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Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

SUMMARIES OF CANMET MINERALS RESEARCH CONTRACTS 1979-1983

COMPILED BY T.P. LANZER

MINERALS RESEARCH PROGRAM
RESEARCH PROGRAM OFFICE

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FOREWORD

This report summarizes minerals related R & D contracts which were sponsored by CANMET and completed in the years 1979 to 1983. The summaries were prepared to assist in transferring to industry the new technology which has been created through CANMET's extensive contracting-out program. The value of minerals related R & D which was contracted-out between 1979 and 1983 exceeded $4.5 million. Minerals contracts completed prior to 1979 were summarized previously in CANMET Reports 78-1 and 79-26.

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, 555 Booth Street, Ottawa, Ontario, K1A 0G1. Telephone: (613)995-4029, TELEX: 053-3395.

The CANMET Research Program Office is grateful to Tom Lanzer of the University of Ottawa for diligently assembling this report during the summer of 1983.

D.A. Reeve
Director
Research Program Office

AVANT-PROPOS

Le présent rapport donne le bilan des contrats de R et D dans le domaine des minéraux qui ont été parrainés par CANMET et qui ont été réalisés entre 1979 et 1983. Les résumés ont été préparés dans le but d'aider à transmettre à l'industrie les nouvelles techniques qui ont été élaborées dans le cadre de l'imposant programme d'impartition de CANMET. La valeur des contrats de R et D accordés entre 1979 et 1983 a dépassé 4,5 millions de dollars. Les contrats réalisés avant 1979 ont fait l'objet de résumés dans les rapports antérieurs n^{os} 78-1 et 79-26 de CANMET.

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, 555, rue Booth, Ottawa (Ontario) K1A 0G1, tél.: (613)995-4029, télex: 053-3395.

Le bureau du programme de recherche de CANMET tient à remercier M. Tom Lanzer, de l'Université d'Ottawa, qui a fait diligence pour rassembler les éléments de ce rapport durant l'été de 1983.

D.A. Reeve
Directeur du Bureau du
programme de recherche

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MINERALS TECHNOLOGY

MINING

TITLE: DESIGN, CONSTRUCTION AND FIELD TESTING OF A PROTOTYPE OIL-FIRED WATER LINE HEATER FOR SURFACE DIAMOND DRILLING IN SUB-ZERO* WEATHER

CONTRACTOR:	Lochhead Haggerty Engineering & Manufacturing Co. Ltd.	FILE NUMBER:	8-9006	FUNDING	
		BEGIN/END:	Oct. 78/March 79		
				CANMET:	$ 30 740
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	V.A. Haw	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 30 740

OBJECTIVES

Develop a water line heater for diamond drilling in sub-zero temperatures that would be sufficient to heat the water to prevent freezing in a pipe 610 m long and 2.54 cm in diameter at sub-zero ambient temperatures (down to about -40°C). The water flow should be up to a rate of 45 L/min, water pressure up to 2069 kPa, and the fuel to be used for the heater should be stove oil or its equivalent. Other objectives that the heater should meet include: maximum weight of 225 kg, capable of being broken down into components that could be handled by one man; rugged and durable, being able to withstand the rough treatment received under field operating conditions; and simple to operate.

PROCEDURE

The contractor was given the general specifications, which are outlined in the objectives, and asked to proceed to design and build a heater accordingly. The contractor has had long experience in building heat exchanging equipment for a variety of purposes in northern climates. The main feature of the heater is that it contains two heat exchangers; a primary one in which combustion of the fuel oil heats a glycol mixture, and a secondary heat exchanger where a coil in which the drill water circulates is heated by the hot glycol which is in continuous circulation within the hot water line heater. A prototype of the designed heater was produced, tested, and ultimately shipped to Canadian Longyear, a diamond drilling contractor and manufacturer in North Bay, for further testing.

RESULTS

The heater met all the specifications required of it except the weight requirement. At present, the overall heater weighs considerably in excess of 225 kg, and at least one component of it weighs about 115 kg, which cannot be handled by one person. Otherwise, the heater has been tested in very cold temperatures and has performed satisfactorily under the given conditions. These last field testing trials were conducted north of North Bay by Canadian Longyear, and the final results have yet to be fully evaluated. The acceptability of such a heater to the diamond drilling industry must be determined, and it is quite possible that some further modifications could be made that would prove beneficial. The question of how such technology could be transferred, given that the heater appears to be marketable, remains to be determined.

APPLICATION AND ONGOING WORK

Field tests of the equipment as designed and produced have been largely completed. The heater, although too heavy at present, may have some limited applications in diamond drilling under sub-zero conditions, but it still remains to be seen what can be done to modify the equipment in order to reduce the weight of individual components so that they can be moved easily in the field. Work will continue along these lines.

*Sub-zero Fahrenheit which equals -17° Celsius and below.

TITLE: NOISE REDUCTION OF DIAMOND DRILLING EQUIPMENT

CONTRACTOR:	Heathwood Engineering Associates Ltd.	FILE NUMBER:	9-9023	FUNDING	
		BEGIN/END:	Nov. 79/March 80	CANMET:	$ 23 657
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	L. Geller	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 23 657

OBJECTIVES

Document the magnitude of the noise pollution problem in the Canadian diamond drilling industry. Recommend ways and means to alleviate the problem.

PROCEDURE

1. Designed and circulated appropriate questionnaire within diamond drilling industry. Evaluated replies.
2. Searched literature and industry for relevant prior work. Evaluated results.
3. Undertook preliminary noise level measurements. Evaluated results.
4. Tabulated all relevant noise control regulations.
5. Recommended schedule of future work.

RESULTS

1. Percentage distribution of currently used equipment and, therefore, the retrofit aspects of future work, was established.
2. General noise levels, and likely major contributors to these, were established.
3. Previous noise control efforts, and the industry's reaction to them, were identified.
4. Recommendations for future work were submitted.

APPLICATION AND ONGOING WORK

A sound control project, under contract, was established for FY 1980/81 to continue with the work described above.

A subcommittee of the CDDA's technical committee was established to assist with logistics support and monitoring of the 1980/81 project. The committee contained members from the CDDA, MAPAO, engineering consultants and MRL.

TITLE: COST EFFECTIVENESS AND TECHNICAL FEASIBILITY STUDY OF OPTIONS AVAILABLE FOR SOUNDPROOFING DIAMOND DRILLING EQUIPMENT - PHASE 1

CONTRACTOR:	Noranda Metals Industries Ltd.	FILE NUMBER:	1-9045	FUNDING	
		BEGIN/END:	Jan. 82/March 83		
				CANMET:	$ 61 922
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	L. Geller	TECHNOLOGY:	Mining Methods & Equipment	TOTAL:	$ 61 922

OBJECTIVES

1. Establish the technical feasibility of the proposed noise abatement techniques for diesel-powered surface drills.
2. Estimate probable costs involved in implementing the above.
3. Establish, on a sound technical and financial basis, whether retrofitting existing drills with noise controls or developing newer and quieter drills is of greater importance.
4. Define any need for, and direction of, future work on diamond drill noise suppression.

PROCEDURE

1. Examined and updated the previously compiled list of diamond drilling equipment used in Canada.
2. Surveyed diesel engine and diamond drill manufacturers to establish the latest state-of-the-art work being done on noise suppression.
3. Cooperated with CANMET's in-house project of building a prototype diesel engine enclosure for retrofitting.
4. Undertook noise measurements in the field to recheck the ranking of the major noise sources and to establish the dosimetric shift-exposure of drill operators.
5. Studied technical options for reducing drill front-end noise.
6. Examined the economics of the above.

RESULTS

1. The ranking of the major noise sources on the most frequently used surface diamond drills was reestablished.
2. Alternatives for silencing prime-mover noise were established, both for retrofit applications and for new drills.
3. Some alternatives for silencing drill front-end noise were also examined, but only tentative conclusions could be reached.
4. The economics of both the retrofit and new design options were examined.

APPLICATION AND ONGOING WORK

A proposal for continuing with Phase 2 of this project has been submitted.

TITLE: DESIGN OF AN UNDERGROUND BULK MINING TRIAL

CONTRACTOR:	Falconbridge Nickel Mines Ltd.	FILE NUMBER:	9-9016	FUNDING	
		BEGIN/END:	July 79/June 80		
				CANMET:	$ 88 338
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	94 099
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Dr. D.F.G. Hedley	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$182 437

OBJECTIVES

Design a bulk mining method for an orebody below 1000 metres depth capable of producing 500 tonnes per shift per stope.

PROCEDURE

1. Orebody selection.

2. Geomechanical evaluation:
   a) Geological structure
   b) Rock properties and strength
   c) In situ stresses
   d) Finite element analysis
   e) Ground support
   f) Monitoring systems

3. Mine design:
   a) Mining methods
   b) Sequence of extraction
   c) Drilling and blasting
   d) Material handling
   e) Costs and productivity
   f) Other stope services

RESULTS

1. With the help of geomechanics and ground control technology, bulk mining methods were designed for Onaping No. 2 orebody.

2. Initial mining method selected for the primary stoping was longitudinal blasthole stoping. The hanging wall would be prepinned, and ore blocks 15 m high would be drilled with electro-hydraulic machines. The bulk of blasted ore would be extracted from the safety of the drawpoints and the undercut, but broken ore beyond reach from the brows would be mucked by remote controlled load-haul-dump machines.

3. The pillars containing 11% of ore reserves were proposed to be mined with sublevel caving.

4. Safety and environmental aspects were of prime consideration in this plan and would be achieved by:
   a) more automation and mechanization; electric machines would be utilized as much as possible;
   b) design of more stable and well-supported permanent and temporary excavations where men are working;
   c) application of grouted rebars, cable bolts, prepinning, higher quality fill and ground monitoring instrumentation programs.

5. A conveyor and ramp system was selected for ore and waste handling. About 50% of the development waste would be placed in the stopes.

6. Comparison of ramp cut-and-fill stoping with bulk mining methods showed that the Net Present Value and Return on Investments was about 30% higher for bulk mining methods.

APPLICATION AND ONGOING WORK

This contract is part of a CANMET project on developing design guidelines for bulk mining methods at depth. The next step is an actual bulk mining trial which will allow field testing of critical parameters in the proposed design to prove the technical and economic viability of the following:
   a) stability of hanging wall;
   b) longitudinal blasthole stoping;
   c) blasting design;
   d) ramp conveyors for material handling;
   e) portable crushers and rock breakers;
   f) dilution and ore recovery.

SUPPORTING DOCUMENTS

Final report: Design of a Bulk Mining Trial.

Appendix 1: Results of Stress Measurements.

Appendix 2: Structural Geology Investigation in the Onaping and Lockerby Mines.

