND ONGOING WORK

The program schedule proposed by IEC Beak is now being used as a basis for detailed program planning. The schedule proposed is being used to control the work in both time and money.

SUPPORTING DOCUMENTS

Final report: "Program Plan for the National Uranium Mine Tailings Office".

TITLE: PRESENTATION OF A BRIEF ON DEVELOPMENT OF THE DISPOSAL TECHNOLOGY RESEARCH COMPONENT OF THE NATIONAL URANIUM TAILINGS PROGRAM AT A SEMINAR IN OTTAWA, ONTARIO

CONTRACTOR: Lawrence A. Melis	FILE NUMBER: 3-9074	FUNDING	
	BEGIN/END: March 83/June 83		
		CANMET:	$ 2 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: V.A. Haw	TECHNOLOGY: Tailings	TOTAL:	$ 2 000

OBJECTIVES

Present a résumé of the report prepared by L.A. Melis on development of the five-year disposal technology research component of the National Uranium Tailings Program, at a seminar in Ottawa.

PROCEDURE

An oral presentation is to be made along with audio-visual material that would describe in detail the different activities proposed for the disposal of uranium mine and mill wastes as prepared by L.A. Melis. Also, the consultant must be in a position to respond to any questions or comments by the audience.

RESULTS

The presentation was made on June 3, 1983, in the presence of representatives from a number of Federal Government departments and agencies that have an interest in uranium tailings management. The presentation was well received and the contract was considered to be completed to the full satisfaction of the National Uranium Tailings Office.

APPLICATION AND ONGOING WORK

This was one of a series of seminars to be held on National Uranium Tailings Program activities on an ongoing basis.

SUPPORTING DOCUMENTS

"Development of the Disposal Technology Research Component of the National Uranium Tailings Program", by L.A. Melis. (Final report for Contract No. 2-9197); March 1983. Summary published in CANMET Report 83-12E.

TITLE: PRESENTATION OF A BRIEF ON THE LONG-TERM PLAN FOR URANIUM TAILINGS RESEARCH AT A SEMINAR IN OTTAWA, ONTARIO

CONTRACTOR: IEC Beak Consultants Ltd.	FILE NUMBER: 3-9075	FUNDING	
	BEGIN/END: June 83		
		CANMET:	$ 2 620
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: V.A. Haw	TECHNOLOGY: Tailings	TOTAL:	$ 2 620

OBJECTIVES

Present a résumé of the report prepared by IEC Beak on planning and scheduling of a five-year program on uranium tailings research, at a seminar in Ottawa.

PROCEDURE

An oral presentation is to be made along with audio-visual material that would describe in detail the proposed program activities prepared by IEC Beak. Also, the consultant must be in a position to respond to any questions or comments by the audience.

RESULTS

The presentation was made on June 3, 1983, in the presence of representatives from a number of Federal Government departments and agencies that have an interest in uranium tailings management. The presentation was well received and the contract was considered to be completed to the full satisfaction of the National Uranium Tailings Office.

APPLICATION AND ONGOING WORK

This was one of a series of seminars to be held on National Uranium Tailings Program activities on an ongoing basis.

SUPPORTING DOCUMENTS

"Program Plan for the National Uranium Mine Tailings Office", by IEC Beak Consultants Ltd. (Final report for Contract No. 2-9195). An outline of the presentation was left with the Director, NTPO, as well as the slides for the presentation.

TITLE: STUDY AT CORY AND ROCANVILLE MINES ON THE EFFECT OF POTASH TAILINGS ON THE SURROUNDING SURFACE ENVIRONMENT AND OPTIONS FOR THEIR CONTAINMENT, AND AN INVESTIGATION OF THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF TAILINGS AND ASSOCIATED CLAYS

CONTRACTOR:	Potash Corporation of Saskatchewan	FILE NUMBER:	3-9177	FUNDING	
		BEGIN/END:	Jan. 84/March 85		
				CANMET:	$ 60 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	E.G. Joe	TECHNOLOGY:	Tailings	TOTAL:	$ 60 000

OBJECTIVES

Effective containment of potash wastes requires a knowledge of the engineering properties of the wastes. To date, however, the behaviour of potash tailings has been poorly documented.

In order to make informed waste management decisions, an understanding of the influence of insoluble slimes on the tailings strength is necessary. The effects on stability of the tails pile when slimes occur as a stratified layer within the tails pile must be assessed. If separate storage of the slimes is considered, the properties of the slimes must be identified. Since slimes would be stored outside, the change in slimes strength resulting from leaching out of salt must be considered.

This program was therefore designed to provide some baseline data on the engineering properties of the salt tails and slimes, both separately and in combination. In order to assess the basic properties, the scope of work was designed to exclude a number of variables affecting salt tails, such as visco-plastic creep and time-dependent characteristics.

PROCEDURE

In order to include slimes variability between mines and ore bodies, samples of potash tails were collected from PCS Mining, Cory Division and PCS Mining, Rocanville Division.

A laboratory testing program was conducted by Golder Associates (Western Canada) Ltd. The samples tested consisted of salt tails (NaCl), salt free insolubles, and various combinations of the two. The laboratory program included classification testing, permeability and consolidation testing, and measurements of shear strength.

RESULTS

The salt tails were confirmed to consist primarily of NaCl with minor amounts of KCl. Mineralogical analyses of the insolubles indicated that the primary constituents are dolomite, quartz, potassium feldspar, anhydrite, and clay (illite, chlorite, and septechlorite).

The grain size distribution of the salt crystals is similar to coarse-grained salt, while the insolubles contain silt and clay sizes. The insolubles classify as medium to highly plastic.

The salt tails classify as free-draining materials with a coefficient of permeability in the order of 10^{-1} to 10^{-2} cm/s. The salt-free insolubles classify as very impervious with permeabilities in the order of 10^{-6} to 10^{-8}. The addition of insolubles to salt tails results in a significant reduction of the permeability. The poor drainage characteristics of the insolubles will have a significant impact on the stability of the tails piles. High pore pressures resulting from rapid loading will not dissipate rapidly and drainage paths within the tails pile will be affected by slimes layers.

The materials all exhibit reasonably high shear strength parameters. The effective angle of internal friction of the insolubles is approximately 30°, comparing favourably with the glacial materials in the foundation. Salt tails have an effective angle of internal friction of approximately 40°, approximating a coarse sand.

It is concluded that the salt tails are a high-strength material, however further investigation of factors affecting strength is required. The addition of slimes in a homogeneous mix will improve pile stability, however slimes occurring as layers in the tails pile will reduce overall stability. High pore pressures can be generated in the insolubles or insoluble rich tails and these can be slow to dissipate. Leaching of salt from slimes will reduce the available strength.

APPLICATION AND ONGOING WORK

Although the study was, of necessity, limited in scope, it has provided baseline data to further the state-of-the-art knowledge of the physical properties of potash tailings. It provides a logical basis for optimizing further efforts.

SUPPORTING DOCUMENTS

Final Report: "Investigation of the Physical and Chemical Characteristics of Potash Tailings in Saskatchewan".

TITLE: RECLAMATION OF PYRITIC TAILINGS USING FLOAT ROCK AND GYPSUM AT THE SULLIVAN CONCENTRATOR, KIMBERLEY, B.C.

CONTRACTOR: Cominco Ltd.	FILE NUMBER: 4-9275	FUNDING	
	BEGIN/END: Jan. 85/June 85		
		CANMET:	$ 19 078
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: E.G. Joe	TECHNOLOGY: Tailings	TOTAL:	$ 19 078

OBJECTIVES

Reclamation study of pyritic tailings using float rock and gypsum. The float rock and gypsum that are produced as waste materials will provide a cover for the reactive tailings to be reclaimed by revegetation. Vegetation uptake of contaminants, especially fluoride from gypsum, and reclamation potential of this method are to be evaluated.

PROCEDURE

Cover a study area of 0.65 hectare with float rock to a thickness of 0.6-0.9 m. Place a layer of gypsum 0.5-0.9 m thick on the float rock. Agricultural grade lime is to be mixed with the gypsum layer at the rate of 22.5 tonnes $CaCO_3$/hectare. The area is to be fertilized and seeded.

RESULTS

The site was prepared and the area will be seeded this spring. Reclamation potential will be studied once the vegetation has been established.

The final report describes the background and objectives of the project, the construction of the experimental site, and briefly discusses revegetation studies planned for establishment on the site during the 1985 growing season.

APPLICATION AND ONGOING WORK

New techniques for reclaiming highly reactive tailings. The use of float rock as a capillary barrier is to be investigated.

SUPPORTING DOCUMENTS

Final Report: "Reclamation Study of Pyritic Tailings Using Float and Gypsum at the Sullivan Concentrator, Kimberley, B.C.".

TITLE: PILOT SCALE EVALUATION OF POND AND TOWER BIOLOGICAL OXIDATION OF THIOSALTS IN MILL EFFLUENTS

CONTRACTOR:	Noranda Metal Industries Ltd.	FILE NUMBER:	9-9026	FUNDING	
		BEGIN/END:	June 79/May 81		
				CANMET:	$ 249 644
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	NORANDA:	$ 70 527
AUTHORITY:	J. Dutrizac	TECHNOLOGY:	Pollution Control	TOTAL:	$ 320 171

OBJECTIVES

The overall objective of the project is to determine the key parameters governing the process design of biological reactors for oxidation of thiosalts in heavy metal milling effluents.

PROCEDURE

1. Design and construct a rock-packed aerated pond, a conventional aerated pond, and three packed aerated columns adjacent to the Brunswick Mining and Smelting, Mining Division (BMS-M) mill at Bathurst, New Brunswick.

2. Operate the pilot facilities for 12 months to evaluate these methods of treating mill thickener overflow streams with a thiosalt concentration of 1000 to 2000 mg/L to achieve 100 mg/L average discharge level.

3. Characterize the process response, for a range of hydraulic loading conditions, for the removal of thiosalts. Controlled variables will be effluent flow and aeration. Response measurements will include: SO_4, thiosalt, thiosulphate, acidity levels, and effluent suspended solids.

4. Determine the following for each reactor:
   a) thiosalt oxidation rates
   b) suspended solids inventory
   c) lime requirements for neutralization of generated acids
   d) a nutrient balance for nitrogen and phosphorus
   e) O_2 (or CO_2) requirements.

5. Produce a final report that will present the above data, as well as preliminary cost estimates for a full-scale thiosalt oxidation treatment system.

RESULTS

The generated data were used to determine the following:

1. Thiosalt oxidation rate - the oxidation rates were determined for each of the reactors, and for each of the stages in the mixed aerated reactor.

2. Suspended solids inventory - the amount of solids generated based on solids measurements in the feed, effluent, and reactors. Solids accumulation on reactor packing were also determined.

3. Nutrient balance - the nitrogen and phosphate determinations in the feed, effluents, and reactors were utilized to provide a nutrient balance.

4. Oxygen and CO_2 requirements - the amount of oxygen and CO_2 required for efficient biological action were determined based on aeration rates and D.O measurements.

5. Lime requirements necessary to neutralize the acid produced were determined by laboratory-scale jar tests.

TITLE: PREPARATION OF A NON-CRITICAL SUMMARY REPORT ON THE CANMET THIOSALT PROGRAM

CONTRACTOR:	Noranda Metal Industries Ltd.	FILE NUMBER:	1-9128	FUNDING	
		BEGIN/END:	Jan. 82/March 82		
				CANMET:	$ 15 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	Dr. J. Dutrizac	TECHNOLOGY:	Pollution Control	TOTAL:	$ 15 000

OBJECTIVES

During the past five years, CANMET, in close collaboration with Noranda Mines Limited and other members of the mining industry, has been examining the scope of the thiosalt problem with special emphasis on the resolution of this environmental concern. As part of this project, a large number of reports and other documentation have been produced at CANMET and as a result of CANMET-sponsored contracts. The objective of this contract was to prepare a non-critical summary of these reports in a form useful to the mining industry and other interested parties. The final document will be issued as a CANMET report.

PROCEDURE

CANMET provided relevant documentation and also technical and editorial support. The contractor reviewed the relevant documents and prepared a detailed report plus bibliography covering the areas of thiosalt sampling, analysis, and generation as well as the important topic of thiosalt removal.

RESULTS

1. A comprehensive report has been produced - CANMET Report 82-4E. The report reviews CANMET's thiosalt program, as well as the relevant open literature on thiosalts, in a non-critical manner.

2. A shorter report highlighting the key areas has also been assembled - Division Report MRP/MSL 83-1(J).

APPLICATION AND ONGOING WORK

1. Will give rise to further studies on the engineering aspects of thiosalt removal.

2. A follow-up contract has been issued for the detailed costing of the more favourable routes identified in the non-critical survey.

SUPPORTING DOCUMENTS

CANMET Report 82-4E: "The Chemistry, Generation and Treatment of Thiosalts in Milling Effluents - A Non-Critical Summary of CANMET Investigations 1976-1982"; by M. Wasserlauf and J.E. Dutrizac; March 1982.

TITLE: TECHNICAL AND ECONOMIC EVALUATION OF THIOSALT TREATMENT ALTERNATIVES

CONTRACTOR: Noranda Mines Limited	FILE NUMBER: 3-9044	FUNDING	
	BEGIN/END: July 83/Aug. 85		
		CANMET:	$ 99 684
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: J.E. Dutrizac	TECHNOLOGY: Pollution Control	TOTAL:	$ 99 684

OBJECTIVES

Perform a technical-economic evaluation of 15 thiosalt treatment alternatives, and comment on the technical feasibility of such processes.

PROCEDURE

Flowsheets were developed for each option and detailed costing was carried out on the flowsheets using data generated by CANMET and participating organizations.

RESULTS

The most promising options are:

1. H_2O_2 chemical oxidation.
2. Cu_2S-catalyzed air oxidation.
3. Bio-oxidation in packed ponds.
4. Natural degradation.

APPLICATION AND ONGOING WORK

Work continues at Brunswick Mining and Smelting.

SUPPORTING DOCUMENTS

Final Report: "Techno-Economic Evaluation of Thiosalt Treatment Processes" (Contract Report No. OSQ83-00071).

TITLE: CATALYZED-AIR OXIDATION OF THIOSALT EFFLUENTS USING COPPER SULPHIDE CATALYSTS

CONTRACTOR: University of Waterloo	FILE NUMBER: 3-9184	FUNDING	
	BEGIN/END: Nov. 83/Nov. 84		
		CANMET:	$ 34 970
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: J.E. Dutrizac	TECHNOLOGY: Pollution Control	TOTAL:	$ 34 970

OBJECTIVES

Investigate the catalyzed air oxidation of thiosalt-bearing milling effluents using copper sulphide mattes and converter white metal.

PROCEDURE

Screen tests on several sulphides were done. The most promising were used for bench and continuous-flow testing.

RESULTS

Copper sulphides catalyze the air oxidation of thiosalts. The rates are sufficiently fast to be of potential industrial interest. Details are presented in the final contract report.

APPLICATION AND ONGOING WORK

Further development work may be carried out by Brunswick Mining and Smelting with Professor Rempel as a consultant.

SUPPORTING DOCUMENTS

Final Report: "Catalyzed-Air Oxidation of Thiosalt Effluents Using Copper Sulfide Catalysts".

TITLE: COMPUTER CALCULATION OF THERMODYNAMIC DATA FOR ARSENIC-BEARING SYSTEMS

				FUNDING	
CONTRACTOR:	Ecole Polytechnique de Montreal	FILE NUMBER:	3-9085		
		BEGIN/END:	Aug. 83/Sept. 83		
				CANMET:	$ 6 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	J.M. Skeaff	TECHNOLOGY:	Pollution Control	TOTAL:	$ 6 000

OBJECTIVES

Arsenic is a toxic and undesirable element that occurs in the processing of metals such as Cu, Ni, and Co. Its presence in high concentrations can prevent the treatment of certain ores that would otherwise be suitable as feed to Canadian smelters. One of the requirements for the development of effective methods for treating high-arsenic ores is good thermodynamic data for arsenates and arsenides. In order to obtain such data from in-house electrochemical measurements, known data for reactants and products involved in arsenate and arsenide reactions must be accessed and entered into analytical expressions that then yield, through regression analyses, the required thermodynamic data. The known data are available from the FACT System in Montreal that is adaptable to the above purposes.

The objective, therefore, is to adapt the FACT System so as to enable the calculation of thermodynamic data for arsentes and arsenides from experimental electrochemical data supplied by the user.

PROCEDURE

1. Develop a computer program coupled into the FACT System that will produce an analytical expression for the known Gibbs free energy of formation of a particular compound for a given temperature range, including such data as that for $As_4O_{6(g)}$ and the dimerization free energy of arsenious trioxide gas.

2. Develop a computer program coupled into the FACT System that will calculate the standard entropy, enthalpy, and free energy as functions of temperature for a designated arsenate or arsenide compound for which experimental data will be supplied by the user.

RESULTS

A computer program called FORT.ARSENIC has been written and is listed in Appendix A of the final report. The final report describes the programs and their capabilities, and includes instructions for the user.

APPLICATION AND ONGOING WORK

The programs are used to process experimental data.

SUPPORTING DOCUMENTS

Final Report: "Computer Program for the Numerical Treatment of Thermodynamic Data for Arsenic Based Systems".

TITLE: BIOLOGICAL DESTRUCTION OF CYANIDE EFFLUENTS

CONTRACTOR: Zenon Environmental Inc.	FILE NUMBER: 4-9184	FUNDING	
	BEGIN/END: Nov. 84/May 85		
		CANMET:	$ 24 915
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: V. Sanmugasunderam	TECHNOLOGY: Pollution Control	TOTAL:	$ 24 915

OBJECTIVES

1. Prepare a critical state-of-the-art review of the biological processes available for the destruction of cyanide in mineral-processing effluents.

2. Evaluate these processes and select those that may be potentially suitable to Canadian mineral processing operations based on a review of critical parameters, capital and operating costs, and legal aspects.

3. Identify information gaps and necessary research prior to industrial application.

PROCEDURE

1. Literature review and information assembly.

2. Evaluation and selection of potential biological processes.

3. Identification of research needs.

RESULTS

The contractor did a good job of summarizing the factors influencing the biodegradability of cyanide effluents and considered the different kinds of reactor configurations that could be used. Further research needs and factors that should be studied for scale-up were included.

APPLICATION AND ONGOING WORK

In view of the decision of Homestake Mining Company to license their patented process, it is unlikely that any further follow-up work would be needed.

However, CANMET's AVR process is expected to rouse the interest of the mining companies.