TITLE: DEVELOPMENT OF A COMPUTER PROGRAM FOR MINING LAYOUT SELECTION (MINLAY)

CONTRACTOR:	Noranda Mines Ltd.	FILE NUMBER:	9-9022	FUNDING	
		BEGIN/END:	Aug. 79/March 80		
				CANMET:	$ 25 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	D.F. Coates	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 25 000

OBJECTIVES

Develop a computer system to assist the mine planner in choosing the optimum layout for his operation. An earlier report to CANMET "Feasibility Study of New Mining Concepts at Depth in Canadian Base Metal Mines", Mine-Met Consultants of Canada) pointed out the need for improvements in mining techniques as deeper ores are mined and competition from other countries grows more intense. Computer-aided planning is one area of potential improvement. This first phase is to produce a conceptual design of a computer program for a system of open stoping at depth.

PROCEDURE

1. Reviewed existing computer-aided mine design systems.
2. Adapted existing and/or developed new systems for mine design.
3. Drafted a conceptual design for a computer program, bearing in mind the limitations of computer access at present and possible developments, e.g., in graphic display.
4. Arranged industrial review of draft design.
5. Produced a report as a starting point for detailed system analysis and coding.

RESULTS

A conceptual design of a computer program was produced. The proposed system will require the user to furnish geological data, mine layout, and production and cost figures. The system will schedule stope development and production to satisfy mill feed requirements and produce detailed cost and grade reports. Rock mechanics aspects (e.g., pillar failure and entry support) can be treated. Financial analyses will provide for inflation and NPV accounting.

APPLICATION AND ONGOING WORK

Phase 2 (in 1980/81) produced detailed system designs, with coding in ANSI FORTRAN done in 1981/82. The programs are applicable to many open stoping operations.

TITLE: VENTILATION AND REFRIGERATION REQUIREMENTS AND COSTS IN CANADIAN DEEP HARD ROCK MINES

CONTRACTOR:	Golder Geotechnical Consultants Ltd.	FILE NUMBER:	9-9029	FUNDING	
		BEGIN/END:	Nov. 79/June 80	CANMET:	$ 34 888
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M. Gangal	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 34 888

OBJECTIVES

Worker efficiency drops in mining operations as temperature increases above the comfort range. This study was undertaken to:

1. Analyze the sources of heat and the thermal environment in deep mines, and review the methods used for the control of heat in the context of current and anticipated mining practice in Canada.

2. Determine the costs of ventilation and refrigeration to achieve a comfortable thermal environment in a large mechanized Canadian mine at depths between 1000 and 3000 m.

PROCEDURE

A detailed literature search of the ventilation and refrigeration systems of deep mines was conducted. Data obtained from the search was analyzed in relation to Canadian conditions.

Computer programs applicable to deep mine environments were reviewed and discussed regarding their suitability for Canadian requirements. Capital and operating costs for refrigeration systems were obtained from various sources to estimate the costs of cooling a Canadian mine. Recommendations for future research work were considered. A final report was submitted.

RESULTS

The contractor's report contains chapters with the following titles:

1. Sources of Heat in Deep Mines.

2. Control of Heat in Deep Mines.

3. Heat Stresses.

4. Control of the Environment in Deep Canadian Mines.

5. Computer Techniques for the Prediction of Mine Cooling and Ventilation Requirements.

6. Estimated Costs to Cool a Deep Mine in Canada.

7. Reducing Heat Loads in Deep Mines in Canada.

8. Opportunities for Research.

APPLICATION AND ONGOING WORK

The final report was discussed at the Industrial Seminar held at Sudbury on May 16, 1980, and was well received by mining companies. The report will assist them in cooling mines with heat problems.

TITLE: CASE HISTORIES OF THE DESIGN OF PRODUCTION BLASTS IN UNDERGROUND MINES USING BULK MINING METHODS AND THE MONITORING OF BLAST VIBRATIONS

CONTRACTOR:	Inco Ltd.	FILE NUMBER:	9-9034	FUNDING	
		BEGIN/END:	Sept. 79/June 81		
				CANMET:	$ 42 820
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	G. Larocque	TECHNOLOGY:	Mining Methods and Equipment	TOTAL:	$ 42 820

OBJECTIVES

Compile information and case histories on the design of blasting patterns for large blasthole open stopes and the equipment and analysis required for monitoring vibrations associated with these production blasts.

PROCEDURE

The case histories and vibration monitoring methods addressed in the final document were situations and methods used at Inco Ltd.'s mines in the Sudbury Basin.

Preliminary analysis indicated that eight case histories would be required to cover the various blasting/monitoring situations encountered in bulk mining. Case histories were selected from past and planned blasts for inclusion in the report.

By reviewing bulk mining procedures at Inco, general bulk mining blast design and vibration monitoring procedures were arrived at for a final document.

A standard format was prepared to present case histories as independent appendices in the final document.

RESULTS

A final document has been prepared outlining, in detail, bulk blast design and monitoring procedures used at Sudbury by Inco Ltd. The document also contains eight case histories covering most situations encountered in bulk mining.

APPLICATION AND ONGOING WORK

The information will be of value if CANMET's Mining Research Laboratories (MRL) proceed to prepare guidelines for deep mining. It will be a source document for a planned chapter on blasting.

TITLE: REQUIREMENTS FOR MINE DEVELOPMENT (PLANNING AND DESIGN) THAT ARE INFLUENCED BY THE NATURE AND SIZE OF EQUIPMENT DEVELOPMENT (EXISTING AND PLANNED)

CONTRACTOR:	Montreal Engineering Co.	FILE NUMBER:	0-9085	FUNDING	
		BEGIN/END:	Feb. 81/Feb. 82		
				CANMET:	$ 24 287
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	Dr. J. Pathak	TECHNOLOGY:	Mining Methods & Equipment	TOTAL:	$ 24 287

OBJECTIVES

In the last ten years, new equipment has had a considerable impact on mine layout and design in Canadian underground hard rock mines. Further changes in mine layout will be experienced with the introduction of equipment presently in the development stage, e.g., portable crushers, Haggland loaders and trains, conveyor systems and possibly continuous mining machines.

Normally, there is a long lead time between the introduction of new mine equipment and appropriate improvements in mine layout. It would be beneficial to evaluate the next generation of mining equipment so that such engineering aspects of mine design as ground control, safety and the working environment can be incorporated more readily.

PROCEDURE

The contractor studied and described case histories where innovative techniques have been used in underground hard rock mining and which have influenced mine design and layout. A questionnaire was issued to operating underground mines in Canada, the U.S.A. and other parts of the world, in an attempt to establish the type of mine, the mining methods being used, the mining equipment in use and the potential for development of mining equipment.

RESULTS

The results of case history studies and detailed analysis of the survey were presented in the form of tables, graphs and comments. They indicated main trends in equipment development for six major areas of mining activity: drilling, loading, transportation, support, mechanized excavation, and safety and control. The contractor also sought information on civil engineering techniques applicable to mining (i.e., tunnelling). The results, recommendations and overall outcome of the study were judged very satisfactory.

APPLICATION AND ONGOING WORK

In-depth studies of the new equipment development identified in Phase 1, will be undertaken in Phase 2 of the project. It was considered that it would be beneficial to the Canadian metal mining industry that these in-depth studies be undertaken in the following areas:

1. Development of an all-electric mine, including computer control of the system.
2. Continuous high-capacity loading and transporting.
3. Automation of mining equipment.
4. High-speed mechanized excavation methods.
5. Remote operating systems and monitoring.
6. Waste rock back-filling.

TITLE: POTENTIAL APPLICATIONS FOR ROBOTICS AND REMOTE CONTROL SYSTEMS IN CANADIAN MINING AND RELATED RESEARCH AND DEVELOPMENT REQUIREMENTS

CONTRACTOR:	Robertson Nickerson Limited	FILE NUMBER:	0-9151	FUNDING	
		BEGIN/END:	Jan. 82/Oct. 82		
				CANMET:	$ 29 600
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	R.J.R. Welwood	TECHNOLOGY:	Mining Methods & Equipment	TOTAL:	$ 29 600

OBJECTIVES

1. Evaluate the current status and level of interest of the Canadian mining industry in robotics applications.

2. Make recommendations and suggestions with respect to a possible role for EMR/CANMET in serving the needs of the industry in this area.

PROCEDURE

A preliminary field survey was conducted which focused on Canadian mining, machinery manufacturing and service companies. Over 100 contacts were made in the industry, involving field interviews and mine tours of all the major mining companies, with limited contacts in the U.S.A. for a broader perspective on mining robotics potential.

The study assembled an overview of the mining industry's awareness of robotics possibilities, and its perception of a possible role for EMR.

RESULTS

The level of robotics awareness in the Canadian mining industry is in the infancy stage.

The area perceived to have the greatest potential for robotics applications is underground mining.

The mining industry in Canada perceives a short-term potential for robotization of existing operational mining machinery and a longer-term potential for development of integrated robotic/automated continuous systems.

EMR's support of mining robotics is viewed as part of the mechanism for maintaining Canada's position in the international minerals market. An EMR-sponsored mining robotics program would act as a catalyst in the development of robot technology applications in Canadian mining.

APPLICATION AND ONGOING WORK

1. Establish a steering group to direct the development of robotics in Canada and its application to Canadian mining operations.

2. Determine the commercial viability of identified priority areas.

3. Sponsor joint mining robotics workshops with USBM.

4. Undertake detailed technological evaluations of potential robotics applications in each identified priority area.

5. Consider establishing a joint effort application group.

6. Identify companies and specific applications for initiation of robotics in Canadian mines.

TITLE: SAMPLING AND TESTING OF CEMENTED BACKFILL IN UNDERGROUND MINES

CONTRACTOR:	Franklin Trow Associates Ltd.	FILE NUMBER:	9-9032	FUNDING	
		BEGIN/END:	Oct. 79/June 80	CANMET:	$ 18 950
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	2 470
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	2 500
AUTHORITY:	G. Herget	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 23 920

OBJECTIVES

Sample in situ backfill at Falconbridge Nickel Mines, Sudbury, and carry out laboratory testing for physical parameters to determine support characteristics and stability of freestanding vertical walls of backfill.

PROCEDURE

1. In situ sampling with drill and Shelby tube.
2. Standard laboratory testing.

RESULTS

1. Shelby tube sampling was more successful than sampling with a drill having a mechanical feed. Hydraulic feed might provide better results.
2. The report provides results on cured backfill properties such as bulk and grain density, moisture content, porosity, saturation, and uniaxial and triaxial compressive strength.

APPLICATION AND ONGOING WORK

Test data will be used to determine stability of a freestanding backfill wall.

Further development of sampling techniques is necessary.

TITLE: PHYSICAL MODEL TESTS ON THE STABILITY OF CEMENTED TAILINGS MINE BACKFILL

CONTRACTOR:	John D. Smith Engineering Associates Ltd.	FILE NUMBER:	9-9077	FUNDING	
		BEGIN/END:	March 80/March 81		
				CANMET:	$ 18 120
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mining	OTHER:	--
AUTHORITY:	M. Gyenge	TECHNOLOGY:	Rock Mechanics	TOTAL:	$ 18 120

OBJECTIVES

Conduct scaled material model tests to establish the strength requirements for stability of cemented backfill in blast-hole stoping operations.