SUPPORTING DOCUMENTS

Final Report: "Biological Destruction of Cyanide in Canadian Mineral Processing Effluents".

TITLE: WELDING FUME CHARACTERISTICS OF COPPER-NICKEL ALLOY GAS METAL ARC ELECTRODES

CONTRACTOR: Welding Institute of Canada	FILE NUMBER: 2-9061	FUNDING	
	BEGIN/END: Aug. 82/March 83		
		CANMET:	$ 18 460
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: M. Sahoo	TECHNOLOGY: Pollution Control	TOTAL:	$ 18 460

OBJECTIVES

The potential for adverse health effects from exposure to welding fumes is receiving greater attention from welders as well as management. It is in the best interests of worker safety and corporate productivity to maintain airborne concentrations of pollutants in welding environments within the established guidelines.

In order to evaluate the degree of control required, it is first necessary to understand the characteristics of fume production and how they are affected by variations in welding parameters. The objective of this study is to establish these characteristics for gas-metal-arc welding of chromium and niobium modified 70/30 Cu-Ni alloys so that concerned personnel are better able to assess the requirements for providing cleaner welding environments.

PROCEDURE

Two types of bare wire electrodes were used: one modified with niobium (Cuprotrode 521) and the other with chromium (Monel 451). A steel chamber, equipped with a Roots model 2506-J vacuum pump to draw air from the chamber, was used for the welding experiments. The welding fumes were collected at the top of the chamber on Owens-Corning PF 105 fibreglass filters. A Metler HK 150 electronic balance was used to weigh the filters containing fumes. All fume samples were analyzed for Cu, Ni, Cr, etc.

Bead-on-plate welds were done for each electrode and welding condition, such as voltage, current, shielding gas, etc. Spot extraction of fumes was done using a Tykron Phase IV portable fume extractor.

RESULTS

1. For 100% argon shielding gas using the Monel 451 wire, the fume generation rate increased as a function of both current and voltage. The values ranged from 300 to 400 mg/min for typical welding conditions.

2. For 100% argon gas using the Cuprotrode 521, the fume generation rate was generally higher than for the Monel 451.

3. The use of an argon and helium gas mixture (50/50) increased the fume level by as much as 300% compared with 100% argon under the same welding conditions.

4. The fume chemistry is approximately 35% copper and 10% nickel for both alloy compositions.

5. The spot extraction nozzle reduced the fume generation rate by about 30% when placed 18 cm from the arc.

6. In situations where ozone is not present, total fume concentrations of 0.6 mg/m^3 should ensure that the copper and nickel fume components are below their respective Threshold Limit Values.

APPLICATION AND ONGOING WORK

This work is being extended to study the fume generation rate in Ni-Al-bronze welding using Ampcotrode 10 and 46 electrodes.

SUPPORTING DOCUMENTS

Final Report: "Study of Welding Fume Characteristics of Copper-Nickel Alloy Gas Metal Arc Electrodes".

TITLE: WELDING FUME CHARACTERISTICS OF NICKEL-ALUMINUM-BRONZE GAS METAL ARC ELECTRODES

CONTRACTOR: Welding Institute of Canada	FILE NUMBER: 3-9026	FUNDING	
	BEGIN/END: July 83/Dec. 83		
		CANMET:	$ 26 505
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: M. Sahoo	TECHNOLOGY: Pollution Control	TOTAL:	$ 26 505

OBJECTIVES

The potential for adverse health effects from exposure to welding fumes is receiving greater attention from welders as well as management. It is in the best interests of worker safety and corporate productivity to maintain airborne concentrations of pollutants in welding environments within the established guidelines.

In order to evaluate the degree of control required, it is first necessary to understand the characteristics of fume production and how they are affected by variations in welding parameters.

Complementary to an earlier study on welding fume characteristics of Cu-Ni alloys (Contract No. 2-9061), this work investigated the particulate fume emissions from two nickel-aluminum-bronze gas metal arc electrodes. These two electrodes warranted evaluation since their different chemistry suggested they would generate considerably different fumes from the two Cu-Ni electrodes studied earlier.

PROCEDURE

Two types of aluminum-bronze bare wire electrodes were used: one containing Al and Fe (Ampcotrode 10) and the other a complex nickel-aluminum-bronze (Ampcotrode 46). A steel chamber, equipped with a Roots model 2506-J vacuum pump to draw air from the chamber, was used for the welding experiments. The welding fumes were collected at the top of the chamber on Owens-Corning PF 105 fibreglass filters. A Metler HK 150 electronic balance was used to weigh the filters containing fumes. All fume samples were analyzed for Cu and Ni. Bead-on-plate welds were done for each electrode and welding condition such as voltage, current, shielding gas, etc. Spot extraction of fumes was done using a Tykron Phase IV portable fume extractor. Aluminum analysis was not done because of its high TLV.

RESULTS

1. Both the Ampcotrode 10 and Ampcotrode 46 electrodes produce twice as much fume with 50% helium shielding than with 15% helium mixed with argon.

2. The fume generation rate in a 50% helium-shielding environment was 20% less for the aluminum-bronze electrodes than for the Cu-Ni electrodes (Cuprotrode 521 and Monel 451).

3. In a 50/50 argon/helium-shielding environment at 300A, the Ampcotrode 46 electrode generates more fumes than the Ampcotrode 10 electrode.

4. Aside from possible ozone formation, the critical fume component was Cu for all electrodes.

5. A gun-mounted local fume extraction unit was found to be potentially feasible for controlling the fume emissions of Ni-Al-bronze electrodes.

APPLICATION AND ONGOING WORK

This work will be helpful to the shipbuilding industries where a lot of welding on Cu-Ni and Ni-Al bronzes is carried out.

No further work is anticipated.

SUPPORTING DOCUMENTS

Final Report: "Study of Welding Fume Characteristics of Nickel-Aluminum-Bronze Gas Metal Arc Electrodes".

MINERALS TECHNOLOGY

MATERIALS DEVELOPMENT

TITLE: TRANSMISSION ELECTRON MICROSCOPY STUDY OF THE EFFECTS OF SIMULATED RAIL LOADING ON AN EXPERIMENTAL PREMIUM RAIL STEEL

				FUNDING	
CONTRACTOR:	Technical University of Nova Scotia	FILE NUMBER:	0-9191		
		BEGIN/END:	Aug. 81/March 85		
				CANMET:	$ 48 490
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	D.M. Fegredo	TECHNOLOGY:	Failure Control	TOTAL:	$ 48 490

OBJECTIVES

Two associated investigations were done for this contract:

1. Determine, by transmission electron microscopy, the effects of simulated, heavy-duty rail/wheel contact on curved track, on three separate microstructures of different hardness of a Cr-Mo alloy rail steel. The simulations were done in the Tribology Section of NRC's Western Laboratory, Vancouver, on a 1/10 scale dual disk-on-disk wear machine.

2. The contract was continued to examine two full-scale outer rails subjected to heavy-duty wear on curved track, by transmission electron microscopy. The rails were tested at the Facility for Accelerated Service Testing, Colorado Springs, Colorado, U.S.A. They were Standard C-Mn, and Japanese head-hardened premium rails, respectively. The objectives were to compare the worn microstructures of both rails and compare these full-scale microstructures with those obtained on disks wear-tested in the laboratory (Part 1 above).

PROCEDURE

The procedures corresponding to Objectives (1) and (2) are as follows:

1. Thin foils were prepared for transmission electron microscopy from various locations of the worn disks and from several depths below the surface. Although standard techniques were used, Ni-plating of transverse sections was necessary prior to the cutting and perforation of 1.5 mm diameter foils. Perfect Ni-bonding was required and the technique used is fully described. Perforated foils were examined.

2. Thin foils were prepared for transmission electron microscopy from four locations across the width and at varying depths from the worn surface. These were at the gauge face, the gauge corner, half the distance between the gauge corner and the centre of the running surface (1/4-width), and the centre of the running surface (1/2-width). Microhardness surveys were also done.

RESULTS

First Investigation:

Thin foils were prepared from 30 specimens of an alloy Cr-Mo rail steel transformed under different conditions. The majority had been tested in a wear machine as inner or outer rails (simulated). The principal results are:

1. An ultra-fine ferrite grain size forms in the near-surface regions, especially within $\sim$30 µm depth from the surface.

2. A texture appears in the ultra-fine grain regions.

3. Cementite deforms and re-aligns parallel to the surface.

4. Carbide morphologies pertaining to the various deformed microstructures are well defined.

Second investigation:

1. The inter-lamellar spacing is considerably reduced near the surface for both rails.

2. The Standard rail suffered gross plastic flow to a depth of over 1 mm; cementite lamellae were broken near the surface. Neither of these phenomena were observed in the head-hardened rail except to a very limited extent.

3. The improved wear resistance of the premium rail is attributed to the contrasting behaviour of its carbide.

4. Carbide behaviour in the premium rail is similar to that observed on pearlitic disks of comparable hardness tested in the laboratory. However, a texture was not found in the full-scale material. Furthermore, a significant amount of spalling occurred on the head-hardened rail, which was not generally seen on the pearlitic disks. But the rails were subjected to approximately four times the service (250 MGT) applied to the disks (60 MGT).

SUPPORTING DOCUMENTS

Final Report: "Transmission Electron Microscopy Study on the Effects of Simulated Rail Loading on an Experimental Premium Rail Steel". Part I and Part 2 (Contract Report No. OSU81-00231).

"The Wear Resistance and Worn Metallography of Pearlite, Bainite and Tempered Martensite Rail Steel Microstructures of High Hardness", by J. Kalousek, D.M. Fegredo, and E.E. Laufer; Wear of Materials 1985; Proceedings of the International Conference on Wear of Materials, Vancouver, B.C., April 14-18, 1985; American Society of Mechanical Engineers.

TITLE: MATERIALS AND DESIGN FOR RESISTANCE TO CRACK GROWTH BY CREEP - PHASE 2

CONTRACTOR: McMaster University	FILE NUMBER: 0-9199	FUNDING	
	BEGIN/END: June 81/July 83		
		CANMET:	$ 79 020
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: W.R. Tyson	TECHNOLOGY: Failure Control	TOTAL:	$ 79 020

OBJECTIVES

Assess the applicability of fracture mechanics methodology to the control of creep crack growth in pressure vessels operated at high temperatures and pressures.

PROCEDURE

The approach to the problem was a combination of experimental assessment of damage in small-scale creep tests with crack growth simulation using finite element methods. The experimental work has been done on coarse-grained 2.25 Cr-1Mo steel, a condition simulating a heat-affected zone near the weld. From the analysis of experiments, it has been concluded that creep damage is controlled by the effective strain.

RESULTS

The finite element simulation of creep crack growth shows that good agreement with experimental results can be obtained provided that an appropriate damage criterion is used. The parameters suitable for crack growth prediction are developed. The methods for determination of accumulated creep damage and remaining life of structures are evaluated.

TITLE: STUDY OF WELD CRACKING IN 2.25 Cr-1Mo STEELS

CONTRACTOR: Welding Institute of Canada	FILE NUMBER: 1-9071	FUNDING	
	BEGIN/END: Sept. 81/Sept. 83		
		CANMET:	--
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	DSS:	$ 92 194
AUTHORITY: R.S. Chandel	TECHNOLOGY: Failure Control	TOTAL:	$ 92 194

OBJECTIVES

Conduct a study of the factors that affect transverse cracking in 2.25 Cr-1Mo steel welds. From the results, evaluate welding techniques to prevent the cracking.

PROCEDURE

A number of welds with varying preheat have been made in 2.25 Cr-1Mo steel plates of various thicknesses. Also, the G-BIG test has been evaluated as a means of assessing transverse cracking.

RESULTS

The results show that before transverse cracking can initiate, root cracking starts. It has been shown that by using a preheat temperature of 200°C root cracking can be avoided. The G-BIG test was not found suitable for assessing transverse cracking.

TITLE: CONSTRUCT THE PROTOTYPE OF A PORTABLE X-RAY STRESS DIFFRACTOMETER

CONTRACTOR:	Proto Manufacturing	FILE NUMBER:	1-9125-1	FUNDING	
		BEGIN/END:	June 82/March 83		
				CANMET:	$ 82 437
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC	D. White	SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	C.M. Mitchell	TECHNOLOGY:	Failure Control	TOTAL:	$ 82 437

OBJECTIVES

By 1984, complete, refine, and evaluate the experimental model of the CANMET Portable X-Ray Stress Diffractometer and in this way contribute to the development of the first commercial prototype of the CANMET instrument to measure stresses nondestructively on the surface of engineering structures in the field.

RESULTS

The performance of this engineering model is being thoroughly evaluated with a view to documenting its operational characteristics and identifying its shortcomings for future revision during commercial development. The instrument performs essentially as designed, and it has good accuracy, but its weight must be reduced further and a number of mechanical features will have to be changed to ensure satisfactory performance in the hands of a potential customer.

APPLICATION AND ONGOING WORK

A contract worth $594 000, approximately two-thirds funded by PILP, has been negotiated with the contractor (Proto Manufacturing) to design and construct the first commercial prototype of the CANMET diffractometer. The features of this model, in terms of operational versatility, have not yet been finally decided. CANMET will continue to provide scientific backup throughout the commercialization process during the next two to three years.

TITLE: DEVELOPMENT OF A CANADIAN SOURCE OF POSITION-SENSITIVE DETECTORS FOR X-RAY STRESS MEASUREMENT

CONTRACTOR: Robertson Nickerson Ltd.	FILE NUMBER: 3-9070	FUNDING	
	BEGIN/END: Sept. 83/Oct. 85		
		CANMET:	$ 47 008
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: D.W.G. White	TECHNOLOGY: Failure Control	TOTAL:	$ 47 008

OBJECTIVES

Part 1

A Marketing Survey for a Source of Position-Sensitive Detectors for X-Ray Measurement.

Determine the potential for a reliable domestic source to supply economically significant X-ray responsive Silicon Photodiode Array (SPDA) detectors for the CANMET Portable X-ray Stress Diffractometer currently under development.

Part 2

A study of the Canadian Market for a Portable X-Ray Stress Diffractometer.

Conduct a market study for portable X-ray stress diffractometers in Canada.

PROCEDURE

Part 1

Through literature searches, correspondence, telephone interviews, and appropriate visits, conduct a market survey to identify Canadian suppliers and/or manufacturers of X-ray responsive, position-sensitive SPDA. If domestic sources for such SPDA detectors cannot be identified, the survey should then identify domestic sources of UV responsive detectors that can be adapted to detect X-rays.

To estimate the market potential, the survey is to address the following items:

1. Selling price of SPDA detectors.
2. Operating characteristics of SPDA detectors.
3. Patent situation for existing UV responsive SPDA detectors and opportunities for developing X-ray responsive SPDA detectors unfettered by patents for UV units.
4. Probability of success in adapting UV detectors for X-ray application.

Part 2

The report covers the Canadian market for a portable X-ray stress diffractometer. Over 60 interviews were conducted throughout Canada in various industry sectors. Budget limitations did not permit an exhaustive study of all industry sectors.

Interviews were also conducted with industry associations, companies offering competitive products, and other industry observers.

RESULTS

Part 1

1. Silicon photodiode arrays are primarily designed to detect light in the 200 to 1100 nanometer range.
2. Light sensitive photodiode arrays can be modified to detect X-rays by:
   a) converting the X-ray image into visible light by means of an image converter tube and then detecting the visible light with the array
   b) depositing an X-ray phosphor directly onto the array or fibre optic face plate
   c) letting the X-ray excite the sensor directly.
3. The major sources of supply of silicon photodiode arrays are:

EG&G Reticon, Sunnyvale, CA
Fairchild CCD, Palo Alto, CA
Texas Instruments, Dallas, TX

4. No Canadian sources were identified that could supply a product to meet CANMET's requirements.

5. Several Canadian companies have similar product lines and the capability to develop a silicon photodiode array.

6. The North American market for all linear silicon photodiode arrays is estimated to be $2 to $5 million (U.S.). The market for X-ray sensitive detectors is estimated to be 2 to 5% of the total market.

7. The price of silicon photodiode arrays ranges from $75 to $5 000 (U.S.).

8. Major applications for light sensitive detectors are facsimile, optical character recognition, and document scanning. The largest area of growth is expected to be in surveillance systems, inspection, and robot vision.

9. Prominent applications for X-ray detectors include scientific research and medical instrumentation.

Part 2

1. A portable diffractometer is perceived by industry as a useful tool. An interest and need for this capability was demonstrated.

2. A limited demand for a portable diffractometer was shown within the private sector.

3. Extrapolated to a total population, this represents a five-year market forecast of 12 to 17 units in Canada.

4. Competitive units are offered by Rigaku, TEC, Denver X-Ray Instruments, American Analytical, and Siemens Allis.

5. The potential buyer population is a spectrum of buyers with varying needs, ranging from the automotive sector to utilities to consulting engineers.

6. The major applications are research and development, inspection of critical welds, and failure analysis.

7. The high price of a portable diffractometer limits its saleability. Several contacts suggested they would be interested if it were priced at $30 000. Further development to simplify the unit and thereby reduce its cost would open the potential market.

8. The U.S. market appears to be similar to the Canadian market in terms of industry sectors, applications, users, level of awareness, etc.

9. The success of the CANMET portable stress diffractometer depends on a strong marketing campaign directed at:
   a) education of buyers about residual stress and its measurement techniques,
   b) position titles rather than industry sectors,
   c) why the unit is different from its competition.

APPLICATION AND ONGOING WORK

As a result of the study by Robertson Nickerson and subsequent activity by CANMET, a contract was eventually let to ITRES Research, Calgary, to evaluate the potential of a specific CCD for CANMET's particular application.

SUPPORTING DOCUMENTS

Final Report: "Study to Determine the Canadian Market for a Portable X-Ray Stress Diffractometer and to Identify a Source of Position-Sensitive Detectors for the Unit" (Contract Report No. OGS83-00307).

TITLE: DESIGN AND CONSTRUCT A PROTOTYPE POSITION SENSITIVE X-RAY DETECTOR

CONTRACTOR: Itres Research Limited	FILE NUMBER: 4-9040	FUNDING	
	BEGIN/END: Nov. 84/March 85		
		CANMET:	$ 44 968
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: R.A. Holt	TECHNOLOGY: Failure Control	TOTAL:	$ 44 968

OBJECTIVES

Design and construct a prototype position sensitive X-ray detector based on a solid-state array-imaging device.

PROCEDURE

1. Assess potential devices.
2. Establish design parameters.
3. Test selected devices in breadboard assembly.
4. Finalize design parameters.
5. Construct prototype detector.
6. Assess commercial potential.

RESULTS

A survey of available solid-state array-imaging devices revealed two potentially useful ones: Reticon RL10245 and EEV P8604. The EEV array was selected because long-term development potential appeared greater.

Design parameters were established and testing conducted on breadboard system. Results indicated probable response in accordance with expectations. Design of prototype was finalized and construction carried out. Subsequent test results on breadboard assembly showed some anomolous behaviour requiring further testing.

Assessment of commercial potential showed good economic possibilities compared to existing technology if technical problems can be solved.

APPLICATION AND ONGOING WORK

Contract is being extended to carry out further testing. Possible PILP project and patent could result.

TITLE: UNDERGROUND CORROSION OF WATER PIPES IN CANADIAN CITIES

CONTRACTOR:	Caproco Corrosion Prevention Ltd.	FILE NUMBER:	I-9036	FUNDING	
		BEGIN/END:	Sept. 81/March 84		
				CANMET:	$ 64 365
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.J. Biefer	TECHNOLOGY:	Failure Control	TOTAL:	$ 64 364

OBJECTIVES

Stimulate a higher level of expertise in the design and maintenance of municipal water distribution systems, particularly with respect to decreasing the excessive number of costly failures of ductile iron and cast iron water pipes.

PROCEDURE

1. Detailed studies of failures of ductile iron and cast iron water pipes in the distribution system of the City of Calgary, Alberta.

2. Dissemination across Canada of the results of the studies at Calgary as typifying the Canadian problem - through distribution of the contractor's final report and presentations by the contractor at appropriate conferences.

RESULTS

Improvements in water pipe technology can only be expected in the long term. So far, there has been an encouraging amount of interest in the CANMET initiative. About 60 requests for the contractor's final report have been received to mid-January 1984. The Canadian trade journal "Corrosion Control" has published an article describing the rationale for the research, and some initial findings.

APPLICATION AND ONGOING WORK

To assist in developing a higher level of technology in municipal water distribution systems in Canada, and thus decrease the excessive number of costly failures of underground pipes.

Further research in this area will be considered only after assessment of the reaction of the technical community involved in water pipe failures to the CANMET-sponsored research.

SUPPORTING DOCUMENTS

Final Report: "Underground Corrosion of Water Pipes in Canadian Cities. Case: The City of Calgary".

TITLE: BIOFOULING PROBLEMS ASSOCIATED WITH ATLANTIC CANADA'S OFFSHORE PETROLEUM INDUSTRY

CONTRACTOR:	Fundy Isles Marine Enterprises Ltd.	FILE NUMBER:	4-9241	FUNDING	
		BEGIN/END:	Nov. 84/March 85		
				CANMET:	$ 25 429
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	J. Gilmour	TECHNOLOGY:	Failure Control	TOTAL:	$ 25 429

OBJECTIVES

The broad objective of this study was to provide industry and government with an up-to-date review of the importance of biofouling and biocorrosion in the development of the Canadian offshore petroleum industry.

This broad objective will be considered in terms of the following immediate objectives:

1. Assemble and analyze existing biofouling/biocorrosion data related to hydrocarbon production off Canada's Atlantic coast.

2. Assemble and analyze data from the North Sea and other areas of the world with similar conditions, and comment on its relevance to the Canadian Atlantic situation.

3. Recommend areas for further study.

PROCEDURE

An exhaustive study was undertaken to assemble and analyze available information on the nature and impact of marine macrofouling, microfouling, and biocorrosion on Atlantic Canada's offshore hydrocarbon exploitation industry.

Information was obtained from public and private sources in Canada and abroad.

RESULTS

The analysis of the data indicates that Canadian government and industry efforts in this regard fall far short of the needs. By comparison, programs in place in the North Sea petroleum industry include ongoing monitoring and predictions of potential impacts to be expected from fouling communities on offshore structures.

Through industry/government/university and private research efforts, considerable data have been developed that form the basis for decision-making on the part of industry in designing and maintaining structures and equipment in the North Sea.

It is concluded that for the safe and successful exploitation of Atlantic Canada's offshore petroleum resources, a similar program will have to be developed. Further, because of the differences in physical and biological characteristics of the North Sea and the Northwest Atlantic, data and experiences from the former are not directly applicable to the latter.

Recommendations are provided concerning the development of a distinctly Canadian program to service this important attribute of offshore petroleum development.

SUPPORTING DOCUMENTS

Final Report: "Biofouling Considerations in the Development of Atlantic Canada's Offshore Petroleum Industry".

TITLE: DEVELOPMENT OF NON-LEADED FREE-MACHINING STEELS - PHASE I

CONTRACTOR: McMaster University	FILE NUMBER: 9-9119-1	FUNDING	
	BEGIN/END: July 80/March 81		
		CANMET:	$ 13 443
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: D. Parsons	TECHNOLOGY: Advanced Materials and Instrumentation	TOTAL:	$ 13 443

OBJECTIVES

1. Compare the machinability of SAE 1146 steel Al-deoxidized with the same steel Ca-deoxidized and containing Nb for control of austenitic grain size.

2. Identify and quantitatively characterize the inclusion content of the control heat and the modified heat.

3. Correlate the inclusion content with machinability rating and flank-wear of carbide and HSS steel tools.

PROCEDURE

Two 40-ton heats of SAE 1146 steel were melted and strand cast as 5 in. x 8 in. blooms and were rolled to 2 in. diameter bar stock. Bar stock from the control and modified heats was examined metallographically, and was tested for machinability at McMaster University in single point turning using both carbide and HSS tools and a range of cutting speeds.

The inclusion content was identified by Cameca microprobe analysis and was measured quantitatively by Cambridge 720 QTM analysis.

RESULTS

The inclusions present in the control steel were mainly high-Al_2O_3 corundum-type oxide inclusions, often associated with MnS sulphide inclusions; however, the modified steel contained lower melting oxide inclusions of the Gehlenite ($2CaO-Al_2O_3-SiO_2$) type with MnS sulphide inclusions, some CaS inclusions, and a trace of Nb-carbide eutectic. In addition to the reduction of Al_2O_3 content, the total number and length of oxide inclusions were reduced in the modified (Ca-treated) steel.

The flank wear rate of both carbide and high speed steel (HSS) tools in single point turning was reduced by a factor of 2 in the Ca-Nb modified steel. Crater wear was unchanged or slightly increased; however, while the improvement in machinability was significant, especially at high cutting speeds (100-300 m/min), it can be further improved by increasing SiO_2 content to achieve Anorthitic ($CaO-Al_2O_3-2SiO_2$) oxide inclusions - useful for modern fast cutting. Control of Nb addition to quantities lower than 0.04% is required.

APPLICATION AND ONGOING WORK

1. Work on Ca-Nb modified 1146 steel is intended to increase the SiO_2 content of the oxide inclusions to achieve low-melting Anorthitic inclusions.

2. Machinability data are being obtained for Atlas Steels "CM" shaft steel after Ca-Nb deoxidation and elimination of Al_2O_3 inclusions.

3. Outside the program, inclusion identification and quantitative analysis are being correlated with the machinability of Algoma-oil country tubing and Atlas 4140 steel, as compared with 4140 steel of foreign manufacture. Low carbon grades such as 1541 and 4615 have been examined prior to machinability testing at McMaster University.

SUPPORTING DOCUMENTS

Final report: "Development of Non-Leaded Free-Machining Steels - Phase I" (Contract Report No. OSU80-00111).

TITLE: DEVELOPMENT OF NON-LEADED FREE-MACHINING STEELS - PHASE 2

CONTRACTOR: McMaster University	FILE NUMBER: 9-9119-2	FUNDING	
	BEGIN/END: Aug. 81/March 83		
		CANMET:	$ 32 871
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: D. Parsons	TECHNOLOGY: Advanced Materials and Instrumentation	TOTAL:	$ 32 871

OBJECTIVES

Following completion of Phase I (literature review), Phase 2 research had the objective of producing fine-grained, free-machining steel that did not contain hard abrasive Al_2O_3 inclusions, and measuring the effect of removal of high-Al_2O_3 inclusions on machinability.

The long-range objective is to adapt the manufacture of Canadian free-machining steel compositions to be competitive with Japanese and offshore competing steels when machined at modern fast cutting rates (up to 300 m/min), and to provide alternate free-machining steels encouraging the elimination of Pb and Bi as free-machining steel additives.

PROCEDURE

Two 40-ton BOF concast heats of SAE/AISI 1146 steel were supplied by Burlington Steel Co. as 2-in. diameter bars. One heat (control "C") was deoxidized by the standard Al procedure, a second heat ("M") was modified by Ca-deoxidation, and contained an addition of Nb for grain size control.

Single point machining was done on bars from both heats using HSS (High Speed Steel) and carbide tooling at cutting rates of 30-70 m/min and 50-150 m/min, respectively.

The inclusion contents were characterized by optical microscopy, by QTM 900 quantitative image analysis, and by micro-electron microprobe analysis.

The chip and shear metallography was done at McMaster University.

RESULTS

The flank wear rate of both HSS and carbide tools was improved by approximately 50% for the Ca-modified 1146 steel (controlled by inclusion content). The crater wear rate (controlled by strength and non-inclusion factors) was slightly increased.

The improved machinability was attributed to both a reduction in the total number of oxide inclusions and to elimination of high-Al_2O_3 corundum-type oxides.

A mixed oxide phase in the Ca-treated steel was identified as Gehlenite (suitable for high cutting rate BUE (Built-Up Edge) machining). It was concluded that a further improvement in machinability would result if the CaO content were reduced and if the SiO_2 content of the oxide phase were increased to ensure the presence of Anorthite rather than Gehlenite.

APPLICATION AND ONGOING WORK

Further work in Phase 3 involves machinability testing and inclusion characterization (McMaster and CANMET) of three additional 1146 Ca-Nb modified heats to be supplied by Burlington Steel - and a similar comparison of Al-deoxidized and Ca-treated Atlas "CM" shaft steel. A further project for Algoma Steel involves a CANMET inclusion characterization of Al-killed 1050 steel and 1025 steel in the resulphurized Te-treated and control conditions with machinability testing at McMaster University.

SUPPORTING DOCUMENTS

Final Report: "Development of Non-Leaded Free-Machining Steels - Phase 2" (Contract Report No. OSU80-00111).

"Characterization of Non-Metallic Inclusions in Steel", by M.T. Shehata, V. Moore, D.E. Parsons, and J.D. Boyd; Division Report MRP/PMRL 83-49(OP-J); July 1983.

TITLE: DEVELOPMENT OF NON-LEADED FREE-MACHINING STEELS - PHASE 3

CONTRACTOR: McMaster University	FILE NUMBER: 3-9134	FUNDING	
	BEGIN/END: March 83/Aug. 84		
		CANMET:	$ 86 133
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: D.E. Parsons	TECHNOLOGY: Advanced Materials and Instrumentation	TOTAL:	$ 86 133

OBJECTIVES

Atlas Steels Ltd. has started a machinability program aimed at controlling the types of oxide inclusions formed in Atlas CM grade steels. One standard Si-Al killed Atlas CM grade will be compared with one new Atlas CM grade (samples A and B).

A further 3 heats of Burlington Steel Co. SAE 1146 steel, modified by additional Ca and Nb, will be examined by optical and quantitative metallography to determine if Anorthitic ($CaO-Al_2O_3-2SiO_2$) inclusions are present.

Three additional Atlas CM heats (samples C, D, E) representing 3 variations of Ca-deoxidation will be examined to determine the inclusion type and effect on machinability.

A further series of 7 commercial heats and 2 CM heats will be examined metallographically.

PROCEDURE

Seven heats of SAE 1541, 4140, and 4150 commercial steels were examined metallographically. Two preliminary 638 CM heats were examined metallographically. Five heats, including a Si-Mn control "CM" heat, were compared with 4 Ca-deoxidized "CM" heats with respect to optical and quantitative metallography, and analyses of inclusions correlated with HSS and carbide tooling and cutting speed for single point turning tests. (Samples A, B, C, D, E-Atlas CM).

Optical and quantitative metallographic examination with Cameca energy dispersive microprobe analysis and wavelength quantitative inclusion analysis, respectively, were done on 3 heats of Ca-Nb modified SAE 1146 Burlington steel. (Machining tests were not done for these 3 SAE 1146 heats.)

RESULTS

The results for five Atlas heats (A-E) CM shaft steel composition were reported in the final Phase 3 report.

Results of the qualitative analysis and microanalysis of 7 commercial steels were submitted by PMRL to McMaster. McMaster's results were reported by Memorandum Supplement to Phase 3, prior to the start of Phase 4.

Results for Atlas CM confirmed that the highest flank wear occurred for Mn-Al deoxidation with Al_2O_3 impregnation of the MnS inclusions. Highest machining force was related to the material strength, as indicated by work done for Algoma Steel in a previous program. A heavy Built-Up-Edge (BUE) deposit and short chips were related to crater wear. BUE deposits caused inferior machined surfaces at high cutting speeds - and was controlled effectively by use of coated HSS tools for Atlas CM steel.

Anorthite-Gehlenite inclusions were observed in 3 SAE 1146 heats. Nb eutectic was controlled in SAE 1146 steels.

APPLICATION AND ONGOING WORK

Phase 4 program will be completed by March 1985.

McMaster will continue research in machinability fundamentals, interparticle spacing, shear angle, etc.

SUPPORTING DOCUMENTS

Final Report: "Development of Non-Leaded Free-Machining Steels - Phase 3" (Contract Report No. OSV83-00048).

TITLE: DEVELOPMENT OF NON-LEADED FREE-MACHINING STEELS - PHASE 4

CONTRACTOR: McMaster University

CANMET SCIENTIFIC AUTHORITY: D.E. Parsons

FILE NUMBER: 4-9242
BEGIN/END: Nov. 84/March 85

MINERALS TECHNOLOGY ACTIVITY
SUB-ACTIVITY: Materials Development
TECHNOLOGY: Advanced Materials and Instrumentation

FUNDING

CANMET:	$ 50 000
CONTRACTOR:	--
OTHER:	--
TOTAL:	$ 50 000

OBJECTIVES

1. Determine the machinability of several grades of commercial machinery steels:
   a) AISI 1536 (LASCO)
   b) AISI 1541 (ATLAS)
   c) AISI 1070 (STELCO).
2. Study the mechanisms of chip formation as a function of steel metallurgy and machining speed.

PROCEDURE

1. Samples of commercial heats were obtained from the 3 steel companies, machinability tests were carried out at McMaster, and the results were correlated with metallurgical evaluation done at McMaster and CANMET.
2. The "quick-stop" technique was used to examine chip formation in AISI grades 1018, 1040 and 4340 at cutting speeds of 73-110 m/min, and compared with samples of CK46 machined at 200-2000 m/min from a German laboratory.

RESULTS

1. The results support earlier work on the effect of non-metallic inclusions on tool flank wear rate. The difficulty of controlling inclusion chemistry in commercial steelmaking operations is also highlighted.
2. Preliminary results show that the chip-formation mechanism is void nucleation and growth at low cutting speeds, and adiabatic shear at high cutting speeds.

APPLICATION AND ONGOING WORK

McMaster will conduct a two-year, $120K program to:

1. Determine thermodynamic data and segregation models for control of inclusion chemistry and distribution in commercial steels.
2. Evaluate the application of micro-alloying to medium-carbon free-machining steels.
3. Study chip-formation mechanisms by experiment and continuum models.

SUPPORTING DOCUMENTS

Final Report: "Development of Non-Leaded Free-Machining Steels - Phase 4" (Contract Report No. OST84-00378).

TITLE: RAPID SOLIDIFICATION TECHNOLOGY WORKSHOP

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	4-9237	FUNDING	
		BEGIN/END:	Sept. 84/Nov. 84		
				CANMET:	$ 6 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	L. Collins	TECHNOLOGY:	Advanced Materials and Instrumentation	TOTAL:	$ 6 000

OBJECTIVES

Rapid Solidification Technology (RST) is a new technology that has attracted worldwide interest and is being investigated actively for its industrial potential. As there has been little development of this technology in Canada, a workshop was organized with the objective of stimulating Canadian interest in RST and perhaps catalyzing some industrial action.

The specific objectives of this workshop were to:

1. Review the effects of rapid solidification on the structure and properties of materials.

2. Examine various techniques of rapid solidification and their application.

3. Increase industrial awareness of facilities, projects, and applications involving RST in Canada.

PROCEDURE

A one-day workshop was organized by the Ontario Research Foundation. Four keynote speakers reviewed the effects of rapid solidification on the structure and properties of materials, and examined various techniques of rapid solidification and their application. Short presentations by Canadian researchers outlined current projects in Canada.

RESULTS

The objectives of the RST Workshop were met fully. The effects of rapid solidification were reviewed, and techniques examined by recognized experts in the subject. Descriptions were given of relevant Canadian activities.

A total of 35 people, excluding the invited speakers, attended the Workshop. They represented 20 organizations that are either active or interested in becoming active in RST.

In all, the Workshop represented the greatest concentration of RST knowledge, expertise, and interest assembled in Canada to date, and as such should serve to stimulate further activity in RST in the Canadian Industrial and Scientific communities.

APPLICATION AND ONGOING WORK

There are currently four related contracts on rapid solidification technology as well as in-house research being carried out under the Advanced Materials Project.

SUPPORTING DOCUMENTS

Final Report: "Rapid Solidification Technology Workshop" (Contract Report No. OGT84-00282).

1. "Overview of Rapid Solidification Technology", by L.E. Collins; Division Report MRP/PMRL 84-62(J).

2. "Current Canadian Activities in Rapid Solidification Technology", by L.E. Collins and D.W. White; Division Report MRP/PMRL 84-79(TR).

TITLE: LASER SURFACE MODIFICATIONS FOR FATIGUE AND WEAR CONTROL

CONTRACTOR:	Battelle Memorial Institute	FILE NUMBER:	5-9058	FUNDING	
		BEGIN/END:	Sept. 85/Dec. 85		
				CANMET:	$ 28 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	L. Collins	TECHNOLOGY:	Advanced Materials and Instrumentation	TOTAL:	$ 28 000

OBJECTIVES

There were two principle objectives of this multi-client study. The first was to perform a series of laser processing experiments on simple geometry test pieces in order to apply current-technology laser surface treatments and to extend the technology through process development. The second objective concerned the evaluation of laser-processed materials in order to rank various laser process/materials combinations in terms of their performance in wear- and fatigue-critical environments and determine if any improvement could be obtained over conventional processing treatments.