PROCEDURE

1. Performed a complete series of initial laboratory tests.

2. Analyzed laboratory test results and then defined design mixes to be used in model testing.

3. Designed and constructed a model test box with the specified dimensions.

4. Conducted model tests according to the specified:
   a) model materials
   b) model dimensions
   c) model preparation
   d) testing procedures
   e) associated post-fault test

5. Calculated and analyzed the test results, correlated obtained data with theoretical calculations and provided recommendations for the design of economical and safe cemented tailings backfill.

RESULTS

The contract was successfully completed. The results of twenty-six small-scale model tests support the derived three-dimensional analysis equation, which can be used for design of safe cemented tailings backfill.

APPLICATION AND ONGOING WORK

The desirability of checking the results with actual mine backfills is under discussion.

TITLE: DETECTION OF FRACTURES IN GEOLOGICAL STRUCTURES UTILIZING SUBSURFACE RADAR

CONTRACTOR: Lakehead University	FILE NUMBER: O-9108	FUNDING	
	BEGIN/END: March 81/Dec. 82		
		CANMET:	$ 30 000
CANMET	MINERALS TECHNOLOGY ACTIVITY	DSS:	90 500
SCIENTIFIC	SUB-ACTIVITY: Mining	GSC:	10 000
AUTHORITY: L. Geller	TECHNOLOGY: Rock Mechanics	TOTAL:	$130 500

OBJECTIVES

Support work at Lakehead University aimed at developing impulse-type radar instrumentation and techniques to detect and map concealed rock fractures underground.

PROCEDURE

Obtained basic components of radar instrumentation from commercial sources. Redesigned and refined equipment to adapt it for practical use underground. Tested rebuilt instrumentation under practical mining conditions.

RESULTS

Instrument package for field successfully developed. Prototype equipment built. Initial field testing completed.

APPLICATION AND ONGOING WORK

No ongoing work. Industry and Lakehead University scientists will first discuss further applications and requirements.

MINERALS TECHNOLOGY

HEALTH AND SAFETY IN MINING

TITLE: EFFECT OF HYDROCARBON INHALATION ON PULMONARY FUNCTION

CONTRACTOR:	Ian W. French & Associates Ltd.	FILE NUMBER:	6-9095	FUNDING	
		BEGIN/END:	April 77/Dec. 78		
				CANMET:	$ 72 584
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 72 584

OBJECTIVES

1. Review and consolidate the relevant medical and scientific literature concerning the health effects of hydrocarbon inhalation (principally diesel soot and tobacco tar) on the underground mine worker. These effects cannot be considered in isolation, but must be assessed in combination with other potentially toxic substances such as the gaseous components of diesel exhaust, ore dusts, radioisotopes, etc.

2. Formulate concrete recommendations for dealing with this type of exposure based on the best current information in the literature.

3. Identify gaps in knowledge in this field, and identify centres of expertise.

PROCEDURE

The contractors, with the aid of several computerized data bases, identified a large body of relevant material. This was combined with information from other sources, such as company visits, discussion at meetings, personal communications, etc. to produce a comprehensive review.

The information gathered was analyzed in order to develop a number of highly specific recommendations.

RESULTS

The contractor's intention to produce a document which would render the medical considerations comprehensible to those with a physical science background, while explaining the engineering aspects to medical personnel, was amply realized in their 350 page contract report.

The report included eight specific recommendations, the implementation of which would greatly reduce the potential for adverse health effects in underground dieselized mines. Perhaps the most significant recommendation was the formulation of a "Health Effects Index" which takes account of the combined effect of diesel exhaust and other pollutants, and thereby permits a more correct balance to be struck between ventilation costs and costs of reducing the noxious emissions at the source.

For those who wish to examine the source material in greater detail, a 1596 page annotated bibliography was prepared which summarizes the papers reviewed on an individual basis.

APPLICATION AND ONGOING WORK

The "Health Effects Index" developed for this contract has been extensively used to evaluate diesel exhaust treatment strategies investigated in-house, and under other CANMET research contracts. It has also formed the basis for the ventilation recommendation for the draft code "Certification of Flameproof Diesel-Powered, Rubber-Tired, Trackless Self-Propelled Vehicles for Use in Underground Coal Mines in Canada".

The index can be readily adjusted to reflect new information on the health impact of diesel exhaust as it becomes available. Periodic assessment of the effect of new information on the index will be necessary.

SUPPORTING DOCUMENTS

Ian W. French and Associates Ltd. - "Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions" (350 pages).

Ian W. French and Associates Ltd. - "An Annotated Bibliography Relative to the Health Implications of Exposure of Underground Mine Workers to Diesel Exhaust Emissions" (two volumes, 1596 pages).

TITLE: DEVELOPMENT OF AN EMISSION CONTROL SYSTEM FOR UNDERGROUND DIESEL POWERED EQUIPMENT

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	7-9098	FUNDING	
		BEGIN/END:	May 78/Dec. 78		
				CANMET:	$ 65 065
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	P. Mogan	TECHNOLOGY:	Mine Environment	TOTAL:	$ 65 065

OBJECTIVES

An earlier research contract* determined that simple wet scrubbers capture 30% of diesel exhaust soot (45% when operated in series with a catalytic purifier). This performance (with catalytic purifier) was just short of adequate, but it suggested that more sophisticated wet scrubbers could be technically viable for the removal of soot from the exhaust of diesel engines working in underground mines.

This study was undertaken to determine the effectiveness of the most promising of the more sophisticated wet scrubbers - the venturi scrubber - and to determine the design parameters needed to apply this scrubbing technique to the removal of diesel soot.

*File No. 5-1241, Serial No. ISQ76-00014

PROCEDURE

Because of the uncertainty in the application of state-of-the-art design criteria to the capture of diesel soot, an annular variable-throat venturi was sized to treat the exhaust of a Deutz engine typical of those in current use in Canadian underground mines.

Precooling of the exhaust by internal water spray (to take advantage of condensation scrubbing) and by external cooling were evaluated. Venturi throat geometry was varied within the constraints imposed by engine back pressure limitations. Flow and location of the scrubbing water sprays were varied. Tests were conducted with a catalytic purifier upstream of the scrubber.

RESULTS

All tests were carried out with the engine at full speed and full load. Primary cooling water was supplied at 2 L/min, and scrubbing water at 8.8, 15.7 and 34.6 L/min. The venturi throat cross-sectional area was adjusted to yield an exhaust back pressure of 50, 100 and 145 cm of water.

1. Increasing the scrubbing water from 8.8 to 34.6 L/min at 100 cm of water exhaust back pressure increased the soot capture from 38 to 49%.

2. Increasing the back pressure from 50 to 145 cm of water with 15.7 L/min of scrubbing water increased the soot capture from 38 to 50%.

3. Adding a catalytic purifier upstream at 15.7 L/min and 100 cm of water increased the soot capture from 44 to 53%.

4. Addition of a surfactant to the water, relocation of the scrubbing water injection point, external cooling, and modification of the venturi throat had little effect on performance.

The venturi scrubber, therefore, achieved only a modest improvement over the simple scrubber with a considerable increase in the complexity of the hardware. The results assumed more significance, however, with the discovery by CANMET scientists that the venturi performance could be predicted by a recently published mathematical model.

APPLICATION AND ONGOING WORK

CANMET in-house research undertaken as an adjunct to a certification investigation verified the mathematical model's application to a 59% soot capture venturi. Since the model indicates a possible 70-75% capture, work is proceeding in-house to demonstrate this potential. If the model proves accurate, development of a prototype unit fitted to an underground mining machine is envisaged, followed by an underground demonstration of effectiveness.

TITLE: DESIGN AND CONSTRUCTION OF A PROTOTYPE DIESEL EXHAUST COOLER

CONTRACTOR:	Hovey and Associates Ltd.	FILE NUMBER:	9-9101	FUNDING	
		BEGIN/END:	May 80/March 81		
				CANMET:	$ 19 764
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 19 764

OBJECTIVES

Design and construct a prototype diesel exhaust cooler (water/gas heat exchanger) suitable for attachment to a Caterpillar 3306 engine exhaust system and compatible with installation in a Wagner ST5 load-haul-dump (LHD) machine.

PROCEDURE

Designed and constructed a heat exchanger incorporating appropriate inlet and outlet pipe diameters, pressure drops, air and gas flows, air and gas temperatures, etc. The design kept in mind that the application is to cool diesel exhaust gas which contains condensible hydrocarbons and carbon particulate matter. Therefore, the design incorporated the features necessary to permit easy cleaning of the gas side of the heat exchanger.

Because diesel exhaust contains SO_2, H_2SO_4, NO_2 and possibly HNO_3, the design of the heat exchanger had to provide maximum resistance to corrosion - i.e., stainless steel construction.

The shape of the heat exchanger had to be compatible with the space available in a Wagner ST5 scooptram equipped with a Caterpillar 3306NA engine.

RESULTS

Tests showed the following performance relative to specified requirements:

	Specification	Test
Inlet Gas Temperature	538°C	550°C
Outlet Gas Temperature	288°C	220°C
Gas Flow Rate	644 kg/h	684 kg/h
Outlet Water Temperature	96°C	35°C
Gas Side Pressure Drop	152 mm H_2O	74 mm H_2O

These results appear to indicate that the cooler performance is satisfactory. In addition, the cooler dimensions enable it to fit into the machinery for which it was intended.

APPLICATION AND ONGOING WORK

The use of exhaust gas coolers in conjunction with either filter or water scrubber units could improve performance, prolong unit life, and/or reduce unit cost by reducing gas volumetric flow rate and temperature. Cooling below the condensation temperature of sulphuric acid could enhance the ability of a filter to remove H_2SO_4 with the particulates. Cooling with a heat exchanger reduces the amount of water needed to cool the exhaust, thus reducing the water burden in the mine atmosphere in turn reducing the tendency to 'fog' the mine workings.

This cooler was installed by BC Resources (formerly Kaiser) on a Wagner ST5 Scooptram to test the feasibility of a high temperature - low maintenance flameproof exhaust system under a 1981/82 contract.

TITLE: PRELIMINARY UNDERGROUND TRIALS OF THE CORNING CERAMIC DIESEL EMISSIONS FILTER

CONTRACTOR:	Inco Ltd.	FILE NUMBER:	0-9154	FUNDING	
		BEGIN/END:	Feb. 82/March 82		
				CANMET:	$ 15 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	60 000
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 75 000

OBJECTIVES

Determine the practicability of the Corning ceramic diesel exhaust filter.

PROCEDURE

Specially designed Corning ceramic filters were purchased by Inco and adapted to the exhaust system of a Wagner ST-5 LHD fitted with a Deutz F8L-714 engine. While the machine was employed in a mucking operation, the exhaust backpressure and temperature were noted with the passage of time and all observations which were pertinent to the filter development were noted.

RESULTS

1. The filter appeared to act as a muffler.

2. Particulates and aldehydes were significantly reduced (reducing eye irritation and diesel odour).

3. No physical damage to filter units during 48 hours of operation. Ceramic element remained clean. Surprisingly, in situ regeneration of the filter must have occurred.

4. The full/load/speed operating conditions responsible for this in situ regeneration were:
   exhaust gas temperature: 547-625°C
   exhaust back-pressure: 4.2-5.0 kPa

5. Whereas in situ regeneration may ultimately prove to be a tremendous advantage in terms of dramatically reducing operating costs, it poses questions regarding:
   a) What are the decomposition products of particulate regeneration and are they harmful?
   b) Is catastrophic destruction of the filter likely under LHD operating conditions?

APPLICATION AND ONGOING WORK

1. Inco, at their cost, will determine the ability of the ceramic element to survive additional operations.

2. ORF, funded by the Ontario Ministry of Labour, will determine the decomposition products of particulate in situ regeneration and the Ames mutagenicity of such products.

TITLE: EFFECT OF A CORNING DIESEL EXHAUST FILTER ON THE PNA CONCENTRATION AND MUTAGENICITY OF DIESEL EXHAUST

CONTRACTOR: Laurentian University	FILE NUMBER: 2-9044	FUNDING	
	BEGIN/END: April 82/Oct. 82	CANMET:	$ 15 632
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Health & Safety in Mining	OTHER:	--
AUTHORITY: D. Dainty	TECHNOLOGY: Mine Environment	TOTAL:	$ 15 632

OBJECTIVES

Measure polynuclear aromatic hydrocarbon (PNA) levels and assess the mutagenicity of the underground environment in a heading where a Corning ceramic filter-equipped LHD diesel machine is operating.

PROCEDURE

Originally, it was intended that this work would take place in the Inco mines of the Sudbury basin. However, the mine shutdown during the recession prevented this. The venue was then changed to the CANMET/MRL/CEAL dynamometer facility in Ottawa which simulated an underground heading with ventilation. The Corning ceramic filter was adapted to the laboratory F6L-912W Deutz engine and operated, with and without filtration, at 7/8 load steady-state, 8-mode LHD cycle, modified 8-mode LHD cycle and Inco hot LHD cycle modes.

PNA and Ames mutagenic samples were taken for most operating modes using Hi-Vol samples at two exhaust dilution ratios. Laurentian University analyzed the PNA samples and the Ontario Research Foundation analyzed the Ames mutagenic samples under subcontract.

RESULTS

1. It has been confirmed that Hi-Vol sampling temperature affects the amount of PNAs collected. For example, reducing the temperature at the sampling site by 12°C increases the PNA capture by an estimated 250%, i.e., by a factor of 2.5 times.

2. It has been demonstrated that the PNA concentrations, and probably the mutagens, in dilute diesel exhaust are strongly dependent on the mode of operation, and most PNAs and mutagens are generated during the hottest part of the cycles when time weighted (6 to 10 times as much as during the other parts of the cycle).

3. The Corning filter reduces the total PNAs, the carcinogenic PNAs, and the mutagens in the exhaust significantly by factors generally between 30 and 90%. This holds true for a non-regenerating (i.e., no soot combustion in the filter during normal operation of the 8-mode cycle) and a partially regenerating (Inco hot cycle) mode of operation. These reductions appear to be related to the soot capture efficiency of this filter configuration which varies between 80 and 95%. (One sample, however, indicated a 65% reduction of carcinogens and a rerun indicated only a 27% reduction.) It seems clear, nevertheless, that filtered exhaust has less impact on health than untreated exhaust, from a cancer-risk point of view. The filter's 90% efficiency of soot removal further suggests a very significant reduction in the possibility of lung tissue damage due to the interaction of acid gases (SO_2 and NO_2) with soot.

4. These tests represent a successful and final stage before underground demonstration of this device in 1984/85 as part of the USBM/CANMET/MOL collaborative project to reduce diesel emissions in underground workings.

APPLICATION AND ONGOING WORK

This work has shown that care needs to be exercised in obtaining Hi-Vol samples in the future, i.e., ventilation dilution and sampling temperature need to be defined, as does the variation in capture with sample temperature. This work suggests that all emission-reduction strategies should undergo similar tests.

TITLE: ADAPTATION OF ON-BOARD DIESEL EMISSIONS REDUCTION DEVICES

CONTRACTOR: Ontario Research Foundation	FILE NUMBER: 2-9047	FUNDING	
	BEGIN/END: July 82/March 83	CANMET:	$ 16 465
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Health & Safety in Mining	JARVIS CLARK:	10 000
AUTHORITY: D. Dainty	TECHNOLOGY: Mine Environment	TOTAL:	$ 26 465

OBJECTIVES

Adapt and surface-test three diesel emissions reduction options installed in a Jarvis Clark 5-yard load-haul-dump (LHD) machine.

PROCEDURE

A Corning filter/exhaust gas recirculation (EGR) emissions control system has been designed, fabricated, and installed on a Jarvis Clark JS500 scooptram. Two exhaust outlet configurations were fabricated, one with a downward directed exhaust, the other with the exhaust pointing upward at a 25° angle relative to grade. Emissions of CO, CO_2, THC, NO and NO_x were measured for three exhaust control strategies:

1. Standard exhaust with Englehard catalysts
2. Modified exhaust with Corning filters
3. Modified exhaust with Corning filters and exhaust gas recirculation (EGR).

The JS500 machine was also subjectively evaluated under simulated 'mucking' conditions in a test area at ORF.

RESULTS

1. Little difficulty was experienced in adapting the three types of equipment and assessing their performances. Of particular note were:
   a) The use of flexible exhaust pipe to mount the filter to the engine which was mounted on rubber vibration dampers,
   b) The rugged construction of clamp-type butterfly flow control valves in air inlet and exhaust recirculation lines,
   c) The Donaldson pipe clamping arrangement to easily install and remove the piping as needed.

   These adaptations were all confined within the outlines of the standard machine. Adaptation of such devices does not appear to be a problem.

2. One of the filters employed had been part of the previous underground Inco tests. This filter appears to have an altered character, i.e., the rate of pressure rise is faster than that of new filters even though oven regeneration at 500°C appears to reestablish initial pressure drops. This may be due to fuel ash accumulation.

3. The toxicity reduction impact of these options was assessed at three vehicle operating conditions: idle, high idle, and load stall. The results relative to the filter-only option for the stall condition are as follows:

	Catalyst	Filter and EGR
CO:	70% lower	27% higher
THC:	54% lower	39% higher
NO:	15% higher	31% lower
NO_2:	188% higher	20% lower

An Air Quality Index estimation incorporating these changes suggests a considerable advantage of the filter over the catalyst, and a marginal improvement using EGR with the filter relative to the use of the filter alone.

APPLICATION AND ONGOING WORK

The JS500 LHD machine will be used in the underground demonstration of emissions-reduction options developed jointly under the collaborative USBM/CANMET/MOL R & D agreement. Successful adaptation of bench apparatus to the mining vehicle is an essential preliminary to these final underground assessments.

TITLE: DEVELOPMENT OF A CORNING FILTER ON-BOARD REGENERATION SYSTEM

CONTRACTOR:	Engine Control Systems Ltd.	FILE NUMBER:	2-9118	FUNDING	
		BEGIN/END:	Dec. 82/May 83		
				CANMET:	$ 43 352
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	E.D. Dainty	TECHNOLOGY:	Mine Environment	TOTAL:	$ 43 352

OBJECTIVES

Design, construct and participate in bench tests of an on-board diesel exhaust filter regeneration system for application to dieselized underground mining machinery.

PROCEDURE

1. Conducted a conceptual engineering study of the electrical and throttling regeneration options for ceramic filter cleaning without filter disassembly or removal. Selected the better option based on cost and practicability.

2. Completed the design of the selected option and fabrication and assembly of three regeneration units. Modified the three filter units as necessary and assemble the regeneration units to the filters. Bench tested the equipment to ensure adequate heating capacity and proper general functioning for the operating conditions of each bank of a Deutz F8L-413 engine.

3. Participated in preliminary dynamometer trials of the system at the Canadian Explosive Atmospheres Laboratory (CEAL).

RESULTS

1. The conceptual study showed throttling to be impracticable so electric heating was pursued.

2. The first in-line spiral-type heater unit proved ineffective.

3. The second straight tube electrical element heater was completely dynamometer characterized: 0.48 m^3/min of air (cranking speed) was heated to 519°C as a result of 9 min of battery pack operation at 19 volts and 800 amps. This was sufficient to produce controlled regeneration (combustion) of the soot in the filter (back pressure at the start was 5 kPa at 2200 rpm). While this result indicates success, further development of this design is necessary to reduce the element's thermal lag time and the number of batteries required.

4. The third design featured a spiral-type heater element in close proximity to the inlet face of the ceramic filter. Sufficiently high local temperatures in the face of the ceramic filter should result in fewer required batteries and a simpler, safer regeneration procedure. It must be demonstrated, however, that such regeneration does not produce excessive thermal gradients which would crack the ceramic material.

APPLICATION AND ONGOING WORK

The third design version will be tested in the EMR/CANMET/MRL/CEAL diesel dynamometer facility and further developed as indicated. If successful, development of the second design version heater will be stopped. The third design version will then be dynamically tested at the Ontario Research Foundation facility in accordance with the collaborative USBM/CANMET/MOL diesel emissions program.

TITLE: INVESTIGATION OF URANIUM MINE VENTILATION USING SULPHUR HEXAFLUORIDE AS A TRACER GAS

CONTRACTOR: James F. MacLaren Ltd.	FILE NUMBER: 7-9106	FUNDING	
	BEGIN/END: Aug. 78/March 80	CANMET:	$ 32 950
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Health & Safety in Mining	OTHER:	--
AUTHORITY: M. Gangal	TECHNOLOGY: Mine Environment	TOTAL:	$ 32 950

OBJECTIVES

1. Undertake a ventilation study at an underground uranium mine using SF_6 as a tracer gas.
2. Assess residence time, both in the active workings and in the mine as a whole.
3. Assess the magnitude of air leakage from sealed areas into the active workings and the recirculation of air in active workings.
4. Develop techniques for the release, sampling and analysis of tracer gas.
5. Carry out the field work in a mine to demonstrate the SF_6 tracer gas technique for mine ventilation trouble shooting.

PROCEDURE

1. Surveyed the literature on tracer gas techniques and mine ventilation.
2. Conducted a laboratory program on SF_6 release, sampling procedures, analysis, sample adsorption and sulphuric acid interference.
3. Conducted field work at the Agnew Lake Mine to study the total mine residence time, auxiliary ventilation system, flow measurements and leakage through a stope leaching area.

RESULTS

A ventilation study was conducted at Agnew Lake Mine using SF_6 as a tracer gas. A laboratory study was initially undertaken to select and validate appropriate SF_6 release, sampling, measurement and analysis techniques.

The literature search prior to the laboratory study found that SF_6 tracer gas techniques have been used on a wide variety of projects, and there is adequate information pertaining to mine ventilation. The United States Bureau of Mines has published reports on many different applications. Available reports are presented in the bibliography, and it is strongly recommended that anyone conducting an SF_6 study obtain these reports.