PROCEDURE

Laser surface modifications were carried out using a 5 kW continuous wave CO_2 laser. Three types of laser process optics were employed: focussing, integrating, and scanning. As well, a system was developed to give a uniform rectangular beam profile. Methods for enhancing laser beam absorption were examined.

Five laser modification methods were investigated for surface hardening: transformation hardening, surface melting, powder cladding, laser melt consolidation of thermal spray coatings, and strip cladding. Ferrous alloys representative of medium-carbon hardenable steels, alloy steels, tool steels, stainless steels, and cast iron were selected for the base alloys. Cladding materials included two hardfacing alloys, one based on cobalt and the other on Ni, and a physical mixture of iron and titanium carbide powders. The microstructures of the laser-treated surfaces were examined and tests were carried out to evaluate sliding and abrasive wear resistance, and bending and rolling contact fatigue behaviour.

RESULTS

The mechanics of laser surface treatment processes were examined in detail. Optimal beam focussing techniques for the various laser surface treatments were developed. A special optical system was designed to give a uniform rectangular laser beam profile. Beam absorption efficiency could be increased by using flat primer paint treatments or surface roughening, depending on the type of laser processing to be used.

Significant microstructural refinement was obtained by laser surface treatment. Laser-treated surfaces showed significant improvements in both abrasion and sliding wear resistance, with the Fe-TiC powder cladding giving the best results in both cases. None of the materials performed particularly well in the rolling contact fatigue resistance test, owing to the shallow case depth of the laser-treated samples. There was no improvement in the bending fatigue resistance following treatments in which the laser scan overlapped previously treated material.

Economic factors and safety considerations in developing laser surface treatment processes are discussed.

APPLICATION AND ONGOING WORK

The background information provided in this report will be used in establishing an in-house research program on the application of lasers in materials processing. Initial work will examine the use of laser surface cladding for corrosion and high-temperature oxidation resistance.

TITLE: COMPILATION OF LONG-TERM DATA ON THE STRENGTH, DURABILITY AND CREEP TEST RESULTS OF HIGH-STRENGTH LIGHTWEIGHT CONCRETE

CONTRACTOR:	University of Calgary	FILE NUMBER:	0-9157	FUNDING	
		BEGIN/END:	Aug. 81/March 82		
				CANMET:	$ 9 590
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 9 590

OBJECTIVES

Compile long-term data on strength, durability, and creep test results of high-strength semi-lightweight concrete.

PROCEDURE

This compilation is part of the study on the development of high-strength lightweight concrete. The long-term data on creep and shrinkage were obtained using ASTM standard test methods.

RESULTS

1. Long-term strength and creep data are inconclusive in some respects but do not give any clear indication that the presence of fly ash adversely affects these properties.
2. Freeze-thaw tests show that this type of semi-lightweight concrete, with or without fly ash or the superplasticizer, cannot pass the ASTM C666 Procedure A test if the aggregate is presoaked before mixing takes place. However, if the concrete is allowed to dry before resoaking prior to the test, as would likely happen in many of its applications, freeze-thaw performance is generally satisfactory, although some mixes with fly ash contents did not perform quite as well as those without fly ash.

SUPPORTING DOCUMENTS

Final Report: "Development of High Strength Concrete Using Less Energy Intensive Materials" (Contract Report No. OSU91-00212).

TITLE: CREEP OF CONCRETE CONTAINING LIMESTONE DUST

CONTRACTOR:	University of Calgary	FILE NUMBER:	2-9022	FUNDING	
		BEGIN/END:	May 82/March 83		
				CANMET:	$ 3 939
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 3 939

OBJECTIVES

Determine the creep of concrete containing limestone dust.

PROCEDURE

ASTM creep tests were performed to determine the creep of concrete containing various percentages of limestone dust as a partial replacement for fine aggregate.

RESULTS

The results indicate that after 200 days of loading, the creep of concrete incorporating 5% limestone dust was comparable to that of the control concrete; however, creep significantly increased with the incorporation of larger quantities of dust. The increase ranged from about 22% at the 10% dust replacement level to about 26% at the 20% dust replacement level.

SUPPORTING DOCUMENTS

A separate report of one Table on this work is not useful. The data are included in Division Report MRP/MSL 83-41(OP-J).

TITLE: CREEP OF CONCRETE CONTAINING FLY ASH

CONTRACTOR: University of Calgary	FILE NUMBER: 4-9013	FUNDING	
	BEGIN/END: March 84/May 85		
		CANMET:	$ 13 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: G. Carette	TECHNOLOGY: Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 13 000

OBJECTIVES

Determine the effect of various Canadian fly ashes on the creep properties of concrete.

PROCEDURE

Forty-eight cylindrical concrete specimens (150 x 300 mm) were provided to the contractor for creep tests. These consisted of 12 sets of quadruplicate specimens, including one control set without fly ash and 11 sets covering the use of 11 different Canadian fly ashes. Creep tests were done according to ASTM C 512. The loading started after 91 days of moist curing and was continued till the age of about 1 year with a constant applied load of 9.7 MPa.

RESULTS

The test results indicate that the incorporation of fly ash as a partial replacement for cement in concrete generally causes a slight decrease in creep strains after a loading period of about 1 year. The decrease does not seem to be related to a particular type of fly ash.

APPLICATION AND ONGOING WORK

This work was part of an in-house project on the characterization and evaluation of performance of Canadian fly ashes in concrete.

SUPPORTING DOCUMENTS

Final Report: "Creep of Concrete Containing Fly Ash". (Contains test data sheets.)

TITLE: RELATIONSHIP BETWEEN POZZOLANIC ACTIVITY OF FLY ASHES AND THEIR PERFORMANCE IN CONCRETE

CONTRACTOR:	Joshi Consultants Ltd.	FILE NUMBER:	1-9085	FUNDING	
		BEGIN/END:	Nov. 81/Dec. 83		
				CANMET:	$ 20 257
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 20 257

OBJECTIVES

Perform fractionation and pozzolanic tests on samples of fly ash from various sources across Canada. The objective was to evaluate the relative value of these materials for use in different applications, particularly concrete.

PROCEDURE

Samples of fly ash (50 kg) were obtained from 14 sources across Canada. Physical and chemical properties of each were determined. In each case, fractionation was carried out to obtain a measurement of the following:

- cenospheres (with density distribution)
- magnetite
- carbon
- material retained on 45-μm sieve
- water-soluble content.

Pozzolanic activity tests were carried out before and after fractionation. The results were examined for possible correlation with other physical or chemical properties.

RESULTS

Of the 14 Canadian fly ashes investigated, more than half seem to have potential for recovery of light-weight particles and cenospheres.

The ashes from eastern Canada have relatively high amounts of magnetic particles and could possibly be used as sources of magnetite for coal processing.

Most ashes have good pozzolanic activity and therefore good potential for use in concrete. Fractionation generally increases such activity.

The pozzolanic activity of the ashes seems to be related to the fraction retained on the 45-μm sieve and the surface area.

SUPPORTING DOCUMENTS

Final Report: "Physical, Chemical and Pozzolanic Properties of Canadian Fly Ashes".

TITLE: ACCELERATED TEST FOR ALKALI DETERMINATION OF FLY ASHES

CONTRACTOR: ASCOR	FILE NUMBER: I-9095	FUNDING	
	BEGIN/END: Jan. 82/Aug. 82	CANMET:	$ 14 330
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Materials Development	OTHER:	--
AUTHORITY: V.M. Malhotra	TECHNOLOGY: Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 14 330

OBJECTIVES

Evaluate a proposed rapid method for the determination of available alkali in fly ash. The proposed rapid method can be completed within 30 minutes as compared to 28 days for the ASTM procedure.

PROCEDURE

Fourteen fly ash samples were obtained from different sources in Canada and tested for their available alkali content. The tests were carried out using both the proposed rapid method and the ASTM C311-77 standard method. The results were statistically analyzed to determine the degree of correlation between the two methods.

RESULTS

1. The rapid method is simple and takes less than 45 minutes to complete. In the technique used, negligible interference was found due to sulphate.
2. The statistical analysis showed that a highly significant correlation exists between the two methods for available alkali content greater than 0.5%, and the precision of the rapid method is at least as good as the ASTM method.
3. Below about 0.5% available alkali, the absolute numerical results for the rapid method were consistently lower than those for the ASTM method. However, the correlation was still statistically significant.
4. Using data obtained from previous studies done from 1961 to 1982 as well as data from the present investigation, the line of best fit obtained from the regression analysis was highly significant at the 90% level.

SUPPORTING DOCUMENTS

Final Report: "Evaluation of a Rapid Test for Available Alkali Determination in Fly Ashes" (Contract Report No. 0SQ81-00154).

The final report is also available as Division Report MRP/MSL 83-10(OP&J).

TITLE: USE OF SILICA FUME TO OBTAIN CONCRETES WITH LOW CEMENT CONTENT, HIGH STRENGTH AND HIGH IMPERMEABILITY

CONTRACTOR:	University of Sherbrooke	FILE NUMBER:	1-9082	FUNDING	
		BEGIN/END:	Oct. 81/March 82		
				CANMET:	$ 18 743
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 18 743

OBJECTIVES

Investigate the application of silica fume in the development of a low cement content concrete having high strength and high impermeability characteristics.

PROCEDURE

Two cement contents were investigated: 175 and 235 kg/m^3. For each cement content, four types of concrete were examined: a reference concrete with no silica fume and three others with 10, 15, and 20% fume as an addition to cement. For each type of concrete, four batches were prepared and specimens were cast to determine the following:

1. Compressive strength at 1, 7, 28, 91, and 365 days.
2. Flexural strength at 14 and 28 days.
3. Modulus of elasticity at 28 days.
4. Drying shrinkage after 3 and 28 days.
5. Permeability and porosity measurements at maturity.

RESULTS

The results indicate that the addition of silica fume increases the strength of concrete at all ages. At 28 days and thereafter, the increase is of the order of 100% with a 10% fume addition. The use of larger additions does not contribute to much larger increases. The flexural strength shows similar improvement, though to a lesser degree.

The use of silica fume drastically reduces the permeability of concrete. Lean concrete made with 175 kg/m^3 of cement and 10% fume shows a coefficient of permeability equal to that of plain concrete with 235 kg/m^3 of cement. The above improvements in strength and permeability characteristics are shown to be the result of changes in the pore size distribution.

With proper curing, drying shrinkage of silica fume concrete shows only a slight increase compared with that of plain concrete.

APPLICATION AND ONGOING WORK

This contract is part of a large program. When it is completed, all this data will be incorporated in the final report that will then be issued to the public.

TITLE: USE OF SILICA FUME IN FLY ASH/PORTLAND CEMENT CONCRETE TO ACHIEVE HIGH EARLY STRENGTH

CONTRACTOR:	Université de Sherbrooke	FILE NUMBER:	2-9087	FUNDING	
		BEGIN/END:	Sept. 82/March 83		
				CANMET:	$ 28 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G. Carette	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 28 000

OBJECTIVES

Investigate the use of silica fume to achieve high early strength fly ash/Portland cement concrete.

PROCEDURE

Three series of non-air-entrained concrete mixes were prepared with water-to-cementitious materials ratios of 0.35, 0.50, and 0.65. Each series included six double-batch mixes designed to incorporate 30% of a class "F" fly ash and up to 20% silica fume, both as partial replacements by weight for portland cement. The mixes of each series were proportioned according to a reference mix (without fly ash or silica fume), and any loss of slump was compensated for by the use of a superplasticizer. From batch No. 1 of each mix, a number of cylinder specimens were cast to determine the compressive strength development (from very early ages) and the elastic properties of the concrete. From batch No. 2, a number of prism specimens were cast to determine the flexural strength properties and drying shrinkage characteristics of the concrete.

Tests were also carried out to determine the chemical, physical, and pozzolanic properties of the fly ash and silica fume used.

RESULTS

The results can be summarized as follows:

At ages up to 7 days, the silica fume concretes showed little or no strength improvement over the control concretes for water-to-cementitious materials ratios of 0.50 and 0.65. With the ratio of 0.35, however, significant improvement was observed as the strength of silica fume concretes approached that of the reference ones. At 28 days, regardless of the water-to-cementitious materials ratios, the above gap had generally disappeared while the strength of the control concrete was still considerably lower, i.e., much or all of the strength loss due to the replacement of 35% of the cement by fly ash had been compensated for by the incorporation of silica fume. At ages from 28 to 91 days, the long-term effect of fly ash was apparently not influenced by the presence of silica fume, as both control and silica fume concretes were found to exhibit parallel increases in strength. As far as overall strength development was concerned, the optimum dosage of silica fume appeared to be about 10%, since any additional gains in strength from the use of larger dosages were only marginal.

In general, the incorporation of silica fume in the concrete was reflected by a small increase in the modulus of elasticity of the material, and either by some slight increase or decrease in drying shrinkage depending upon the initial curing time of the concrete.

APPLICATION AND ONGOING WORK

In many applications, the use of fly ash (especially class F) cannot be considered because of the slow strength development of the concrete. Silica fume could, in many cases, provide an efficient solution to this problem.

TITLE: CHARACTERIZATION OF NONFERROUS SLAGS FROM CANADIAN SOURCES

CONTRACTOR:	Trow Limited	FILE NUMBER:	2-9095	FUNDING	
		BEGIN/END:	Oct. 82/June 84		
				CANMET:	$ 13 295
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V. Malhotra/E. Douglas	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 13 295

OBJECTIVES

Phase 1

1. Collect 181 kg (400 lb) samples of copper, nickel and lead slag from eight locations in Quebec, Ontario, and New Brunswick. The samples from foreign sources are also to be obtained.

2. Remit selected samples and revitrify to increase the glass content.

3. Grind the slags to 2000, 3000, 4000, and 5000 cm^2/g specific surface and determine the energy required for grinding.

4. Test pozzolanic and slag activity, with and without activators, as well as compressive strength development to ninety days.

Phase 2

1. Six of the most prominent slags at two fineness levels will be tested in eleven different concrete mixes. Two tailing mixes for cemented mine backfill will be tested as well.

PROCEDURE

The different procedure involved in the mortar testing of the slag/portland cement mixes were described in the Phase I Report - mainly ASTM procedures with slight modifications, in some cases, on the curing temperatures.

Concrete mixes were prepared with 50% absolute volume replacement of portland cement by ground nonferrous slags with a specified formulation described in the enclosed report.

The tailings for cemented fill were prepared with 70% solids by weight, using two different slags in each case.

RESULTS

The test results are promising for concrete applications but the small number of tests with cemented mine backfill indicate the need for more specific and adequate studies in this area.

TITLE: METHODOLOGY FOR MEASUREMENT OF HEAT OF HYDRATION OF NONFERROUS SLAG BINDERS

CONTRACTOR:	E.E. Berry & Associates Limited	FILE NUMBER:	3-9095	FUNDING	
		BEGIN/END:	Aug. 83/Oct. 83		
				CANMET:	$ 1 200
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:	$ 1 200

OBJECTIVES

1. Description of the methodology for measurement of heat of hydration of nonferrous slag binders.

2. Annotated bibliography on the determination of early heat of hydration of cementitious materials.

PROCEDURE

Use a conduction calorimeter to study the mechanism and kinetics of cementing processes.

RESULTS

This report is concerned with the practical application of conduction calorimetry to the determination of heats of hydration of blended cements and supplementary cementing materials based on nonferrous slags. In addition, some consideration is given to the research applications of conduction calorimetry in as much as they are extensions of the methodology employed to determine simple heats of hydration.

The report takes the form of a bibliographic review of some major published sources. The first section comprises a short introduction to the theoretical basis for the application of calorimetry to the study of cement hydration, followed by consideration of some of the types of conduction calorimeter available to the cement chemist. The final section presents a detailed consideration of the Wexham Instruments conduction calorimeter, which offers a particularly suitable means to obtain integrated heats of hydration without the complications introduced by the use of more precise and sensitive instruments.

APPLICATION AND ONGOING WORK

Measurement of heat of hydration of binders with different levels of cement replacement.

SUPPORTING DOCUMENTS

Final Report: "Methodology for Measurement of Heat of Hydration of Nonferrous Slag Binders".

TITLE: EVALUATION OF SINTERED COLLIERY WASTE AS LIGHTWEIGHT CONCRETE MASONRY AGGREGATE

CONTRACTOR:	Besser Canada Limited	FILE NUMBER:	3-9209	FUNDING	
		BEGIN/END:	May 84/Aug. 84		
				CANMET:	$ 3 660
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	H.S. Wilson	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 3 660

OBJECTIVES

Evaluate lightweight aggregate, produced at CANMET, as aggregate in concrete masonry units. The evaluation was to be based on possible commercial acceptance of the aggregate.

PROCEDURE

The aggregate was compared with commercially produced expanded slag and pumice lightweight aggregates. A series of concrete masonry units were made using each aggregate in a series of mix proportions. The strengths, weights, and absorptions were determined.

RESULTS

The masonry units made with the CANMET aggregate did not have the strength of those made with the expanded slag aggregate. They compared favourably in all properties to those made with the commercial pumice lightweight aggregate.

APPLICATION AND ONGOING WORK

There are no plans for immediate ongoing work, but when the full study has been published, industry may pick up the technology.

SUPPORTING DOCUMENTS

Final Report: "Evaluation of Sintered Colliery Waste as Lightweight Concrete Masonry Aggregate".

TITLE: DEVELOPMENT OF HIGH-STRENGTH FLY ASH/PORTLAND CEMENT CONCRETE FOR PRECAST INDUSTRY - PHASE I

				FUNDING	
CONTRACTOR:	Canada Cement Lafarge Limited	FILE NUMBER:	2-9133		
		BEGIN/END:	Aug. 82/May 83		
				CANMET:	$ 20 940
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 20 940

OBJECTIVES

The test consisted of an evaluation of high-strength air-entrained concrete containing type 30 Portland cement and four fly ash contents (0%, 20%, 30%, and 40% by weight of cement) in combination with two commercially available admixtures (a superplasticizer and an air-entraining agent). The following series of concrete mixes were made:

1. Program A - Reference Mixes
   Determine the mechanical properties of concrete made with three water-to-cement ratios: 0.45, 0.40, and 0.35.

2. Program B - Fly Ash Mixes
   Determine the mechanical properties of concrete made by adding 20, 30, and 40% fly ash to the reference mixes above. The fly ash replaces part of the fine aggregate.