The laboratory study determined that release of SF_6 from a lecture bottle with septum adapter was an appropriate technique. The quantity of SF_6 was determined by weighing the bottle before and after release. A simple sampling technique was also selected and proved successful in field tests.

Sulphur hexafluoride analysis by gas chromatography using electron capture detection was chosen. This method permitted detection of low concentrations (1 ppb) and cost less than $7 per sample for approximately 600 samples. It is recommended that samples be analyzed within 48 h of being taken to prevent inaccuracies due to sample decay from adsorption. The effect of sulphuric acid on low-level concentrations of SF_6 was insignificant.

After the laboratory study, two field programmes were undertaken. Using the SF_6 tracer gas technique, residence times in the active workings and in the mine as a whole were determined. An auxiliary ventilation system was investigated, and residence times were determined at the working face and at the heading entrance where the air was exhausted. The graph of SF_6 concentrations versus time permits interpretation of residence time and flow patterns. These initial tests have shown the value of SF_6 in evaluating the total mine ventilation system. The next step would be to locate sample points throughout the main ventilation distribution system to ascertain air flow routes and their individual travel times.

The test conducted to assess air leakage through crushed rock strata was not as successful. Residual SF_6 from previous tests resulted in high background levels in the low flow stagnant sampling locations. Any SF_6 released for this test could not be distinguished from the high background. It is recommended that leakage tests be conducted three to four months after any other tests, and that the tests themselves continue for a period of four to six weeks. Leak rates should be small, and it would take considerable time for the SF_6 to migrate throughout the system.

In the evaluation of the auxiliary ventilation system and its residence time, recirculation of air was assessed. Travel times to peak concentration and the residence times indicate that a considerable quantity of the air flow is lost at the gap between the two ducts and short circuits back to the entrance.

The laboratory studies and the field tests have proven that SF_6 tracer gas techniques can be used successfully in Canadian hard rock mines. This project was a feasibility study, and the tests and investigations ranged from preliminary to detailed and in depth. This initial assessment has raised more questions and has shown that SF_6 tracer techniques are a needed supplement to conventional methods.

APPLICATION AND ONGOING WORK

The SF_6 tracer gas technique is useful in measuring mine air flows under conditions where conventional methods have failed. It can be used to determine leakage, very low flow, flow in airways with large cross sections, residence time, recirculation of air and ventilation system.

TITLE: QUANTITATIVE ASSESSMENT OF POLYNUCLEAR AROMATIC HYDROCARBON LEVELS IN URANIUM MINES - PHASES 1 AND 2

CONTRACTOR:	Laurentian University	FILE NUMBER:	8-9129	FUNDING	
		BEGIN/END:	May 79/March 80		
				CANMET:	$ 31 418
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	B. Kirk	TECHNOLOGY:	Mine Environment	TOTAL:	$ 31 418

OBJECTIVES

1. Determine the levels of the polynuclear aromatic hydrocarbons (PNA or PAH) found associated with the filterable particulate in diesel exhaust in underground mines.

2. Relate the PNA levels in the mine to those currently found in Canadian cities.

PROCEDURE

Hi-Vol samples were collected from one of Inco's nickel mines in Sudbury and from Rio Algom's Panel mine in Elliot Lake. The PNA's were removed by a combination of sonication and soxhlet extraction and were quantitatively analyzed by thin-layer chromatography and spectrofluorometry.

RESULTS

1. Out of thirteen identified PNA's, seven are known to be carcinogenic.

2. PNA's were present in both mines, where derated indirect injection diesel engines were in use.

3. The PNA concentrations were significantly higher in dieselized underground mines than in the air above ground.

APPLICATION AND ONGOING WORK

A follow-up contract was used to:

1. Expand the data base.

2. Study the effectiveness of PNA reduction by use of oxy-catalytic purifiers on the diesel exhaust.

3. Conduct an Ames test for carcinogenicity of the PNA's.

TITLE: QUANTITATIVE ASSESSMENT OF POLYNUCLEAR AROMATIC HYDROCARBON LEVELS IN UNDERGROUND MINES - PHASES 3 AND 4

CONTRACTOR: Laurentian University	FILE NUMBER: 9-9140	FUNDING	
	BEGIN/END: Apr. 80/Aug. 81		
		CANMET:	$ 37 443
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Health & Safety in Mining	OTHER:	--
AUTHORITY: B. Kirk	TECHNOLOGY: Mine Environment	TOTAL:	$ 37 443

OBJECTIVES

1. Assay the polynuclear aromatic hydrocarbon (PNA) levels found associated with the filterable particulates in underground mines at representative sites.
2. Determine the effect of catalytic converters on the production of PNAs.
3. Conduct Ames mutagenic activity testing of PNAs from diesel engines with and without catalytic converters.

PROCEDURE

The PNAs were analyzed by:

1. Sonicator extraction with appropriate solvent.
2. Separation of PNAs by quantitative thin-layer chromatography (TLC).
3. Quantitative analysis by spectrofluorometry.

The mutagenic activity was determined by the Ontario Research Foundation using the Ames Salmonella bio-assay technique.

RESULTS

1. PNAs were found in all underground test sites at levels significantly above the background atmospheric levels (sixfold increase).
2. The PTX catalytic converter did not cause any significant changes in the mutagenic activity of the diesel exhaust. The Dieseler III catalytic converter caused an elevenfold increase in the mutagenic activity as compared with raw diesel exhaust.

APPLICATION AND ONGOING WORK

Ongoing work is aimed at determining the effect of different engine types and different vehicle types (i.e., trucks and other haulage vehicles).

TITLE: THERMODYNAMIC VENTILATION NETWORK COMPUTER PROGRAM FOR DEEP CANADIAN MINES

CONTRACTOR:	University of British Columbia	FILE NUMBER:	0-9045	FUNDING	
		BEGIN/END:	Sept. 80/March 81	CANMET:	$ 9 364
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	Dr. M. Gangal	TECHNOLOGY:	Mine Environment	TOTAL:	$ 9 364

OBJECTIVES

Generate a suitable computer model which could be used to simulate air flow in deep Canadian mines. The model should incorporate density changes, moisture lift and various natural ventilation effects in mines. The model should simulate stalled fans and give an optional cost printout. Also, a plotting subroutine for the network model should be developed to provide a visual representation of the airflow circuits.

PROCEDURE

1. Developed a network simulation model as described in the objectives.
2. The program was coded in FORTRAN IV.
3. The model was fully tested on test data, and the software of the model was transferred to the departmental computer.
4. Default messages were incorporated in the model to prevent small errors in input data.
5. Prepared a final report including a user's manual.

RESULTS

The CANMET ventilation network model is a valuable analytical tool which can assist the ventilation engineer in planning deep mine ventilation systems based on quantitative assessments.

The optional printout feature of the model prints the ventilation costs, and the optional plotting feature plots the initial and updated network.

The model was successfully tested on published data from a deep mine.

APPLICATION AND ONGOING WORK

The network model allows the ventilation engineer to simulate many alternative ventilation strategies at a low cost and in a very short time. The accuracy of the results depends on the quality of the barometric survey data of the mine. The model is useful in ventilation planning and predicting the effects of emergency conditions.

TITLE: REVIEW OF FIBROUS DUST PROBLEMS AND RESEARCH REQUIREMENTS IN MINING

CONTRACTOR:	Memorial University of Newfoundland	FILE NUMBER:	1-9007	FUNDING	
		BEGIN/END:	June 81/Sept. 82	CANMET:	$ 41 894
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mine Environment	TOTAL:	$ 41 894

OBJECTIVES

In the mining and processing of ores from Canadian mines, it is highly probable that some fibrous minerals are present in the dusts produced in such operations. Whether they exist in concentrations sufficient to cause fibre-related disease, or in a size range large enough to be in the respirable range is largely unknown. Also, the effect of concentrations of dust below the limit of resolution of the microscope is largely unknown.

The purpose of this study was threefold:

1. Determine from the literature the properties of fibres which are implicated in the inducement of disease.

2. Examine the methods used to collect and analyze fibrous minerals with a view to determining their adequacy.

3. Determine the extent to which fibres may present a problem in Atlantic Canada mine atmospheres.

PROCEDURE

The objectives were accomplished by an extensive examination of the literature and by an analysis of dust samples collected from more than 90% of the mines in Atlantic Canada. It was felt that if a fibre problem existed in Canada, the mines in Newfoundland, Nova Scotia, New Brunswick and P.E.I. were diverse enough to be representative of the rest of the country.

RESULTS

The inhalation of asbestos minerals has led to serious health problems in numerous individuals engaged in mining and processing. Some individuals not involved with the asbestos industries have also suffered disease from secondary exposure. Long, thin fibres are considered most injurious to health. However, lung biopsies reveal predominantly sub-micron size fibres, and these may well be a serious cause of disease.

It appears likely that most fibres which have dimensions below 10 μm in length and which are durable in body fluids have a carcinogenic potential, either in their own right or due to the surface absorption of carcinogens due to the fibres' surface charge.

Substitutes for asbestos fibre, both natural and man-made, should be assumed dangerous until specifically shown to be otherwise through animal and cell culture studies.

Analysis of a representative sampling of Atlantic Canada mines has shown a lack of fibrous components in that portion of the respirable range which is optically visible. Some mines, however, have host rocks which have been subjected to temperature and pressure conditions which can lead to the development of minerals which are known to have a fibrous morphology. Optical methods of identification of asbestos minerals, such as dispersion staining, can be incorporated with the phase contrast system to effect identification of a specific asbestos mineral during routine counting.

APPLICATION AND ONGOING WORK

Further work has been recommended, to be done in-house or by experienced contractors such as McGill University or the Ontario Research Foundation.

TITLE: DESIGN AND DEVELOPMENT OF A PROTOTYPE ASBESTOS FIBRE MONITORING SYSTEM - PHASE 1

CONTRACTOR:	Metrex Instruments Ltd.	FILE NUMBER:	8-9139	FUNDING	
		BEGIN/END:	Aug. 79/Oct. 80		
				CANMET:	$ 42 843
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	20 000
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	G. Knight	TECHNOLOGY:	Mine Environment	TOTAL:	$ 62 843

OBJECTIVES

1. Develop a sensing head for airborne fibres based on the alignment of fibres in an electric field and measurement of diffracted light.

2. Develop instrument packages for use as:
   a) portable sampler
   b) shift period personal sampler
   c) continuous monitor

PROCEDURE

1. Designed optical diffraction system.

2. Tested applied electric field.

3. Developed timing cycles for measurements with electric field on (fibres and dust) and with electric field off (dust only).

4. Optimized at low dust concentrations.

5. Carried out laboratory tests of prototype.

6. Carry out field tests of prototype.

7. Complete development.

(Stages 6 and 7 were not included in this contract since they required assessment of Stage 5.)