PROCEDURE

A total of 12 mix series were made. The Portland cement content (Type 30) was kept constant at 370 kg/m^3. The three reference mixes had no fly ash and had water-to-cement ratios of 0.45, 0.40, and 0.35, respectively. This sequence was then repeated with three different fly ash contents: 20, 30, and 40%. The fly ash replaced part of the fine aggregate. The slump was maintained the same throughout the project by the use of a superplasticizer, while the air content was controlled through the use of an air-entraining agent.

The properties of the fresh concrete, i.e., slump, density, and air content were determined immediately after mixing; the concrete one-day density was determined after demoulding. Hardened concrete was subjected to mechanical and freezing and thawing testing.

RESULTS

It is possible to produce high-strength concrete with a constant cement content of 370 kg/m^3 and incorporating additions of fly ash up to 40% by weight of cement without affecting the mechanical properties of concrete at early ages (1 and 7 days). The benefits of fly ash are not felt until 28 days when the concrete is cured at room temperature (23 $\pm$ 2°C). At this temperature, the fly ash reacts much too slowly to be of interest to the precast industry.

To accelerate the benefits from the use of fly ash on the early strength of concrete, further studies should be undertaken, including heat curing of the concrete at elevated temperatures as is commonly practised by the precast industry. In this manner, it may be possible to demonstrate the beneficial use of this low-energy product in the production of high-early-strength concrete.

APPLICATION AND ONGOING WORK

Further work on high-temperature curing of concrete is being undertaken.

TITLE: DEVELOPMENT OF HIGH-STRENGTH FLY ASH/PORTLAND CEMENT CONCRETE FOR PRECAST INDUSTRY - PHASE 2

CONTRACTOR:	Canada Cement LaFarge Limited	FILE NUMBER:	3-9069	FUNDING	
		BEGIN/END:	July 83/Feb. 84		
				CANMET:	$ 23 087
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 23 087

OBJECTIVES

Develop high-strength fly ash/portland cement concrete for use in the precast industry.

PROCEDURE

The investigation covered a total of 36 superplasticized air-entrained concrete mixes made with W/C ratios ranging from 0.35 to 0.45, using type 30 Portland cement and four fly ash contents (0, 20, 30, and 40% by mass of cement). The heat-curing cycles included temperatures between 40 and 70°C. Concretes were evaluated in terms of mechanical properties such as compressive, flexural, and splitting-tensile strengths, as well as modulus of elasticity.

RESULTS

Heat curing of fly ash/Portland cement concrete increased the early compressive strength by as much as 50%, indicating good potential of the particular fly ash for use as a cementitious material in the precast industry. The heat-curing cycle, however, needs further optimization.

APPLICATION AND ONGOING WORK

Further optimization of the curing cycle is required in order to make it attractive in practice.

SUPPORTING DOCUMENTS

Final Report: "Development of High-Strength Fly Ash/Portland Cement Concrete for Precast Industry - Phase 2".

TITLE: DEVELOPMENT OF HIGH-STRENGTH FLY ASH/PORTLAND CEMENT CONCRETE FOR PRECAST INDUSTRY - PHASE 3

CONTRACTOR:	Centre de Recherche Appliquees de Canfarge	FILE NUMBER:	4-9076	FUNDING	
		BEGIN/END:	July 84/Jan. 85	CANMET:	$ 29 500
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 29 500

OBJECTIVES

Determine the optimum heat-curing cycle for the development of a high-strength Portland cement concrete containing 40% subbituminous fly ash for use in the precast industry.

PROCEDURE

The test program consisted of an evaluation of high-strength air-entrained concrete containing Type 30 Portland cement and 40% fly ash by weight of cement in combination with two commercially available admixtures (a superplasticizer and an air-entraining agent). All mixes were made with a water-to-cement ratio of 0.40 and proportioned as for similar mixes in Phase 2. The optimization investigation of the heat-curing cycle used two preset times: 2 and 4 hours; four heating durations: 8, 12, 16, and 20 hours; and three heat-curing temperatures: 55°C, 70°C, and 90°C.

A total of 104 concrete batches were prepared and 824 concrete test specimens were cast. Test cylinders were tested in compression at the end of each cycle, and at 7 and 28 days for each set of curing conditions. Flexural strength and modulus of elasticity were determined at 14 and 28 days, respectively, for each curing cycle.

RESULTS

Heat-curing of fly ash/Portland cement concrete catalyzes the fly ash reaction in concrete. For the fly ash (subbituminous) investigated, heat-curing increases the one-day compressive strength by up to 50% as compared with plain concrete cured at room temperature. When compared to plain concrete also heat-cured, the corresponding increases range up to 35%.

Various heat-curing cycles can be used to achieve a given level of strength at early ages for the fly ash concrete, from which the precast producer can select an optimum cycle that best meets his production requirements.

As a general rule, an increase in the curing temperature from 55 to 90°C is beneficial for short cycles such as 12 h; however, for longer cycles (24 h), the use of temperatures higher than 55°C does not seem to be justified.

The results of the investigation indicate that Portland cement concrete (W/C = 0.40) in which 18% of fine aggregate has been replaced by fly ash, can be heat-cured to accelerate strength development at 12 to 24 h age, and compressive strengths of the order of 30 to 45 MPa can be achieved at these ages. The most promising heat-curing cycles for the materials under investigation appear to be a 12-h cycle with a preset time of 2 h and a heating temperature of 90°C, and a 24-h cycle with a preset time of 4 h and a curing temperature of 55°C.

APPLICATION AND ONGOING WORK

The data obtained can readily be used by precast producers to optimize their curing procedures for fly ash concrete. The data, however, are applicable only in cases involving the use of a similar type of fly ash to that investigated. Further studies would be required to determine the effect of various heat-curing cycles on concrete incorporating lignite and bituminous fly ashes.

TITLE: DEVELOPMENT OF ULTRA HIGH-STRENGTH SEMI-LIGHTWEIGHT CONCRETE

CONTRACTOR:	B.H. Levelton and Associates Limited	FILE NUMBER:	3-9201	FUNDING	
		BEGIN/END:	Dec. 83/Nov. 84		
				CANMET:	--
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	DSS:	$ 42 800
AUTHORITY:	H.S. Wilson	TECHNOLOGY:	Performance and Durability of Concrete Incorporating Waste Materials	TOTAL:	$ 42 800

OBJECTIVES

Develop, in the laboratory, an ultra high-strength semi-lightweight concrete. The target compressive strength was 70 MPa and an air-dry density of less than 1900 kg/m^3. The mixes were to contain superplasticizer, fly ash, and silica fume, as well as normal portland cement, and were to incorporate entrained air to provide freeze-thaw durability.

PROCEDURE

1. Review work by CANMET and others in regard to anticipated performance of lightweight concrete incorporating the materials specified.

2. Prepare a large number of trial mixes containing:
   a) two lightweight aggregates
   b) three dosages of fly ash
   c) three dosages of silica fume
   d) three cement factors.

3. On specimens prepared from the mixes, determine:
   a) compressive strength
   b) split tensile strength
   c) unit weight.

RESULTS

As was anticipated, a wide range of properties resulted. These indicated that concrete could be produced from one of the lightweight aggregates to have compressive strength of at least 70 MPa, with a density of about 2000 kg/m^3.

APPLICATION AND ONGOING WORK

Further work is being done using the information obtained here to reduce variability and to optimize such properties as splitting tensile strength and air content.

TITLE: DEVELOPMENT OF ABRASION RESISTANT GLASSCERAMICS FROM INDUSTRIAL WASTE PRODUCTS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	2-9079	FUNDING	
		BEGIN/END:	Aug. 82/Aug. 83		
				CANMET:	$ 30 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	K.E. Bell	TECHNOLOGY:	Abrasion-Resistant Ceramics	TOTAL:	$ 30 000

OBJECTIVES

Previous work had demonstrated the feasibility of preparing glassceramics (i.e., materials melt-formed and recrystallized by subsequent heat treatment) having abrasion resistance between that of quartzite (Moh 7) and corundum (Moh 9), tiles or blocks of which would be suited for lining materials handling systems. The best of these had compositions approximating those of steel-making slags.

This work was undertaken to demonstrate whether products of equal abrasion resistance could be made from modified steel-making slags, a low-cost raw material.

PROCEDURE

A literature study was completed, with particular reference to nucleating additives and requisite thermal treatment.

Twenty-four samples, representing four base compositions (slag/sand/nucleating agents), were melted and cast as glasses. The glass properties relevant to recrystallization were measured. Specimens were recrystallized at various appropriate heat treatments. Their mineralogical compositions were determined and their microstructures examined. Their abrasion resistance, flexure strength, and thermal expansion were measured.

RESULTS

The slagceramics produced in these studies showed improved abrasion resistance, but lower strengths, than the equivalent glassceramics prepared from the individual raw materials; this may be attributable to their lower Al_2O_3 contents.

Fe_2O_3/C combined is the preferred nucleating agent.

APPLICATION AND ONGOING WORK

The technology was included in Promotech with no feedback. This technology is widely practised in Europe and the Warsaw Pact countries, but is foreign to Canada. Corning is the only North American practitioner, producing highly specialized versions of tableware and related materials for advanced applications.

No further work in this area is contemplated at this time.

TITLE: PREPARATION OF DURABLE CERAMIC COATINGS BY SPRAY PYROLYSIS

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	2-9135	FUNDING	
		BEGIN/END:	Sept. 82/Nov. 83		
				CANMET:	$ 40 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	DSS:	115 000
AUTHORITY:	K. Bell	TECHNOLOGY:	Abrasion-Resistant Ceramics	TOTAL:	$ 155 000

OBJECTIVES

1. Develop and evaluate the methodology for applying abrasion-resistant coatings.

2. Assess the industrial potential of such abrasion-resistant coatings.

PROCEDURE

A computer-automated apparatus had been previously constructed at ORF. Initial work established the operating parameters of the equipment, using SnO_2 coatings on glass substrates. At the same time, a very comprehensive review of the relevant literature was conducted.

All attempts to produce acceptable Al_2O_3 coatings on glass failed. Subsequent chemicophysical analysis showed that the temperatures required would be beyond the capabilities of the substrate.

At the mid-term review meeting, the work was redirected to application of ZrO_2 coatings and the use of metallic substrates. Thin, abrasion-resistant coatings were successfully applied to a variety of steels, uncoated and coated with TiC, Ni, and porcelain enamel. Thin films of Al_2O_3 were also applied on glass and steels by pyrolysis of aluminum esc-butoxide in toluene.

RESULTS

It was demonstrated that adherent thin films of abrasion-resistant materials can be applied by the spray pyrolysis technique. The films are limited to thicknesses of 1-2 µm, which is inappropriate for applications envisioned in materials handling systems or, for example, ZrO_2 coatings on internals of hot diesel engines. A number of potential applications are identified, all outside of the objectives of the abrasion-resistant ceramics project.

APPLICATION AND ONGOING WORK

Owing to limitations on thickness of the applied coatings, they are unsuited to the applications sought.

No further work in this area is envisioned at this time.

SUPPORTING DOCUMENTS

Final Report: "Preparation of Durable Ceramic Coatings by Spray Pyrolysis - Phase I".

MINERALS TECHNOLOGY

METALS PROCESSING

TITLE: HIGH TECHNOLOGY CUPRO-NICKEL CASTINGS FOR TECHNOLOGY DEMONSTRATION AND SUBMARINE SERVICE EVALUATION

CONTRACTOR:	Burnstein Castings Ltd.	FILE NUMBER:	9-9088	FUNDING	
		BEGIN/END:	Feb. 80/March 80		
				CANMET:	$ 23 962
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	M. Sahoo	TECHNOLOGY:	Metal Casting	TOTAL:	$ 23 962

OBJECTIVES

CANMET/PMRL was requested by the Department of National Defence - Chief, Engineering and Maintenance (DND-CEM) to provide technical support to obtain from Canadian sources two ship's sets, each of 8 large cast manifolds, in niobium-modified 90/10 and 70/30 cupro-nickels. These would replace existing tin-bronze castings and, at the same time, would enable a comparative evaluation of the performance of the two Cu-Ni alloys under sea water service conditions.

The object of the contract was to: (a) supply a strategic need from Canadian sources and (b) upgrade the technological capability of the Canadian foundry industry.

PROCEDURE

The melting procedure established at PMRL was followed at the bronze foundry.

The experience gained at PMRL in the casting of medium-size commercial fittings was applied to the design of gating and risering systems. Hot-metal distribution was improved by using an unpressurized gating system and by gating into most of the side risers. The measured pouring rate varied from 2.3 to 3.6 kg/s (5 to 8 lb/s). Insulated blind risers were used in most cases to improve the casting yield. Cast-iron chills were used to eliminate "chill blows".

RESULTS

1. All 16 castings passed the 2760 kPa (400 psi) pressure-test and met the mechanical properties specified in ASTM B369-78. In addition, all were judged to meet the ASTM radiography requirements either in toto, or at least in critical areas.

2. The average casting yield was 50%.

3. For similar gating and risering systems, the casting quality was better in the short freezing range 90/10 alloys. In the 70/30 alloys of intermediate freezing range, some porosity was produced in areas of low thermal gradient.

4. Technically, the project represents a successful exchange of experience between a commercial foundry and the laboratory, to the mutual benefit of both.

APPLICATION AND ONGOING WORK

To complete the technology transfer program, technical support will be provided to produce a six-valve chest casting, weighing about 318 kg (700 lbs), and its accompanying components in the Canadian foundry (Contract No. 0-9090).

SUPPORTING DOCUMENTS

Final report: "High-Integrity Cupro-Nickel Castings for Technology Demonstration and Sea-Water Service Evaluation"; M. Sahoo and J.O. Edwards; Division Report MRP/PMRL 80-61(TR).

TITLE: EFFECT OF TUYERE VELOCITY ON CUPOLA MELTING PERFORMANCE

CONTRACTOR: Hatch Associates Ltd.	FILE NUMBER: 2-9074	FUNDING	
	BEGIN/END: Oct. 82/March 83		
		CANMET:	$ 28 759
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: R.D. Warda	TECHNOLOGY: Metal Casting	TOTAL:	$ 28 759

OBJECTIVES

Establish, at a commercial foundry, a closely controlled and documented cupola operation in which the influence of tuyere velocity on combustion efficiency can be isolated from that of other variables and defined unambiguously.

PROCEDURE

1. Ensure cupola and ancillary equipment are in good working order.
2. Ensure blast rate and all fuel and metallic inputs are measured accurately.
3. Measure stack gas and metal outputs to define heat and materials balances.
4. Define cupola performance at "normal" tuyere velocities.
5. Decrease tuyere area to increase velocity and report tests for tuyere velocities of 50, 100, 150, and 200 fps (15, 30, 45, and 60 m/s).
6. Relate tuyere velocity to cupola performance.

RESULTS

1. The tuyere velocity was shown to exert a significant influence on cupola combustion and performance.
2. As tuyere velocities increased, the reduction reaction in the cupola increased in importance, increasing the CO content of the stack gas.
3. The net result was a significant shift in the cupola heat balance outputs.
4. Operational requirements and a deficiency in cupola charging practice prevented the contractor from changing the cupola practice to take advantage of (3) and increase cupola efficiency.

APPLICATION AND ONGOING WORK

This work defined unambiguously the influence of tuyere velocity on combustion in a coke-fired cupola furnace. The results and methodology could be applied to a number of cupola operations to alter combustion characteristics and increase melting efficiency. There is no on-going work at present.

SUPPORTING DOCUMENTS

Final Report: "Summary of the Tuyere Velocity Study".

TITLE: DETERMINATION OF THE OPERATING FACTORS GOVERNING CARBON, SILICON AND MANGANESE YIELD IN FERROUS FOUNDRY CUPOLAS

CONTRACTOR: Hatch Associates Ltd.	FILE NUMBER: 3-9181	FUNDING	
	BEGIN/END: Jan. 84/Jan. 85	CANMET:	$ 71 712
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: R.D. Warda	TECHNOLOGY: Metal Casting	TOTAL:	$ 71 712

OBJECTIVES

Investigate and improve the recoveries (yields) of carbon, silicon, and manganese in iron foundry cupolas through an investigation of relevant operating factors at four iron foundries in Ontario.

PROCEDURE

1. Monitor operating factors and all parameters related to the input and output of carbon, silicon, and manganese at four iron foundries.
2. Construct material balances for each element and determine yields.
3. Relate yields to operating factors for each foundry.
4. Select two foundries and attempt to improve yields by modifying operating practices.

RESULTS

1. Yields were quantified and related to operating factors at all four foundries.
2. Operating factors were identified that had significant influences on yields.
3. Changes in operating practice in one of the two foundries selected for further study had a significant impact on yield of silicon and also on other material requirements. Operating changes at this foundry made as a direct result of the study should result in estimated annual savings in coke, limestone, and silicon of $200 000.

APPLICATION AND ONGOING WORK

The results of the work will be communicated to other Canadian foundries using cupola furnaces. This technology is also being transferred, where applicable, by the Mobile Foundry Laboratory.

SUPPORTING DOCUMENTS

Final report: "EMR Cupola Yield Study" (Contract Report No. ISQ-00245).

TITLE: HORIZONTAL CONTINUOUS CASTING OF STEEL - CANMET S.T.A.R.T. PROGRAM

CONTRACTOR:	Lake Ontario Steel Co. Ltd.	FILE NUMBER:	4-9069	FUNDING	
		BEGIN/END:	Oct. 84/Jan. 85		
				CANMET:	$ 23 330
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	Dr. R. Thomson	TECHNOLOGY:	Metal Casting	TOTAL:	$ 23 330

OBJECTIVES

Determine the potential role of Horizontal Continuous Casting (HCC) steel production at LASCO.

PROCEDURE

Review HCC technology and practice, and analyze market potential for HCC products.

RESULTS

1. The market potential for SBQ bar is excellent.
2. HCC is seen as relevant to LASCO as an incremental casting capability.
3. In LASCO's view, the technology is not mature enough for immediate transfer to a production scenario. Further work is required to improve control over surface quality, in their view.
4. LASCO is not prepared at this time to involve itself in pilot-plant trials at their location. They will, however, cooperate with U of T to tackle the problem referred to in (3).

SUPPORTING DOCUMENTS

Final Report: "An Investigation into the Horizontal Continuous Casting of Steel".

TITLE: MATHEMATICAL MODELLING OF HEAT FLOW IN PERMANENT MOLDS

CONTRACTOR: University of Ottawa	FILE NUMBER: 0-9188	FUNDING	
	BEGIN/END: June 81/March 84		
		CANMET:	$ 67 255
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: K. Davis	TECHNOLOGY: Metal Casting	TOTAL:	$ 67 255

OBJECTIVES

Write a computer program modelling heat flow in permanent mold casting processes.

RESULTS

A mathematical model has been developed to investigate the solidification process in a casting. A finite-difference scheme using the alternating direction implicit (ADI) method was used to solve the heat transfer equations. A computer program has been written for a simple two-dimensional geometry defined in both cartesian and cylindrical polar coordinate systems. The program was tested for a simple geometry and gave reasonable results.

Further work will include the modelling of the complex-shape mold, at present being considered at EMR, and the development of a three-dimensional program.

APPLICATION AND ONGOING WORK

A contract extension is now underway to improve the existing program and to start work on stress distributions.

SUPPORTING DOCUMENTS

Final Report: "Mathematical Modelling of Heat Transfer in Permanent Molds" (Contract Report No. OSU81-00137).

TITLE: CANMET RISERING SOFTWARE

CONTRACTOR: Queen's University	FILE NUMBER: 4-9083	FUNDING	
	BEGIN/END: Aug. 84/Nov. 84		
		CANMET:	$ 3 929
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: K. Davis	TECHNOLOGY: Metal Casting	TOTAL:	$ 3 929

OBJECTIVES

Modify the existing program for CANMET risering.

1. The program should treat the case in which a ring-shaped riser is used on a hollow-cylinder casting.

2. The program should analyze casting designs in which different regions are fed by both open and blind risers.

PROCEDURE

Rewrite certain sections of the program. Write addendum to documentation.

RESULTS

Program with extended capability.

The report summarizes the changes necessary to accommodate two extensions to the program, the addition of two elementary shapes useful in describing the size and shape of casting sections, and the extension of the ring riser design to tapered rectangular risers (wedge risers).

SUPPORTING DOCUMENTS

Final Report: "CANMET Risering Software" (Contract Report No. OST84-00219).

TITLE: EVALUATION AND MEASUREMENT OF SAND PROPERTIES AT CANADIAN FOUNDRIES

CONTRACTOR:	Robert Shnay & Associates Ltd.	FILE NUMBER:	3-9127	FUNDING	
		BEGIN/END:	Dec. 83/March 85		
				CANMET:	$ 81 775
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	R.K. Buhr	TECHNOLOGY:	Metal Casting	TOTAL:	$ 81 775

OBJECTIVES

Measure the various properties of sand used in foundries visited by the Mobile Foundry Laboratory, and report the results to the foundry and to CANMET.

PROCEDURE

1. Design a testing program suitable for evaluating foundry sands.
2. Devise a standard format to report to the foundries the condition of their sands at present, as well as recommendations that can be implemented to improve their properties.
3. Visit all foundries with the MFL, obtaining necessary sand samples and determining their properties.
4. Write confidential reports for transmission to the foundries.
5. Write a final summation report at the end of the testing program.

RESULTS

A total of 52 foundries were visited by the end of March, 1985. Confidential reports were written for all 52 foundries together with recommendations to improve the sand properties and sand control procedures. A final summary report on the visits was also written and supplied to the Scientific Authority.

The reports issued to the foundries have been very well received, and most of the recommendations made have been acted upon.

The contract has been completely successful and the results have exceeded expectations.

SUPPORTING DOCUMENTS

Final report: "Sand Properties at Canadian Foundries - Evaluation and Measurement".

TITLE: MOBILE FOUNDRY LABORATORY EVALUATION

CONTRACTOR: Kanata Consulting Group	FILE NUMBER: 4-9195	FUNDING	
	BEGIN/END: Aug. 84/Sept. 84		
		CANMET:	$ 6 250
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: R. Buhr	TECHNOLOGY: Metal Casting	TOTAL:	$ 6 250

OBJECTIVES

Document the technological and economic benefits accruing to 8 foundries from the visit of the Mobile Foundry Laboratory (MFL), and identify any problems they had experienced. Also, determine whether the methodology employed in the pilot study was capable of assessing the results of the visits, and estimate the cost of a study of the remaining 42 foundries scheduled for visits.

PROCEDURE

The eight foundries were supplied with a list of questions they would be asked. The foundries were personally visited to get the answers and were also asked, on a point by point basis, whether the individual recommendations made in the confidential report had been implemented. If not, the reasons why were solicited.

RESULTS

Those foundries with access to technical expertise claimed only small benefits resulting from the visit of the MFL. They claimed that recommendations made by the MFL team members were already known to the company and were due for implementation when capital was available. For those foundries without access to technical expertise, all claimed considerable benefits from the MFL visit, and most of the inexpensive changes had been instituted. Over a five-year period, these foundries claimed an expected benefit of about $ 650 000.

SUPPORTING DOCUMENTS

Final Report: "Mobile Foundry Laboratory Evaluation".

TITLE: PREVENTION OF DUPLEX GRAIN STRUCTURES IN CONTROLLED-ROLLED HSLA STEEL PLATE - PHASE 3

CONTRACTOR:	McGill University	FILE NUMBER:	0-9179-2	FUNDING	
		BEGIN/END:	April 83/March 84		
				CANMET:	$ 50 213
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	G.E. Ruddle	TECHNOLOGY:	Metal Working	TOTAL:	$ 50 213

OBJECTIVES

Conduct experimental research to determine the causes of the undesirable duplex grain structure that develops during controlled rolling of microalloyed high-strength steels, and examine processing methods to prevent or minimize the duplexing of the steel microstructure.

1. Examine and characterize the development of austenite microstructure and the austenite-to-ferrite (π-to-θ) transformation in simulated rolling deformation of a base composition microalloyed steel.

2. Examine the effects of starting austenite grain size, and the effects of austenite deformation and grain growth in the complete, partial, and non-recrystallization temperature ranges, on the above characteristics.

3. Clarify how duplex grain structure is developed, and determine guidelines for thermomechanical treatment to minimize or prevent its development.

4. Examine the effects of specific microalloying additions to the base composition on the development of austenite microstructure during simulated rolling deformation.

PROCEDURE

The possible causes of duplex grain structure were investigated, and means of minimizing or eliminating its occurrence were explored by three different approaches. These were:

1. Simulation of rolling by torsional deformation in a Mo-Nb-V microalloyed steel.

2. Modelling of dynamic recrystallization in both plain C and microalloyed steels.

3. Modelling of the dynamic θ-to-π transformation in both plain C and microalloyed steels.

The effects of the following factors on the formation of duplex grain structures were explored: the reheated grain size, the roughing and finishing deformation temperatures, the number of roughing and finishing passes, the strain per pass, and the cooling rate after finishing. Also investigated were the conditions in which dynamic recrystallization and dynamic π-to-θ transformation lead to formation of duplex grain structures.

RESULTS

The causes of the formation of mixed grain sizes were determined to be:

1. Mixed initial grain sizes.

2. Abnormal grain growth due to light reductions at high temperature.

3. Incomplete dynamic recrystallization during deformation and incomplete static recrystallization between deformations.

4. Inhomogeneous deformation and recrystallization.

5. Dynamic π-to-θ transformation.

Simulations of rolling by torsional deformation demonstrated the thermomechanical processes necessary to decrease grain size without forming duplex grain structure.

The study of dynamic recrystallization delineated the conditions, in relation to industrial rolling processes, that lead to refinement and to coarsening of grain size, and to formation of mixed grain size.

APPLICATION AND ONGOING WORK

This work is important for Canadian industrial development of thermomechanical processes to improve grain structure, strength, and toughness in microalloyed steels for automotive, tubing, linepipe, structural, and marine applications.

SUPPORTING DOCUMENTS

Final Report: "Prevention of Duplex Grain Structures in Controlled-Rolled HSLA Steel Plate - Phases I to 3" (Contract Report No. OSU83-00024).

This report includes a bibliography of publications that also document the research results.

TITLE: MICROSTRUCTURAL FEATURES WHICH LIMIT FORMABILITY IN MASS-PRODUCED COLD FORGINGS

CONTRACTOR: McMaster University	FILE NUMBER: 0-9190	FUNDING	
	BEGIN/END: July 81/Aug. 83		
		CANMET:	$ 55 494
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: Dr. A.F. Crawley	TECHNOLOGY: Metal Working	TOTAL:	$ 55 494

OBJECTIVES

Devise and investigate test methods to determine the strain at fracture in samples of materials used for cold forging, and examine the microstructural features associated with damage, strain localization, and cracking in test samples. The materials included were carbon steel in the "as-hot-rolled", spheroidized, and normalized states. The steels were chosen to have a range of carbon and sulphur levels.

PROCEDURE

1. Conduct a systematic investigation of the strain paths and stress states in existing and modified upsetting tests that lead to cracking in ductile steels. These tests included:
   a) compression test (Kuhn type)
   b) Collar-type test
   c) Small diameter punch test
   d) Controlled buckling test.

2. Develop metallographic and fractographic techniques for microstructural studies associated with failure.

3. Study a range of steels and compare their forging limits in appropriate mechanical tests, and investigate the relationship of inclusion size, morphology, and distribution to crack behaviour.

RESULTS

1. The punch and collar tests are proposed as the most satisfactory upsetting tests. These tests result in relatively low fracture strains and thus promote fracture in ductile materials. The collar test permits direct, accurate measurement of hoop and axial stress.

2. The stress-strain behaviour in the upsetting tests can be analyzed by simple plasticity theory to reveal the associated stress states based on the combined hoop and axial strain paths.

3. A finite element model of the upsetting tests was developed. This model permits the prediction of stress and strain states at any point during the deformation process. The finite element model, however, does not predict the onset of failure because of the absence of a reliable failure criterion.

4. Three types of fracture behaviour were observed: ductile fracture, ductile failure terminated by macroscopic fracture and by intergranular fracture. In medium carbon steels, ductile failure was the only failure mechanism observed. Failure initiates by void nucleation beginning at large inclusions or groups of inclusions where the local stresses are highest. The results of the collar test clearly demonstrate that increasing inclusion content leads to a rapid decrease in ductility. Fracture in most steels was dominated by sulphide content. In these cases of high sulphide content, spheroidizing or decarburizing to increase surface zone ductility yielded only limited improvement. Clearly, therefore, steel cleanliness is the paramount criterion for improvement in forgeability.

APPLICATION AND ONGOING WORK

1. Provision of data and information for development of deformation-microstructure coupled predictive models for forging processes.

2. Basis for the development of a modelling program for use in establishing die design in small forging plants.

TITLE: MICROCHEMISTRY AND TRANSFORMATION KINETICS OF EXPERIMENTAL BATCH ANNEALED DUAL PHASE STEELS

CONTRACTOR: McMaster University	FILE NUMBER: 0-9192	FUNDING	
	BEGIN/END: Aug. 81/June 83		
		CANMET:	$ 40 169
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: A.F. Crawley	TECHNOLOGY: Metal Working	TOTAL:	$ 40 169

OBJECTIVES

Conduct a study of the microchemistry of dual phase steels to gain an understanding of the poor ductility of batch-annealed C-Mn steels compared to continuously annealed and as-hot-rolled steels. This study will involve a comparison of the effects of intercritical annealing by both processes as shown by:

1. Effect of cooling rates on the microchemistries, distribution, and morphology of the second phase.
2. Effects of transformation kinetics on the final microchemistry and microstructure.
3. Plastic flow and fracture behaviour.

PROCEDURE

Effect of Cooling Rates

1. Determine the effects of three cooling rates on the microchemistry and second phase distribution in continuous annealed steels.
2. Determine the effects of simulated tight and open coil batch annealing on microstructures and microchemistries of a 3% Mn/0.06% C steel.

Transformation Kinetics

The kinetics of austenite growth and shrinkage were analyzed employing computer simulations of the processes of microstructural development.

Fractography

The fracture path was determined by microstructural evaluation of steels in the fracture zone and physical modelling.

RESULTS

1. The superior formability of continuous annealed dual-phase steels results from:
   a) a lower strength ferritic phase, and
   b) an absence of severe Mn banding as occurs in high Mn compositions used for batch annealing. This banding dominates work hardening and fracture behaviour.
2. Dual-phase steels for batch processing should not rely on global values for alloying elements to achieve austenite hardenability. Rather, lower alloy contents should be combined with more novel processing technology, such as protracted sub-critical annealing, that will concentrate the alloying elements in the austenite.

APPLICATION AND ONGOING WORK

Provision of alternate processing routes for dual phase steels in the Canadian steel industry, which does not have continuous annealing facilities.

TITLE: DESIGN OF AN AUTOMATIC SCREW-DOWN FOR A HIGH-SPEED COMPRESSION-TESTING MACHINE

				FUNDING	
CONTRACTOR:	W.R. Davis Engineering Limited	FILE NUMBER:	3-9011		
		BEGIN/END:	April 83/July 83		
				CANMET:	$ 9 292
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	D.L. Baragar	TECHNOLOGY:	Metal Working	TOTAL:	$ 9 292

OBJECTIVES

Provide a detailed design for a modification to a high-speed compression testing machine - the Cam Plastometer. The modification is to provide an automatic system for rapidly bringing the load cell of the Cam Plastometer into contact with the sample die after each strike. At present, the main screw-down has to be manually reset after each test. The automatic system should be capable of making the adjustment in 0.1 second. Cost estimates, design drawings, and recommended suppliers of component parts will be required.

PROCEDURE

The two conceptual designs involve either the movement of the main screw-down or maintaining the sample die in constant contact with the load cell on the main screw-down.

RESULTS

Davis Engineering presented two conceptual designs that would meet the requirements. CANMET selected the pneumatically operated Wedge Take-Up System as the one offering the greatest probability of success, and the contractor then produced a detailed design.

The report describes additional details of the system and offers some guidelines for its commissioning. Manufacturers' specifications of major components are contained in the Appendix of the report and a drawing package is provided under separate cover.

SUPPORTING DOCUMENTS

Final Report: "Design of an Automatic Screw-Down for a High-Speed Compression-Testing Machine".

TITLE: UPGRADING OF HYDRAULIC CONTROL AND MONITORING SYSTEM OF A 500 TON HYDRAULIC PRESS

CONTRACTOR: Westinghouse Canada Inc.	FILE NUMBER: 4-9039	FUNDING	
	BEGIN/END: Aug. 84/July 85		
		CANMET:	$ 52 649
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: Dr. J. Too	TECHNOLOGY: Metal Working	TOTAL:	$ 52 649

OBJECTIVES

Upgrade a 500 ton press by developing and designing major modifications to the hydraulic control system and by incorporating state-of-the-art technology to allow fully instrumented computerized control of preprogrammed and repeatable deformation schedules for forging and pressing operations.

PROCEDURE

1. Discuss the operational requirements of scientists conducting research using the press.
2. Thoroughly examine the existing system and its capability to meet requirements.
3. Design the modified system including control instrumentation and inclusion of computer control system.

RESULTS

A design has been proposed that provides the capability for preprogrammed and repeatable controlled deformation schedules over a wide range of conditions of strain, strain rate, and temperature.

SUPPORTING DOCUMENTS

Final Report: "Upgrading of Hydraulic Control and Monitoring System of a 500 ton Hydraulic Press".

TITLE: DEVELOPMENT AND IMPLEMENTATION OF APPLICATION SOFTWARE FOR AN ON-LINE ACCELERATED COOLING SYSTEM

CONTRACTOR: SNC Inc.	FILE NUMBER: 4-9052	FUNDING	
	BEGIN/END: Aug. 84/March 85		
		CANMET:	$ 35 031
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: A.F. Crawley	TECHNOLOGY: Metal Working	TOTAL:	$ 35 031

OBJECTIVES

Develop and implement application software for an on-line accelerated cooling system designed and fabricated by SNC Inc.

PROCEDURE

Develop a software code to provide the following:

1. A preformatted VT-100 screen driver that gives technical staff information relative to an upcoming trial.
2. A FORTRAN IV program to sequence the operations of the OLAC system according to input instructions from technical staff.
3. A FORTRAN IV program to provide a hard copy summary of process data logged during a run.

RESULTS

The software has been developed and tested.

SUPPORTING DOCUMENTS

Program discs, listing, and instructions.

TITLE: TECHNOLOGY ASSESSMENT OF THE CANADIAN METAL FORMING INDUSTRY

CONTRACTOR:	Robertson-Nickerson Ltd.	FILE NUMBER:	3-9081	FUNDING	
		BEGIN/END:	Oct. 83/Feb. 85		
				CANMET:	$ 155 846
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	A.F. Crawley	TECHNOLOGY:	Metal Working	TOTAL:	$ 155 846

OBJECTIVES

1. Undertake a study to assess the technological posture and outlook of the Canadian metal forming industry (sheet metal forming and forging).

2. Compare the state of the Canadian industry with its international competition.

3. Report on areas where research and development are required to improve the competitiveness of the industry.

PROCEDURE

1. Extensive analysis of published data relating to production of both finished products and components.

2. Extensive review and analysis of published information relating to new materials, processes, production methods, and equipment.

3. Collection and analysis of trade catalogues, bulletins, and technical literature of raw material suppliers, fabricators, and machinery and equipment suppliers.

4. Extensive series of interviews and plant tours with sheet metal processors, forging companies, equipment suppliers, and raw material suppliers in Canada, United States, Europe, and Japan.

RESULTS

The report answered all requirements of the objectives, and the conclusions were based on a large volume of information. The main points are:

1. There is little difference in the level of technology used or in the technological awareness of different countries. Differences that do not exist relate more to scale.

2. The superior economic productivity of the Japanese can be attributed to a dedication to quality control and the application of certain manufacturing techniques within firmly established technologies.

3. The Japanese have a distinct superiority in the quality of their raw materials.

APPLICATION AND ONGOING WORK

Distribution to industry and a seminar.

SUPPORTING DOCUMENTS

Final Report: "Technological Assessment of the Canadian Metal Forming Industry - Summary Report".

TITLE: A COMPUTER PROGRAM FOR THE AVOIDANCE OF HYDROGEN CRACKING

CONTRACTOR:	Santarossa Trading Co. Ltd.	FILE NUMBER:	3-9133	FUNDING	
		BEGIN/END:	Sept. 83/March 84		
				CANMET:	$ 26 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	J. Bowker	TECHNOLOGY:	Welding	TOTAL:	$ 26 000

OBJECTIVES

Develop a computer program that evaluates the fabricator's welding procedure variables and provides data to indicate the minimum welding variables which preclude hydrogen cracking.