RESULTS

1. Items 1 to 5 successfully completed.

2. Laboratory tests showed a sensitivity of about 1 fibre/cm^3 as specified.

3. Prototype sampler (as components, not assembled into a field-usable package) and report supplied.

APPLICATION AND ONGOING WORK

Stages 6 and 7, including Objective 2, were completed in Phase 2.

TITLE: DEVELOPMENT OF A MICROPROCESSOR-BASED DUST AND ASBESTOS FIBRE MONITORING SYSTEM - PHASE 2

CONTRACTOR:	Metrex Instruments Ltd.	FILE NUMBER:	0-9163 & 2-9012	FUNDING	
		BEGIN/END:	April 82/April 83		
				CANMET:	$100 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Health & Safety in Mining	OTHER:	--
AUTHORITY:	Dr. G. Knight	TECHNOLOGY:	Mine Environment	TOTAL:	$100 000

OBJECTIVES

Design, develop, fabricate, and laboratory-test two prototype instruments capable of real-time selective detection and measurement of airborne fibrous-shaped asbestos particles.

PROCEDURE

The operation of this fibrous aerosol monitor is based on the alignment of fibres in two different directions by means of an electric field applied with a frequency of about 6 to 10 Hz, with a field strengh in the order of 2500 V/cm. This field induces a dipole charge separation on the fibres and aligns them with the applied field. The selective detection of the fibres is effected by synchronous detection of the resulting modulation of the light scattered from the particles, illuminated by a pair of powerful infrared LEDs.

RESULTS

The asbestos monitor is a portable, battery-powered instrument capable of operating continuously for about 12 h between battery charges. Preliminary tests with crocidolite and crysotile asbestos as well as with talc, soot, fibreglass, mineral dust, etc., showed that the discrimination between fibrous particles and other non-elongated particles is very good. Laboratory tests showed a good sensitivity to elongated particles; better than 0.2 fibres/mL. Field tests in several plants manufacturing asbestos-based products showed that the system can distinguish individual fibres on a general background corresponding to a concentration of about 0.1 fibre/mL.

APPLICATION AND ONGOING WORK

The sensor is to be tested in the Elliot Lake Laboratory dust chamber to determine its response to fibres of varying length and diameter.

The unit is expected to be widely used in the asbestos industry and to be useful in other mines for detecting fibrous dust.

MINERALS TECHNOLOGY

CONSERVATION AND RESOURCE ASSESSMENT

TITLE: IDENTIFICATION AND CHARACTERIZATION OF MANGANESE IN CANADA

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	1-9066	FUNDING	
		BEGIN/END:	Dec. 81/May 82		
				CANMET:	$ 13 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Conservation and	EMR:	2 000
AUTHORITY:	W. Craigen		Resource Assessment	TOTAL:	$ 15 000
		TECHNOLOGY:	Commodity Background Studies		

OBJECTIVES

1. Classify domestic and foreign sources of manganese.
2. Identify and characterize domestic resources and possible processes.
3. Prepare analyses of manganese availability and possible courses of action to ensure supply.

PROCEDURE

A review of manganese sources, products and manufacturing technologies, and their use and availability in Canada and on the world market was carried out, based on information from the available literature and some test work conducted at ORF.

RESULTS

Listed:

1. Principal manganese products and processes.
2. Canadian manufacturers of manganese products.
3. Uses and users of manganese products.

Identified:

1. World supply potential of manganese ores and products.
2. Alternate supply of manganese from Canadian low-grade deposits and waste streams.
3. Promising procedure for the manufacture of manganese (in place of ferro-manganese).

Recommended:

Possible course of action in case imported manganese ore was cut off.

APPLICATION AND ONGOING WORK

The information in the report will be used in the EMR-Mineral Policy Sector report: "Manganese: An Imported Mineral Commodity".

MINERALS TECHNOLOGY

MINERAL PROCESSING

TITLE: DEVELOPMENT OF A CLASSIFICATION MODEL FOR THE SIMULATION OF AN INDUSTRIAL GRINDING CIRCUIT PROCESSING FINE-GRAINED SULPHIDE ORES

CONTRACTOR:	Université Laval	FILE NUMBER:	8-9067	FUNDING	
		BEGIN/END:	Nov. 78/March 79		
				CANMET:	$ 29 662
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	W.H. Cameron	TECHNOLOGY:	Beneficiation	TOTAL:	$ 29 662

OBJECTIVES

Develop a simulation model of a concentrator grinding and classification circuit for fine-grained sulphide ores.

This model would permit a study of conditions which lead to the overproduction of fines and help in defining a method of grinding the fine-grained sulphide ores of the New Brunswick area to -37 µm (400 mesh) without producing excessive fines.

PROCEDURE

1. Developed a materials balance computer program, a residence time resolution program for continuous closed circuits, and parameter estimation programs that would permit analysis of Heath Steele's sampling campaign results, as well as results of laboratory batch and pilot-plant experiments on grinding and hydrocycloning.

2. Established relationships between grinding and hydrocyclone model parameters and operating conditions.

3. Developed a simulation algorithm combining mills and hydrocyclones, and simulated the present operating conditions of Heath Steele's grinding circuit.

RESULTS

An important transfer of technology was made to CANMET in the form of a computer program and classification results.

This particular report develops a model of the Heath Steele Mines rod mill and gives an evaluation of a combined rod mill/grinding circuit simulation.

This is only one report of several issued under this particular contract and requisition number which provided a critical step in the overall simulation of the Heath Steele Mines grinding circuit.

APPLICATION AND ONGOING WORK

The establishment of a fine grind with minimum extreme fines is necessary for the greater than 90% recovery that is the aim of the Comminution and Beneficiation Project. Efforts are made in industry to achieve such a grind, but progress is slow because of many variables.

Because modelling and simulation reduce the number of variables and provide an understanding of their interrelationship, this approach has been adopted by CANMET. It is non-restrictive and can be applied to other ores. It is considered necessary to develop this pertinent expertise particularly in view of industry's demand for more automatic control and on-line optimization.

TITLE: SAMPLING METHODOLOGY FOR INDUSTRIAL MINERAL AND COAL SLURRIES

CONTRACTOR:	University of Toronto	FILE NUMBER:	9-9133-1	FUNDING	
		BEGIN/END:	March 80/March 81		
				CANMET:	$ 14 695
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	W. Cameron	TECHNOLOGY:	Beneficiation	TOTAL:	$ 14 695

OBJECTIVES

Write an engineering manual on sampling methodology for industrial mineral and coal slurries, with 5 main sections:

a) The purpose and utilization of sampling as a source of data for circuit evaluation and process modelling.
b) The selection of sampling variables to obtain meaningful and rich data on an industrial slurry, the influence of model types and unit types on variables selected for sampling.
c) Sampling instrumentation and on-line sampling, sampling techniques, special techniques for special variables, e.g., tracer measurement for residence time, special techniques for special units.
d) Sampling errors: sources of errors, how to minimize them, how to evaluate them.
e) Sampling campaigns: preparation, execution, aftermath, based on case histories.

PROCEDURE

1. The available literature was searched and private industrial contacts were made.

2. Much of the material used was drawn from the author's own extensive experience in carrying out sampling campaigns in Canada and Australia.

3. The chapter on sampling design was based on work which was already in progress and completed by the author, but not charged to this contract.

4. An additional section was added by the author on how material balance calcluations can affect the error sensitivity of a sampling experiment.

5. Chapters were written covering each of the five objectives, and a final report was submitted conforming to the SPOC project.

RESULTS

An in-depth, comprehensive manual on sampling methodology is now available to industry. To the best of our knowledge, this is the first manual written which deals exclusively with industrial sampling methodology and should prove invaluable to people in industry concerned with this subject.

APPLICATION AND ONGOING WORK

This manual is intended to be used as a text and teaching guide for CANMET workshops on sampling methodology which will be given this fiscal year. It is hoped that Dr. Smith will be an active participant.

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: MATERIAL BALANCE PROGRAM FOR PROCESS EVALUATION AND MODELLING IN MINERAL ENERGY PROCESSING PLANTS

CONTRACTOR:	Laval University	FILE NUMBER:	9-9133-2	FUNDING	
		BEGIN/END:	May 80/March 81		
				CANMET:	$ 27 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	J.M.D. Wilson	TECHNOLOGY:	Beneficiation	TOTAL:	$ 27 000

OBJECTIVES

Write a batch and interactive FORTRAN program to calculate mass balanced data from raw experimental data for general process flowsheets. The experimental data must be adjusted in a least-square sense to fit a given error model and mass conservation equations provided in the input data. Missing flowrates must be calculated. The program must use a hierarchical decomposition of streams in order to balance simultaneously different levels of data: water data (flowrates, % solids), solids data (flowrate, particle size distribution, assays), and at least one lower level of data such as the assays of individual size fractions. At least one method of error estimation for the calculated flowrates must be provided. Statistical tests for the detection of bias must be included, and sample runs with real data must be given in the documentation manual which will be prepared according to CANMET standards.

PROCEDURE

1. Since a material balance program (BILMAT), written in APL, already existed and met all the objectives, the first step was to translate this program into FORTRAN.

2. The FORTRAN version was compiled and tested on the CDC Cyber 74 computer at CANMET.

3. Documentation was done according to guidelines provided by CANMET.

4. A final report was written having a format similar to that used for the Pit Slope project.

RESULTS

1. A working FORTRAN version of BILMAT has been obtained which meets all the objectives.

2. The program is supplied with two sets of test data. Program documentation conformed to CANMET guidelines.

APPLICATION AND ONGOING WORK

The acquisition of this material balance program permits a more in-depth evaluation of a mineral or coal processing circuit.

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: STUDY OF MODELLING METHODOLOGY ILLUSTRATING PRINCIPLES AND BENEFITS IN MINERAL ENERGY PROCESSING PLANTS

CONTRACTOR:	McGill University	FILE NUMBER:	9-9133-3	FUNDING	
		BEGIN/END:	May 80/March 81		
				CANMET:	$ 24 992
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	D. Laguitton	TECHNOLOGY:	Beneficiation	TOTAL:	$ 24 992

OBJECTIVES

Write a chapter of the SPOC engineering manual dealing with the general principles of computer simulation applied to mineral and coal processes. The selection and calibration of a model should be illustrated using concrete examples, and the required elements of statistics should be introduced in user-oriented language.

PROCEDURE

1. Made a literature search for dissertations on computer simulation and applications to mineral or coal processes.

2. Wrote a user-oriented description of the concepts and case histories.

3. Wrote concrete data processing examples leading to process simulation and illustrating various statistical tools.

RESULTS

A unique report was produced which will be distributed by CANMET and used as a hand-out for workshops on modelling methodology.

APPLICATION AND ONGOING WORK

Course notes for workshops on modelling and reference manual for engineers.