PROCEDURE

A literature survey was carried out to obtain information appropriate to the development of a computer program for the avoidance of hydrogen cracking in welds. In addition to surveying the applicable industrial codes of practice, published data were used to devise explanations for the different features of the computer program. The program was developed so that the user could input welding procedure variables and obtain recommended preheat and electrode runout lengths to avoid hydrogen-cracking problems.

RESULTS

A computer program has been successfully developed to calculate recommended minimum preheat and interpass temperatures for a given steel composition and set of welding variables in order to avoid hydrogen cracking. The program is written in MS-DOS Basic and is compatible with the IBM personal computer.

APPLICATION AND ONGOING WORK

Potential application to the small fabricator involved in welding practices.

SUPPORTING DOCUMENTS

Final Report: "A Computer Program for the Avoidance of Hydrogen Cracking".

MINERALS TECHNOLOGY

STANDARDS AND SPECIFICATIONS

TITLE: HOMOGENEITY TESTING OF REFERENCE IRON ORE CONCENTRATE MW-1

CONTRACTOR:	Lakefield Research of Canada Ltd.	FILE NUMBER:	0-9122	FUNDING	
		BEGIN/END:	Feb. 81/March 81		
				CANMET:	$ 1 176
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	Dr. H.F. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 1 176

OBJECTIVES

Determine the homogeneity of reference iron ore MW-1 with respect to sodium and silicon.

PROCEDURE

The contractor analyzed 15 randomly selected bottles of MW-1 in triplicate for each of sodium and silicon. He also analyzed one quality control sample for sodium and silicon in triplicate, to verify the accuracy of the analytical techniques.

RESULTS

MW-1 was found to be homogeneous to a very high degree.

APPLICATION AND ONGOING WORK

MW-1 was subjected to an interlaboratory program to certify it for 12 constituents.

The results of the interlaboratory program are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 82-16E: MW-1 - A Certified Reference Iron Ore.

TITLE: HOMOGENEITY TESTING OF TANTALUM ORE TAN-I

CONTRACTOR: X-Ray Assay Labs Ltd.	FILE NUMBER: 2-9019	FUNDING	
	BEGIN/END: May 82/Aug. 82		
		CANMET:	$ 1 600
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: H.F. Steger	TECHNOLOGY: Reference Materials	TOTAL:	$ 1 600

OBJECTIVES

Determine the homogeneity of tantalum reference ore TAN-I with respect to tantalum.

PROCEDURE

The contractor analyzed 30 randomly selected bottles of TAN-I for tantalum in quintuplicate and reported the results as total X-ray counts. He also analyzed one bottle by X-ray fluorescence and reported the results as % Ta_2O_3.

RESULTS

TAN-I was found to be homogeneous for use as a reference material.

APPLICATION AND ONGOING WORK

TAN-I was certified for tantalum content by an interlaboratory program. The results of the interlaboratory program are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 83-10E: TAN-I - A Certified Tantalum Reference Ore.

TITLE: HOMOGENEITY EVALUATION OF REFERENCE ORE KC-1a

CONTRACTOR:	Bondar-Clegg & Co. Ltd.	FILE NUMBER:	3-9165	FUNDING	
		BEGIN/END:	March 84/June 84		
				CANMET:	$ 648
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	Dr. H.F. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 648

OBJECTIVES

Analyze 15 randomly selected bottles of zinc-lead-tin-silver reference ore KC-1a for zinc and silver.

PROCEDURE

The between-bottle variance was compared to the within-bottle variance of the determined values for zinc and silver.

RESULTS

KC-1a was confirmed to be sufficiently homogeneous for use as a compositional reference material.

APPLICATION AND ONGOING WORK

KC-1a has subsequently been certified as a reference material.

Recommended values for KC-1a are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 84-6E: KC-1a - A Certified Reference Ore.

TITLE: HOMOGENEITY EVALUATION OF REFERENCE ORE MA-2a

CONTRACTOR:	Chemex Labs Ltd.	FILE NUMBER:	5-9060	FUNDING	
		BEGIN/END:	April 85/June 85		
				CANMET:	$ 338
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC	H. Steger	SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	C.W. Smith	TECHNOLOGY:	Reference Materials	TOTAL:	$ 338

OBJECTIVES

Provide scientific evidence that gold is homogeneously distributed in bottled samples of compositional gold-ore MA-2a; to prove its suitability as a certified reference material for gold.

PROCEDURE

Three randomly selected subsamples from each of fifteen bottles of MA-2a were analyzed for gold concentration by fire assay/neutron activation analysis methodology. Values were submitted for statistical analysis of variance treatment at CANMET.

RESULTS

Two independent sets of values were provided, since the contractor was not satisfied with the apparent reproducibility in the first run. In the second set, atomic absorption spectroscopy was used for measurement. Statistical analysis of both sets provided the required evidence for homogeneity of MA-2a. Values of the ratio (between-bottle/within-bottle) of mean square variances for the neutron activation and atomic absorption results were 0.67 and 0.89, respectively, compared to the F statistic at 5% significance (for 14 and 30 degrees of freedom) at 2.04.

APPLICATION AND ONGOING WORK

An interlaboratory certification project to establish a certifiable value for gold concentration in MA-1a, MA-2a, and MA-3 is just being completed by the Canadian Certified Reference Materials Project. These reference gold ores are required to replace earlier gold reference materials, the stock of which has been depleted.

SUPPORTING DOCUMENTS

Results of this study and their interpretation will be incorporated in a forthcoming CANMET Report describing the certification of gold ores MA-1a, MA-2a, and MA-3.

TITLE: HOMOGENEITY EVALUATION OF REFERENCE ORE MP-2

				FUNDING	
CONTRACTOR:	Bondar-Clegg and Company Ltd.	FILE NUMBER:	0-9123		
		BEGIN/END:	Feb. 81/March 81		
				CANMET:	$ 1 356
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	H. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 1 356

OBJECTIVES

Determine the homogeneity of tungsten-molybdenum reference ore MP-2 with respect to silver and bismuth.

PROCEDURE

The contractor analyzed 15 randomly selected bottles of MP-2 in triplicate for each of silver and bismuth. He also analyzed one quality control sample for silver and another for bismuth, in triplicate, to verify the accuracy of the analytical techniques.

RESULTS

MP-2 was found to be homogeneous to a very high degree.

APPLICATION AND ONGOING WORK

MP-2 was subjected to an interlaboratory program to certify it for the silver, bismuth, molybdenum, and tungsten content.

The results of the interlaboratory program are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 83-14E: MP-2 - A Certified Tungsten-Molybdenum Reference Ore.

CANMET Report 84-10E: Reference Materials CZN-1, CPB-1, CCU-1, MP-1a and MP-2 - Additional Recommended Values.

TITLE: CERTIFICATION OF CCRMP REFERENCE MATERIALS

CONTRACTOR: Various	FILE NUMBER: 3-9164-1 to 3-9164-10	FUNDING	
	BEGIN/END: Nov. 83/March 84		
		CANMET:	$ 7 210
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. H.F. Steger	TECHNOLOGY: Reference Materials	TOTAL:	$ 7 210

OBJECTIVES

Obtain additional values for certain elements leading to their certification in available reference materials. These are:

MP-1a	W
MP-2	Sn
CZN-1	Bi, Se, Sn
CPB-1	Mn, Sn, Se
CCU-1	Fe, S, As, Se

PROCEDURE

Each contractor provided quintuplicate determinations of the concentrations of the required elements in one sample of the appropriate reference material.

The contractor's results will be combined in a statistical analysis of variance treatment to give the best estimate of the concentrations of the denoted elements. Should the appropriate criteria be satisfied, these estimates will be certified.

RESULTS

The analytical data were reasonable in magnitude and were adequately precise for use in the subsequent statistical analysis.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 82-14E: MP-1a - A Certified Reference Ore.

CANMET Report 83-14E: MP-2 - A Certified Tungsten-Molybdenum Reference Ore.

CANMET Report 79-14: Zinc Concentrate CZN-1 - A Certified Reference Material.

CANMET Report 79-15: Lead Concentrate CPB-1 - A Certified Reference Material.

CANMET Report 79-16: Copper Concentrate CCU-1 - A Certified Reference Material.

CANMET Report 84-10E: Reference Materials CZN-1, CPB-1, CCU-1, MP-1a, and MP-2 - Additional Recommended Values.

TITLE: HOMOGENEITY EVALUATION OF REFERENCE ORES BL-2a AND BL-4a

CONTRACTOR:	Chemex Labs Ltd. Bondar-Clegg & Company Ltd.	FILE NUMBER: BEGIN/END:	0-9193/1-9041 June 81/July 81	FUNDING	
				CANMET:	$ 2 176
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	Dr. H.F. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 2 176

OBJECTIVES

Determine the homogeneity of reference ores BL-2a and BL-4a with respect to uranium.

PROCEDURE

Two contractors each analyzed 15 randomly selected bottles of each of BL-2a and BL-4a for uranium in triplicate; one by a neutron activation method, the other by the optical fluorimetric method. Each contractor also analyzed two quality control samples for uranium in triplicate, to verify the accuracy of the analytical methods.

RESULTS

Both BL-2a and BL-4a were found to be homogeneous for use as reference materials.

APPLICATION AND ONGOING WORK

BL-2a and BL-4a were certified for uranium content by the volumetric-umpire method at CANMET.

Recommended values for these reference ores are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 82-6E: BL-2a and BL-4a - Certified Uranium Reference Ores.

TITLE: DETERMINATION OF RADIUM-226 IN URANIUM BEARING REFERENCE MATERIALS FOR CERTIFICATION PURPOSES

CONTRACTOR: Various	FILE NUMBER: 2-9064-1 to 2-9064-5	FUNDING	
	BEGIN/END: Aug. 82/Jan. 83		
		CANMET:	$ 10 100
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. C.W. Smith	TECHNOLOGY: Reference Materials	TOTAL:	$ 10 100

OBJECTIVES

Obtain and report Ra-226 activities (Bq/g) in four independent subsamples in each of CCRMP (Canadian Certified Reference Materials Project), reference uranium and uranium-thorium ores BL-5, BL-4a, DH-1a, and DL-1a.

PROCEDURE

Measurement of alpha-particle emission rate of Ra-226 following quantitative radiochemical separation from the ore matrix. Technique to be calibrated using U.S. N.B.S. radium reference material.

RESULTS

The results from the participating laboratories are used in establishing the certified recommended activities for Ra-226 in the above materials, as part of a project to extend the use of these materials as radiochemical compositional reference materials.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

APPLICATION AND ONGOING WORK

A similar certification program for additional isotopes of environmental or geological interest is to be carried out in 1983-84.

SUPPORTING DOCUMENTS

CANMET Report 79-4: Uranium Ore BL-5 - A Certified Reference Material.

CANMET Report 80-10E: DL-1a - A Certified Uranium-Thorium Reference Ore.

CANMET Report 81-11E: DH-1a - A Certified Uranium-Thorium Reference Ore.

CANMET Report 82-6E: BL-2a and BL-4a - Certified Uranium Reference Ores.

CANMET Report 83-9E: Radium-226 in Certified Uranium Reference Ores DL-1a, BL-4a, DH-1a, and BL-5.

TITLE: RADIOCHEMICAL DETERMINATION OF CCRMP REFERENCE MATERIALS FOR CERTIFICATION PURPOSES: LEAD-210 ACTIVITY MEASUREMENTS

CONTRACTOR: Various	FILE NUMBER: 3-9148-1 to 3-9148-7	FUNDING	
	BEGIN/END: Nov. 83/Feb. 84		
		CANMET:	$ 19 054
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. C.W. Smith	TECHNOLOGY: Reference Materials	TOTAL:	$ 19 054

OBJECTIVES

Determine the activity of lead-210 in CCRMP uranium ores BL-4a and BL-5, and in uranium-thorium ores DL-1a and DH-1a from quadruplicate measurements in each case.

Apply the expertise of the laboratory to minimize deleterious influences on the precision and accuracy of these results befitting their incorporation in an interlaboratory certification project.

PROCEDURE

1. Beta-counting of bismuth-210 following its isolation from the matrix by radiochemical procedures.

2. Gamma-ray counting of lead-210 in situ at 46.5 keV by high-resolution gamma-ray spectrometry.

RESULTS

The values obtained by the laboratories participating in this consensus project are used to determine recommended values for the activity of lead-210 in these Canadian reference materials.

These materials have previously been certified as to uranium (some as to thorium), and radium-226 content. The project additionally provides comparative methodological information for isotope determinations in compositional matrices for which there is currently a scarcity of information.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

CANMET Report 79-4: Uranium ore BL-5 - A Certified Reference Material.

CANMET Report 80-10E: DL-1a - A Certified Uranium-Thorium Reference Ore.

CANMET Report 81-11E: DH-1a - A Certified Uranium-Thorium Reference Ore.

CANMET Report 82-6E: BL-2a and BL-4a - Certified Uranium Reference Ores.

CANMET Report 84-11E: Lead-210 in Certified Uranium Reference Ores DL-1a, BL-4a, DH-1a, and BL-5.

TITLE: HOMOGENEITY OF Zn/Al ALLOYS

CONTRACTOR: Kidd Creek Mines Ltd.	FILE NUMBER: 5-9149	FUNDING	
	BEGIN/END: Oct 85/Feb. 86		
		CANMET:	$ 5 500
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: C.W. Smith	TECHNOLOGY: Reference Materials	TOTAL:	$ 5 500

OBJECTIVES

Ascertain the degree of homogeneity of concentrations of component elements in discs of each of seven different zinc/aluminum alloys. These alloys (designated NZA-1 to NZA-7) are candidate reference materials of the Canadian Certified Reference Materials Project (CCRMP). Homogeneity testing is required to assess the suitability of the discs as reference materials for use with physical techniques, particularly optical emission spectrometry.

PROCEDURE

One hundred and forty discs of the seven alloys were selected by applying random-sampling procedures for concentration measurements and subsequent statistical analysis of the data. Relative elemental concentrations of each of aluminum, tin, magnesium, copper, and iron were to be provided as the photomultiplier output signal from corresponding optical emission wavelengths by employing spark source emission spectrometry. Each disc was to be surfaced and subject to ten surface burns at different sites within an analytical surface area in a sequence defined by a template. Additionally, a control disc for each alloy was to be resurfaced and repeatedly remeasured at random intervals within the disc measurement sequence.

Any cessation and restart of an alloy measurement sequence was to end and begin with the control disc measurements.

The contractor provided all required measurements, and additionally provided zinc concentration and read-time data.

RESULTS

Results of the measurements (in excess of eleven thousand correlated data) are compiled in the contractor's final report. Cumulative interim data were communicated to CANMET in January and early February and have been entered in a disc file that is accessible by the EMR Computer Sciences Centre CDC computer. Statistical assessment of homogeneity was started in early March 1986.

APPLICATION AND ONGOING WORK

Concentrations of seven elements in each alloy have been determined in an interlaboratory consensus project whereby a fraction of the stock of each alloy was chipped, blended, and analyzed chemically. The analysis of information from the homogeneity measurement project will provide information as to (i) concentration distributions in the cast forms of the alloys and their effect on concentration uncertainties in small-area, single-shot emission measurements, (ii) the number of such measurements required to reliably obtain concentrations and, ultimately, (iii) the utility of the discs as emission spectrometry reference materials. Provided that the results are satisfactory, zinc/aluminum alloys NZA-1 to NZA-7 will be made available for sale by CCRMP, CANMET.

SUPPORTING DOCUMENTS

Final report: "Homogeneity of Zn/Al Alloys". This report contains the results of the homogeneity measurement project.

Results of the statistical analysis of this information will be incorporated with those from the interlaboratory project in a forthcoming CANMET Report describing zinc/aluminum reference materials NZA-1 to NZA-7.

TITLE: CERTIFICATION OF Zn/Al ALLOYS

CONTRACTOR: Various	FILE NUMBER: 4-9155-1 to 4-9155-12	FUNDING	
	BEGIN/END: Sept. 84/March 85		
		CANMET:	$ 22 385
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: H.F. Steger	TECHNOLOGY: Reference Materials	TOTAL:	$ 22 385

OBJECTIVES

Obtain analytical values for aluminum, copper, iron, magnesium, cadmium, lead, and tin leading to their certification in a suite of seven zinc-aluminum alloys (designated NZA-1 to NZA-7).

PROCEDURE

Each contractor provided quintuplicate determinations of the concentrations of the required elements in one sample of each alloy.

The contractor's results will be combined in a statistical analysis of variance treatment to give the best estimate of the concentrations of the denoted elements. Should the appropriate criteria be satisfied, these estimates will be certified.

RESULTS

The analytical data were reasonable in magnitude and were adequately precise for use in the subsequent statistical analysis.

Results of the statistical analysis will be incorporated in a forthcoming CANMET Report describing the certification of zinc/aluminum reference materials NZA-1 to NZA-7.

TITLE: RECOMMENDED VALUES FOR BRITHOLITE ORE OKA-2

CONTRACTOR: Various	FILE NUMBER: 5-9062-1 to 5-9062-7	FUNDING	
	BEGIN/END May 85/Jan. 86		
		CANMET:	$ 4 732
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: C.W. Smith	TECHNOLOGY: Reference Materials	TOTAL:	$ 4 732

OBJECTIVES

Provide analytical concentration values for uranium, thorium, potassium, and lanthanide-group elements suitable for incorporation in a multi-laboratory consensus certification project for proposed reference material OKA-2.

PROCEDURE

Using analytical methods of their choice, the contractors were to determine and report concentrations of as many of the elements targeted for certification as possible. Each element was to be determined in five separate subsamples from bottles provided. The reports were to contain brief descriptions of the methodologies employed.

RESULTS

Results from the participating laboratories will be combined to ascertain if there is a sufficient degree of concentration consensus to warrant certification of the various elements. If successful, OKA-2 will provide a unique Canadian reference material containing lanthanides at relatively high concentration levels. Additionally, comparative results for lanthanides by various analytical methodologies will be made available. OKA-2 has been identified as a suitable source material for calibration of laboratory gamma-ray spectrometers for equivalent thorium. A quantity of this material will be diluted with silica by the Canadian Certified Reference Materials Project for distribution by the International Atomic Energy Agency (IAEA).

SUPPORTING DOCUMENTS

Results of this study will be incorporated in a future CANMET Report describing the certification of OKA-2, to be prepared early in 1986. Results for radiogenic elements (K, U, Th) will be incorporated in IAEA documentation describing the diluted gamma-ray calibration material.