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: MATHEMATICAL MODELS OF COMMINUTION AND FLOTATION FOR MINERAL AND COAL PROCESS PLANTS

CONTRACTOR:	University of British Columbia	FILE NUMBER:	9-9133-4	FUNDING	
		BEGIN/END:	July 80/March 81		
				CANMET:	$ 26 052
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	R. Pilgrim	TECHNOLOGY:	Beneficiation	TOTAL:	$ 26 052

OBJECTIVES

Produce a series of standard unit models and simulators by literature search and contacts with private sources. It was required that each model be coded in standard FORTRAN to be integrated at a later date into the executive structure developed at CANMET. It was also required that each program be documented according to guidelines provided by CANMET and that test data be included with each simulator. This task included two families of process units; comminution units and flotation units.

PROCEDURE

1. Appropriate literature was searched and private contacts were made to obtain mathematical models of the required simulators.

2. Computer programs for each unit model were coded in FORTRAN and compiled and tested on the computing facility at UBC.

3. An appropriate data set was obtained to test each simulator.

4. Documentation was done according to guidelines provided by CANMET.

5. The compiled and tested programs were transferred to CANMET and loaded on the CDC Cyber 74 computer at CANMET.

6. A final report was written having a format similar to that used for the Pit Slope project.

RESULTS

1. Mathematical models were obtained for seven unit simulators:
   a) primary gyratory crusher
   b) primary jaw crusher
   c) secondary cone crusher
   d) tertiary cone crusher
   e) crushing rolls
   f) autogenous mill
   g) flotation cell.

2. FORTRAN programs were developed and test data were supplied and tested for each model. Program documentation conformed to the CANMET guidelines.

APPLICATION AND ONGOING WORK

The acquisition of these comminution and flotation models permits some preliminary work on simulation of milling circuits.

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: NORMALIZATION OF MINERAL AND COAL PROCESS MODELS AND REVIEW OF THE EXECUTIVE STRUCTURE AND SOFTWARE METHODOLOGY OF FLOWSHEET SIMULATION PROGRAMS

CONTRACTOR:	University of Alberta	FILE NUMBER:	9-9133-5	FUNDING	
		BEGIN/END:	May 80/March 81		
				CANMET:	$ 30 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	M. Mikhail	TECHNOLOGY:	Beneficiation	TOTAL:	$ 30 000

OBJECTIVES

Produce a series of standard unit models and simulators by literature search and contacts with private sources. It was required that each model be coded in standard FORTRAN to be integrated at a later date into the executive structure developed at CANMET. It was also required that each program be documented according to guidelines provided by CANMET and that test data be included with each simulator. This task included two families of process units; classification units and coal units.

PROCEDURE

1. Appropriate literature was searched and private contacts were made to obtain mathematical models of the required simulators.

2. Computer programs for each unit model were coded in FORTRAN and compiled and tested on the computing facility at the University of Alberta.

3. An appropriate data set was obtained to test each simulator.

4. Documentation was done according to guidelines provided by CANMET.

5. The compiled and tested programs were transferred to CANMET and loaded on the CDC Cyber 74 computer at CANMET.

6. A final report was written having a format similar to that used for the Pit Slope project.

RESULTS

1. Mathematical models were obtained for nine unit simulators:
   a) rotary breaker
   b) roll crusher
   c) screens (by Karra)
   d) screens (by Whiten)
   e) screens (by Valliant)
   f) sieve bend
   g) hydrocyclone
   h) gravity classifiers
   i) specific gravity separators.

2. FORTRAN programs were developed and test data were supplied and tested for each model.

   Program documentation conformed to the CANMET guidelines.

APPLICATION AND ONGOING WORK

The acquisition of these models permits some preliminary work on simulation of mineral and coal circuits.

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: SUPPLEMENT TO CHAPTER 2 - SPOC MANUAL

CONTRACTOR:	University of Toronto	FILE NUMBER:	2-9010	FUNDING	
		BEGIN/END:	May 82/Nov. 82		
				CANMET:	$ 24 862
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	Dr. D. Laguitton	TECHNOLOGY:	Beneficiation	TOTAL:	$ 24 862

OBJECTIVES

Prepare a computer package to support methods contained in Chapter 2 of the Simulated Processing of Ore and Coal (SPOC) manual, (Sampling).

Produce interactive and conversational FORTRAN programs implementing the theoretical content of Chapter 2 of the SPOC manual.

PROCEDURE

1. Provided a means for flowsheet description in an easily usable form.
2. Entered process data.
3. Formulated the mass balance equations.
4. Performed singular value analysis (SVA).
5. Rescaled SVA if necessary.
6. Tested alternate sets of mass balance equations.
7. Assessed the effect of changed data by SVA.
8. Documented the recommended experimental design and suggested method of material balance computation.
9. Wróte and documented the computer programs.

RESULTS

The SANBAL program, documented as Supplement 2.1 of the SPOC manual, has been developed. It allows a user to enter sampling data and flowsheet description for mass balance computation by the minimum node imbalance technique. Several options are provided for data or equation modifications in search of the least error-sensitive solution of the material balance problem.

APPLICATION AND ONGOING WORK

The program can be used as a stand-alone system for rapid mass balance computations without data adjustment or as a first step in a generalized least-square solution requiring special software such as MATBAL and BILMAT already available from CANMET.

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: SIMULATED PROCESSING OF ORE AND COAL (SPOC) PROJECT - PHASE 3

CONTRACTOR:	University of British Columbia	FILE NUMBER:	2-9040	FUNDING	
		BEGIN/END:	Nov. 82/Dec. 82		
				CANMET:	$ 19 782
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	Dr. D. Laguitton	TECHNOLOGY:	Beneficiation	TOTAL:	$ 19 782

OBJECTIVES

Complete a detailed investigation of the various alternatives open for the off-line plant optimization that will constitute Phase 3 of the SPOC project. In particular, identify the most appropriate industrial sites for such a study, expose the grounds for this choice (type of problem, company's plan to find a solution in 1983 and 1984), outline the technical steps (experimental design, staff, budget, schedule), and submit a report to the SPOC Steering Committee by November 30, 1982.

PROCEDURE

1. Reviewed the mineral and coal plants that present the best potential for a successful application of off-line optimization methodology.

2. Retained a maximum of two 'best' sites in the mineral sector and two 'best' sites in the coal sector.

3. Analyzed and described the rationale behind this choice, and described the technical problem and its chances of being solved within two years.

4. Described the data supply for the study:
   a) Existing data
   b) Experimental design to acquire more data

5. Described the milestones of the study in terms of tasks and realistic calendar.

6. Quantified the required resources in terms of:
   a) Staff: scientific, technical, administrative
   b) Budget: breakdown of costs, scenarios for financing (cost-sharing, public vs private).

7. Documented the assessment that the proposed site's management is willing to enter contract negotiations to materialize the above plans.

8. Submitted a report of the study findings to the steering committee.

RESULTS

On December 1, 1982, the recommendations of the feasibility study were presented to the project steering committee. They were as follows:

1. A university, such as UBC, should act as contractor with CANMET to develop a grinding circuit simulator and conduct off-line optimization studies at Equity Silver Mines Limited. Equity Silver Mines would act as subcontractor and contribute approximately 44% of the budget. (Brenda Mines was proposed as an alternative site.)

2. A sampling and material balancing project should be conducted either at DEVCO's Victoria Junction plant or at Luscar Sterco under a suitable financing arrangement with CANMET.

3. A university, such as McGill, should act as a contractor with CANMET to develop a rod mill model at Kidd Creek Mines Ltd. Kidd Creek would act as a subcontractor and contribute a portion of the budget.

4. CANMET should circulate to industry and universities a request to bid on a proposal to develop a cyclone model.

APPLICATION AND ONGOING WORK

Preliminary work on coal plant inventory at DEVCO was in progress in 1983.

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: ECONOMIC EVALUATION OF PRECONCENTRATION OF URANIUM ORES

CONTRACTOR:	Lummus Company Canada Ltd.	FILE NUMBER:	0-9064	FUNDING	
		BEGIN/END:	Nov. 80/March 81		
				CANMET:	$ 35 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	W. Gow	TECHNOLOGY:	Beneficiation	TOTAL:	$ 35 000

OBJECTIVES

Evaluate the economics and advantages of preconcentrating low-grade Elliot Lake uranium (1 kg U_3O_8/tonne) using procedures developed by CANMET staff, and recovering the uranium from the preconcentrate by hydrochloric acid leaching.

PROCEDURE

Lummus engineers met with CANMET engineers and scientists to obtain test results on which to base the economic assessment. Gaps in the data were identified, and CANMET did further test work to provide missing information. Lummus estimated operating and capital costs based on the data provided.

Two preconcentration options were considered as follows:

1. Preconcentration by uranium flotation and high-intensity magnetic separation.

2. Preconcentration using high-intensity magnetic separation alone.

In each case, it was assumed that most of the pyrite in the ore would be recovered by froth flotation, dewatered and roasted, to produce sulphuric acid and a calcine suitable for acid leaching.

Preconcentration options were compared with the Base Case in which pyrite flotation tailings and roaster calcine are combined and leached.

RESULTS

The results were somewhat inconclusive because some data was either unavailable or questionable. Preconcentration followed by HCl leaching is marginally less expensive than HCl leaching of the whole ore.

Conversely, unless a higher ratio of preconcentration can be attained, sulphuric acid leaching of a preconcentrate is no cheaper than leaching the whole ore.

APPLICATION AND ONGOING WORK

Further in-house work will be done to clarify settling, filtering and other unit operations so that a more precise comparison can be made between conventional leaching and preconcentration.

TITLE: LITERATURE STUDY AND EXPERIMENTAL TEST PROGRAM FOR THE FLASH FURNACE CHLORINATION OF ZINC-LEAD-COPPER SULPHIDE BULK CONCENTRATE

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	8-9064	FUNDING	
		BEGIN/END:	Sept. 79/Apr. 81		
				CANMET:	$102 616
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	40 000
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	P. Pint	TECHNOLOGY:	Metal Extraction	TOTAL:	$142 616

OBJECTIVES

The primary objectives of the investigation were to develop, study the feasibility of, and optimize on a miniplant scale the design and operating parameters for flash furnace (burner) chlorination of a Zn-Pb-Cu-Ag sulphide concentrate to produce metal chlorides and elemental sulphur. The ultimate goal was to provide engineering and scale-up data for costing of a commercial plant.

PROCEDURE

1. Conducted literature survey.
2. Designed and tested small-scale chlorination burner. Obtained information on conversions, retention times, etc.
3. Designed and tested a mini pilot-scale chlorination burner. Conducted experiments to obtain mass balances under various operating conditions.
4. Provided engineering scale-up data and costing for a commercial plant.

RESULTS

Designed burners and demonstrated that metal sulphide/chlorine gas reactions proceed rapidly with good conversions of sulphides to chlorides and sulphur.

Results suggest that this system could be applicable to the treatment of other sulphide concentrates.

Additional work is required to verify the feasibility of extended operation of a continuous reactor and to obtain scale-up data.

APPLICATION AND ONGOING WORK

Results are being used to develop a conceptual design for a 91 000 MTPY zinc plant. Results have been presented at a conference and discussed with industry. A contract to study the chemistry of metal sulphide/chlorine flames is expected to be awarded.