TITLE: HOMOGENEITY OF REFERENCE URANIUM TAILINGS UTS-1, UTS-2, UTS-3 AND UTS-4

CONTRACTOR:	Chemex Laboratories Ltd.	FILE NUMBER:	2-9146	FUNDING	
		BEGIN/END:	Oct. 82/March 83		
				CANMET:	$ 4 484
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	Dr. H.F. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 4 484

OBJECTIVES

Confirm the homogeneity of uranium tailings samples UTS-1, UTS-2, UTS-3, and UTS-4 with respect to uranium and iron.

PROCEDURE

The contractor analyzed 15 bottles of each of the four samples in triplicate, for uranium and for iron.

RESULTS

The samples were shown to be homogeneous with respect to uranium. Samples UTS-1 and UTS-2 were also found to be homogeneous with respect to iron. Samples UTS-3 and UTS-4 showed some inhomogeneity with respect to iron, but this is insignificant compared to the level of between-laboratory agreement expected.

APPLICATION AND ONGOING WORK

These four samples were subjected to two interlaboratory certification programs: the first involving 18 laboratories for 9-11 elements/constituents; the second involving 7 laboratories for 5 radionuclides.

The results of both interlaboratory programs are presented in CANMET Report 84-14E: Certified Reference Materials.

SUPPORTING DOCUMENTS

National Uranium Tailings Program Report NUTP-2E: Uranium Tailings Reference Materials.

TITLE: RECOMMENDED VALUES FOR REFERENCE URANIUM TAILINGS

CONTRACTOR: Various	FILE NUMBER: 2-9144-1 to 2-9144-11	FUNDING	
	BEGIN/END: Nov. 82/March 83		
		CANMET:	$ 20 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. H.F. Steger	TECHNOLOGY: Reference Materials	TOTAL:	$ 20 000

OBJECTIVES

Provide analytical values for iron, titanium, aluminum, calcium, barium, uranium, thorium, sulphur, sulphate, nickel, and arsenic in four uranium tailings samples: UTS-1, UTS-2, UTS-3, and UTS-4.

PROCEDURE

Quintuplicate results for each constituent were to be provided for one bottle of each of four uranium tailings samples.

The results from the participating laboratories will be statistically analyzed to arrive at recommended values for the concentrations of the various constituents.

RESULTS

The analytical results were reasonable in magnitude and were adequately precise.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

APPLICATION AND ONGOING WORK

These uranium tailings samples are to be used as reference materials for quality control.

SUPPORTING DOCUMENTS

National Uranium Tailings Program Report NUTP-2E: Uranium Tailings Reference Materials.

TITLE: RECOMMENDED VALUES FOR REFERENCE URANIUM TAILINGS

CONTRACTOR: Various	FILE NUMBER: 3-9101-2 to 3-9101-4	FUNDING	
	BEGIN/END: July 83/Sept. 83		
		CANMET:	$ 1 820
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. H.F. Steger	TECHNOLOGY: Reference Materials	TOTAL:	$ 1 820

OBJECTIVES

Provide analytical values for barium, total sulphur, and sulphate sulphur in uranium tailings samples UTS-1 to UTS-4.

PROCEDURE

Quintuplicate results for barium and sulphate sulphur were provided for one bottle of each uranium tailings sample. Results for total sulphur were requested for UTS-4 only.

The results from the participating laboratories will be statistically analyzed to arrive at recommended values for the concentrations of barium, total sulphur, and sulphate sulphur.

RESULTS

The results were reasonable in magnitude and were adequately precise.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

APPLICATION AND ONGOING WORK

These uranium tailings samples are to be used as reference materials for quality control.

SUPPORTING DOCUMENTS

National Uranium Tailings Program Report NUTP-2E: Uranium Tailings Reference Materials.

TITLE: RECOMMENDED VALUES FOR REFERENCE URANIUM TAILINGS

CONTRACTOR:	Various	FILE NUMBER:	3-9116/3-9116-1	FUNDING	
		BEGIN/END:	Aug. 83/Sept. 83		
				CANMET:	$ 700
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	Dr. H.F. Steger	TECHNOLOGY:	Reference Materials	TOTAL:	$ 700

OBJECTIVES

Provide analytical values for thorium in two uranium tailings samples.

PROCEDURE

Quintuplicate results for thorium were provided for one bottle of each uranium tailings sample.

The results from the participating laboratories will be statistically analyzed to arrive at a recommended value for the concentration of thorium.

RESULTS

The results were reasonable in magnitude and were adequately precise.

Recommended values for these reference materials are presented in CANMET Report 84-14E: Certified Reference Materials.

APPLICATION AND ONGOING WORK

These uranium tailings samples are to be used as reference materials for quality control.

SUPPORTING DOCUMENTS

National Uranium Tailings Program Report NUTP-2E: Uranium Tailings Reference Materials.

TITLE: RADIOCHEMICAL DETERMINATIONS FOR TAILINGS REFERENCE MATERIALS

CONTRACTOR: Various	FILE NUMBER: 2-9145-1 to 2-9145-6	FUNDING	
	BEGIN/END: Nov. 82/March 83		
		CANMET:	$ 38 700
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. C.W. Smith	TECHNOLOGY: Reference Materials	TOTAL:	$ 38 700

OBJECTIVES

Provide radioactive isotope concentration values (Bq/g) for quadruplicate subsamples of uranium tailings reference materials UTS-1 to UTS-5 as part of an interlaboratory project. The required isotopes are Th-230, Ra-226, Pb-210, and Po-210 for all materials, and additionally Th-232, Ra-228, and Th-228 for UTS-1, UTS-2, and UTS-5.

PROCEDURE

Following appropriate isolation of target radioisotopes, apply alpha-, beta-, and gamma-ray spectrometry methods to measure activities relative to recognized calibration standards.

RESULTS

Activity concentrations of all required isotopes and uncertainty estimations, as well as details of methodology, are summarized in Report NUTP 2E: Uranium Tailings Reference Materials.

Recommended values are also presented in CANMET Report 84-14E: Certified Reference Materials.

APPLICATION AND ONGOING WORK

UTS-1 to UTS-4 are representative tailings materials derived from four existing uranium tailings sites in Canada. They are intended for use as quality control reference materials for chemical and radiochemical measurements to be carried out within the National Measurement Program of the National Uranium Tailings Research Program.

SUPPORTING DOCUMENTS

National Uranium Tailings Program Report NUTP 2E: Uranium Tailings Reference Materials.

TITLE: DEVELOPMENT OF DIRECT CURRENT PLASMA ANALYTICAL METHODS FOR USE IN CANADIAN GOLD MINING AND MILLING OPERATIONS

CONTRACTOR:	Witteck Development Inc.	FILE NUMBER:	3-9191	FUNDING	
		BEGIN/END:	Dec. 83/Oct. 84		
				CANMET:	$ 18 398
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	DSS:	9 634
AUTHORITY:	R. Churchill	TECHNOLOGY:	Analytical Methodology	TOTAL:	$ 28 032

OBJECTIVES

Provide a comprehensive analytical guide for the assaying of solutions from typical Canadian gold mill operations using Direct Current Plasma Emission Spectroscopy.

PROCEDURE

1. A thorough literature search was undertaken.
2. Solutions were obtained from typical gold mill operations and optimum analytical conditions were established using these solutions.
3. Quantitative assays were made and accuracy was checked by using a second analytical technique (Atomic Absorption) and by mass balance calculations.

RESULTS

Recommended wavelengths and operating conditions were established for the determination of Au, Ag, Cu, Fe, and Zn in gold-milling solutions in a cyanide matrix. It was established that the Direct Current Plasma technique is not suitable for the assay of As and Hg in a cyanide matrix. Detailed procedures and analytical characteristics of selected wavelengths are provided.

APPLICATION AND ONGOING WORK

Valuable information for any analytical laboratory in the gold mining industry. Could be used as the basis for selecting a suitable analytical technique.

TITLE: FILM ON NONDESTRUCTIVE TESTING OF CONCRETE

CONTRACTOR:	Scott Films Ltd.	FILE NUMBER:	8-9096	FUNDING	
		BEGIN/END:	Feb. 79/June 79		
				CANMET:	$ 26 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Concrete Testing	TOTAL:	$ 26 000

OBJECTIVES

Make a 30-minute film on the state-of-the-art of nondestructive testing (NDT) of concrete.

PROCEDURE

The contractor used CANMET facilities to make this film. Some sequence work was also shot outside, especially at construction sites.

RESULTS

This contract resulted in a 27.5-minute color film on NDT of concrete. The film has received worldwide acceptance and is being used by a number of universities in the U.S.A. and Canada as a teaching aid.

APPLICATION AND ONGOING WORK

Film is being revised at present.

TITLE: NONDESTRUCTIVE TESTING OF CONCRETE

CONTRACTOR: Scott Films Ltd.	FILE NUMBER: 1-9123	FUNDING	
	BEGIN/END: Aug. 82/March 83		
		CANMET:	$ 25 780
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: V. Malhotra	TECHNOLOGY: Concrete Testing	TOTAL:	$ 25 780

OBJECTIVES

Revise and update CANMET film on nondestructive testing (NDT) of concrete.

PROCEDURE

Normal procedures of film making were employed, site visits were made, and progress meetings with CANMET staff and Scott Films Ltd. were held.

RESULTS

A 30-minute color movie of excellent quality has been produced that is ideal for teaching in schools, colleges, and universities.

SUPPORTING DOCUMENTS

Films are available from the Head of the Construction Material Section.

TITLE: NONDESTRUCTIVE TESTING OF CONCRETE

CONTRACTOR: Scott Films Limited	FILE NUMBER: 4-9290	FUNDING	
	BEGIN/END: Dec. 84/March 85		
		CANMET:	$ 3 637
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: V. Malhotra	TECHNOLOGY: Concrete Testing	TOTAL:	$ 3 637

OBJECTIVES

Make video cassettes of a film on nondestructive testing (NDT) of concrete.

PROCEDURE

The contractor, using the current technology, converted the NDT films to video cassettes.

RESULTS

The video cassettes are available from the contractor.

TITLE: LITERATURE SURVEY ON NON-DESTRUCTIVE TESTING OF CONCRETE FOR THE PERIOD 1975-1983

CONTRACTOR: N.G. Zoldners	FILE NUMBER: 3-9211	FUNDING	
	BEGIN/END: Dec. 83/May 84		
		CANMET:	$ 3 775
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Standards & Specifications	OTHER:	--
AUTHORITY: Dr. J.A. Soles	TECHNOLOGY: Concrete Testing	TOTAL:	$ 3 775

OBJECTIVES

Update bibliography on nondestructive testing of concrete.

PROCEDURE

Review pertinent international literature in books and refereed journals, and prepare an annotated bibliography spanning the period 1975-1983 that will be released in a forthcoming symposium on the subject. Synopses of articles to be included.

RESULTS

Publication:

"An Annotated Bibliography on Non-Destructive Testing of Concrete, 1975-1983", by N.G. Zoldners and J.A. Soles; Proceedings, International Conference on In Situ/Non-Destructive Testing of Concrete; Ottawa, Ontario, Oct. 2-5, 1984.

SUPPORTING DOCUMENTS

Final report: "An Annotated Bibliography on Non-Destructive Testing of Concrete, 1975-1983".

MINERALS TECHNOLOGY

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

TITLE: COMPUTER MODEL FOR PREDICTING DETONATION PROPERTIES OF SLURRY EXPLOSIVES

CONTRACTOR: University of Ottawa	FILE NUMBER: 2-9178	FUNDING	
	BEGIN/END: Jan. 83/March 84		
		CANMET:	$ 41 965
CANMET	ADMINISTRATION OF THE CANADA	CONTRACTOR:	--
SCIENTIFIC	EXPLOSIVES ACT	OTHER:	--
AUTHORITY: K.K. Feng	SUB-ACTIVITY: Explosives Testing and Research	TOTAL:	$ 41 965

OBJECTIVES

1. Develop a model for predicting the detonation properties of slurry explosives by using TIGER CODE to enhance the understanding of the behaviour of non-ideal explosives.

2. Acquire necessary thermodynamic data for different slurry explosives for calculating properties such as C-J state, Hugoniot curve, constant volume explosion point, points at specified conditions, as well as grid of points and isolines.

PROCEDURE

1. Evaluate equations of state (EOS) used in the determination of the C-J condition. Propose a suitable EOS, in conjunction with the application of the TIGER CODE, that can reasonably represent ammonium nitrate-loaded slurry explosives at the C-J condition.

2. Evaluate the rate efficiency of ammonium nitrate in slurry explosive mixtures in terms of the difference between observed and calculated detonation properties.

3. Evaluate the effects of inert constituents in explosives (in the range of 1 to 10% by mass) on the behaviour of non-ideal explosives. Inert constituents such as calcium oxide or carbonate, silica, or sodium oxide should be assessed.

RESULTS

1. The CS equation is capable of producing the desired detonation properties.

2. The adjustable parameter λ is essential in the application of the CS equation. The λ values should be studied further using additional experimental values.

3. It is feasible to maintain the desired detonation temperature, pressure, and detonation velocity, as well as saving the cost and minimizing the production of toxic gases (NO and CO) by adjusting the amounts of Al, Si, Na, and Ca in slurry explosives.

4. Judicial elimination of possible gaseous/condensed detonation products in the calculation could save computation time up to 95%.

APPLICATION AND ONGOING WORK

The computer model could be used to predict the hazards associated with detonation properties and detonation products.

SUPPORTING DOCUMENTS

Final report: "Computer Model for Predicting Detonation Properties of Slurry Explosives".

TITLE: INTERPRETATION AND MODELLING OF THERMODYNAMIC DATA GENERATED BY ACCELERATING RATE CALORIMETER

CONTRACTOR: University of Ottawa	FILE NUMBER: 4-9063	FUNDING	
	BEGIN/END: Sept. 84/Mar. 85	CANMET:	$ 21 000
CANMET	ADMINISTRATION OF THE CANADA	CONTRACTOR:	--
SCIENTIFIC	EXPLOSIVES ACT	OTHER:	--
AUTHORITY: K.K. Feng	SUB-ACTIVITY: Explosives Testing and Research	TOTAL:	$ 21 000

OBJECTIVES

1. Interface the Accelerating Rate Calorimeter (ARC) with existing laboratory computer.
2. Develop the necesssary software to use not only existing ARC equations but also thermodynamic equations to interpret existing data.
3. Evaluate existing data using several potential thermodynamic equations to provide best fit analysis.
4. Verify that, in fact, a thermodynamic approach is feasible and establish the necessary guidelines for future development of a detailed thermodynamic model.

PROCEDURE

1. Interface the ARC using existing RS-232 port with T.I. business computer, so that data from the ARC can be stored on floppy disk for future retrieval and analysis.
2. Develop software for the computer that can read the stored data and analyze the data using the Arrhenius-type equations used by the ARC.
3. Identify suitable thermodynamic approaches, incorporate the necessary equations into the software developed in (2), and evaluate existing data to provide a best fit analysis.
4. Correlate thermodynamic parameters determined in (3) with literature values to determine whether a thermodynamic approach is, in fact, feasible.

RESULTS

1. An interface between the ARC and a T.I. computer available in the laboratory was established, making it feasible to directly feed the data generated by the ARC to the computer's diskette.
2. The model was found to be adequate for describing thermokinetic events for relatively simple thermal decompositions. The assumption of an order of reaction of zero was found to be suitable for correlating the data for the samples tested, and the values of J were found to be close to 4.

APPLICATION AND ONGOING WORK

A computer program could be used to interface the ARC and T.I. microcomputer to evaluate existing data to provide a best fit analysis.

SUPPORTING DOCUMENTS

Final Report: "Interpretation and Modelling of Thermodynamic Data Generated by ARC (Accelerating Rate Calorimeter)".

TITLE: EVALUATION OF PROPAGATION SENSITIVITY OF COMMERCIAL EXPLOSIVES

CONTRACTOR:	Mining Resource Engineering Limited	FILE NUMBER:	4-9026	FUNDING	
		BEGIN/END:	July 84/March 85		
				CANMET:	$ 25 000
CANMET		ADMINISTRATION OF THE CANADA		CONTRACTOR:	--
SCIENTIFIC		EXPLOSIVES ACT		OTHER:	--
AUTHORITY:	R.R. Vandebeek	SUB-ACTIVITY:	Explosive Testing and Research	TOTAL:	$ 25 000

OBJECTIVES

Characterize the factors that can affect propagation sensitivity of commercial explosives including confinement, cartridge diameter, explosive composition (type), temperature, medium between cartridges, and relative tightness of fit between cartridge and borehole wall.

PROCEDURE

1. Determine the propagation sensitivity of six different explosives in four different diameters in granite and/or steel.

2. Study the effect of temperature (-5°C, +5°C, +20°C) on propagation sensitivity of three explosives in two different diameters.

3. Study the effect of relative tightness of fit (external channel effects) between the cartridge and borehole on propagation sensitivity for three different explosives.

4. Study the effects of changing the medium from air to water, drill cuttings, or spacer on propagation sensitivity for three different explosives.

RESULTS

The results obtained allowed scaling laws to be derived relating charge diameter to air, sand, and water gap lengths at 5, 50, and 95% cross-propagation probability for slurry/water gel and emulsion type products. Although tests concentrated on small charge diameters, the scaling laws derived may also be applicable to large diameters. Several possible applications of the scaling laws are outlined in the report.

The small-diameter Emulsion products were shown to have very poor cross-propagation sensitivity for all test conditions. It is apparent that the methods used in loading small-diameter cartridged products can cause problems with maintaining a steady state detonation.

The cross-propagated gap distances for the slurry/water gel-type products were found to be larger than anticipated. These products, at a 2-inch (2.54 cm) charge diameter, will cross-propagate an air gap distance of 5 feet (1.52 m) 5% of the time and 3.5 feet (1.07 m) 95% of the time. The propagation sensitivity of the water gel products, however, varied more than the slurry or emulsion products. At 5°C, the 1-inch (2.54 cm) diameter water gel product failed when fully coupled and when it was decoupled in a 1.75 inch (4.45 cm) diameter hole.

APPLICATION AND ONGOING WORK

1. This study has increased the knowledge of how these different types of explosives behave under different field conditions.

2. Results of this study will be useful to explosives' manufacturers in designing products that will function properly under certain conditions.

3. The large gaps obtained identify possible reasons for interdeck propagation underground and inter-borehole propagation in large surface applications.

SUPPORTING DOCUMENTS

Final report: "Evaluation of Propagation Sensitivity of Commercial Explosives".