TITLE: SAMPLE PREPARATION AND ANALYTICAL METHODS FOR ELEMENTS ENCOUNTERED IN PRODUCTS FROM CHLORINATION OF SULPHIDE CONCENTRATES

CONTRACTOR:	Bondar-Clegg & Co. Ltd.	FILE NUMBER:	9-9128	FUNDING	
		BEGIN/END:	March 80/July 80		
				CANMET:	$ 6 077
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	P. Pint	TECHNOLOGY:	Metal Extraction	TOTAL:	$ 6 077

OBJECTIVES

Develop a sample preparation technique and analytical methods, including error limits, for the determination of concentrations of Zn, Pb, Cu, Fe, As, Ag, S and Cl in the products from the chlorination of Zn-Pb-Cu-Fe-Ag sulphide concentrates and from oxidized chlorination products.

PROCEDURE

1. Selected leaches to satisfy the criteria set forth under Objectives.
2. Tested leaches on samples provided by CANMET.
3. Analyzed solutions and residues for specified elements.
4. Verified the absence of exchange reactions.

RESULTS

1. The water leach was found to be the preferred sample preparation technique and was shown to be satisfactory in the following aspects:
   a) The chlorinated components of the product were readily dissolved
   b) Negligible leaching of the sulphides
   c) No precipitation occurred during the leaching due to the formation of AgCl, $PbCl_2$, or $Fe(OH)_3$.
   d) The leach solution, after being acidified to 20% HCl, was stable.

   However, it failed to completely satisfy one criterion; the absence of all exchange reactions. No significant exchange reactions between chlorides and sulphides of Cu, Zn and Fe were detected. The Pb component in the sulphide concentrates was found partially dissolved into the chlorides solution while Ag in the chlorides solution precipitated, presumably as AgS, due to the exchange reaction.
2. The EDTA-(di) Na leach was proven ineffective to dissolve the silver component in the chlorinated product as was the NH_4OH leach. During the NH_4OH leach, the silver seemed to be transferred into certain insoluble forms which was indicated by the failure of dissolution with a subsequent water leach.
3. The sample preparation and analytical techniques demonstrated good reproducibility.

APPLICATION AND ONGOING WORK

The methods developed are being used at CANMET and at the Ontario Research Foundation for the preparation and analysis of products from the Dry-Way Chlorination/Oxidation Process.

TITLE: MEASUREMENTS OF DENSITIES OF MOLTEN LEAD CHLORIDE SYSTEMS

CONTRACTOR:	University of Toronto	FILE NUMBER:	9-9085	FUNDING	
		BEGIN/END:	Feb. 80/Oct. 80		
				CANMET:	$ 6 495
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Mineral Processing	OTHER:	--
AUTHORITY:	K. Bartels	TECHNOLOGY:	Metal Extraction	TOTAL:	$ 6 495

OBJECTIVES

Measure the densities, compositions and temperatures of the $PbCl_2$-KCl-LiCl and $PbCl_2$-KCl-NaCl molten salt systems.

PROCEDURE

Measurements of the densities, compositions and temperatures were obtained using a specially designed density bob and bottom balance inside a vertical tube furnace.

RESULTS

Both systems were found to behave approximately ideally. Molar volumes were calculated by applying the Gibbs-Duhem equation for ternary melts. From this model, isodensity lines were calculated in the liquid region of the respective phase diagrams. These calculated densities agreed well with the measured values. For tables and figures, see report.

APPLICATION AND ONGOING WORK

High-purity lead chloride, obtained from hydrometallurgical operations, is electrolyzed in a fused cell. Many problems are still encountered in the fused-salt electrolysis of lead chloride. This contract established some of the fundamental data required of such systems.

SUPPORTING DOCUMENTS

Final Report: A. Gutiérrez and J.M. Toguri, "Densities and Molar Volumes of the Ternary Systems $PbCl_2$-KCl-NaCl and $PbCl_2$-KCl-LiCl"; Dept. of Metallurgy and Materials Science, University of Toronto; October 1980.

MINERALS TECHNOLOGY

ENVIRONMENTAL TECHNOLOGY

TITLE: INDEX OF PLANT SPECIES EVALUATION

CONTRACTOR:	Dames & Moore	FILE NUMBER:	8-9134	FUNDING	
		BEGIN/END:	July 79/Sept. 79		
				CANMET:	$ 4 722
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	D. Murray	TECHNOLOGY:	Tailings	TOTAL:	$ 4 722

OBJECTIVES

Throughout North America and internationally, many criteria are used to select and evaluate plant species for reclamation work. There is a definite need to compile all these criteria and document associated references in one comprehensive report. This is one means of acquainting researchers in government, universities and industry with the mass of species data presently available.

PROCEDURE

1. Obtained the selection criteria for plant assessments considered by plant introduction groups, such as:
   United States Department of Agriculture
   Canada Department of Agriculture
   Soil Conservation Society of America

2. Recommended criteria for plant selection for mine wastes.

RESULTS

Present-day concepts dictate that mined land should be reclaimed with a rapidly establishing, fast growing, temporary vegetative cover and long-range productive vegetation for maximum land use benefits. A great number of plant criteria are currently used for selecting suitable species for all types of reclamation work.

The criteria which are most commonly used in agricultural species' selection and in reclamation of natural disturbed areas, and transmission line, highway and pipeline rights-of-way are generally similar to those used for mine waste reclamation.

Certain criteria are generally specific to the reclamation of mine waste, including tolerance to heavy metals and pH. Species' specific data pertaining to selection criteria are available from the many species' evaluation and selection programmes operating throughout North America. Salt and drought tolerance, nitrogen fixing information, winter hardiness, seedling vigour and many other characteristics have been determined for a great number of species. Thus, for purposes of mine reclamation there is often no need to carry out detailed analyses of many plant characteristics. From the available data base one may preselect species with certain characteristics, then, by using competent researchers to conduct field or laboratory assessment trials, make a good subjective decision as to whether or not a species is suitable for the specific site and waste conditions to be revegetated.

APPLICATION AND ONGOING WORK

This information is required for development of a data base for plant selection for the mining industry.

TITLE: INDEX OF SOIL AMENDMENTS

CONTRACTOR:	Techman Ltd.	FILE NUMBER:	8-9135	FUNDING	
		BEGIN/END:	Aug. 79/Sept. 79		
				CANMET:	$ 4 669
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	D. Murray	TECHNOLOGY:	Tailings	TOTAL:	$ 4 669

OBJECTIVES

The establishment of vegetation on mine wastes has required the study of suitable soil amendments. Any additive to the soil could be considered (even fertilizer and water). Increased interest, however, has been concentrated on mulches and surface stabilizers used for improving the establishment of vegetation on mine wastes. Amendments in these two groups have been numerous when considering tailings treatment. It is necessary to know the applicability of the materials available so that suitable choices can be made when required.

PROCEDURE

1. Compiled a list of soil amendments suitable as a surface stabilizer or mulch on mill tailings.

2. Described each material and its use, including information on the following:

   a) Type of soil it is designed for
   b) Method of application
   c) Influence of frost action
   d) Duration of product
   e) Maintenance requirements
   f) Time required to handle material
   g) Equipment needed for application
   h) Time to apply material
   i) Cost

3. Gave examples of use of the soil amendments with references and indicated failures where possible. Examples need not be limited to mill tailings.

4. Indexed the above information by individual mulch or soil stabilizer to permit recognition of the usefulness of the various products to handle different situations on mill tailings.

RESULTS

This report presents the findings of an overview investigation of soil amendments suitable for use on mill and mine tailings. Surface stabilizers such as mulches and several other amendments were considered. These include: water, fertilizers, soil, subsoil materials, organic materials, and chemical amendments. The findings were based on a review of pertinent literature, information supplied by product manufacturers and distributors, and the answers to a questionnaire prepared for this study, which drew on the revegetation experience of working mines and reclamationists throughout Canada.

APPLICATION AND ONGOING WORK

The report forms a basis from which recommendations can be made in answer to inquiries from industry and for research planning where more information is needed.

TITLE: PIEZOMETER INSTALLATION IN WEST ARM OF NORDIC TAILINGS DAM, ELLIOT LAKE

CONTRACTOR:	University of Waterloo	FILE NUMBER:	0-9048	FUNDING	
		BEGIN/END:	Aug. 80/Nov. 80		
				CANMET:	$ 21 865
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	D.R. Murray	TECHNOLOGY:	Tailings	TOTAL:	$ 21 865

OBJECTIVES

Install a series of piezometer nests in a grid pattern on the Nordic West Arm Tailings in Elliot Lake to permit:

1. Monitoring of water head gradients for flow net pattern development.
2. Water sampling for depth profile characterization.

PROCEDURE

1. Set out a grid for a minimum of ten installation sites within the tailings area and a minimum of four installation sites outside the tailings area.
2. Installed 5 to 10 individual piezometers at each selected site within the tailings area, with points at 0.5 and 1.0 m intervals.
3. Installed a minimum of two multi-level piezometers in the sand underlying the tailings and at all sites outside the tailings area.
4. Flushed and labeled each piezometer to ensure its integrity and position for further studies on water heads and sample quality.

RESULTS

A total of 145 piezometers were installed at a total of 26 locations, and the location and integrity of each reported on in the contractor's report. Data on water level, pH and conductivity was obtained and some preliminary observations were made. The flow pattern is extremely varied, and the water quality has extreme conditions at various locations on the site related mainly to the texture of the tailings.

APPLICATION AND ONGOING WORK

The wells provided data that was useful in interpreting the flow pattern in the study area. They also remained available for sampling and monitoring for hydrological studies intended by other workers for the 1981-82 season.

TITLE: CONTINUOUS CORE SAMPLING OF URANIUM TAILINGS AND UNDERLYING UNCONSOLIDATED GLACIAL TILL

CONTRACTOR:	Gartner Lee Associates Ltd.	FILE NUMBER:	0-9058-A	FUNDING	
		BEGIN/END:	Oct. 80/Feb. 81		
				CANMET:	$ 25 800
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	T.P. Lim	TECHNOLOGY:	Tailings	TOTAL:	$ 25 800

OBJECTIVES

In order to develop an overall chemical and radioisotope balance in an abandoned uranium tailings area, as well as their distribution with depth, it is necessary to obtain drill core samples of the tailings solids for analysis.

PROCEDURE

The solid samples were obtained from the Nordic West Arm uranium tailings area in Elliot Lake using a continuous core sampling method to obtain a continuous core from surface to the base of the underlying glacial till. It was important to obtain soil samples which are relatively undisturbed and uncontaminated.

Various sampling techniques were tried; for instance, using a classical Shelby tube sampler, piston sampler, split spoon sampler and modified Shelby tube sampler.

RESULTS

The modified Shelby tube sampling technique was the most commonly used procedure during this investigation, especially in the tailings below the water table.

Although the technique was new and relatively untried, it appeared to work well over most of the tailings area for a number of reasons. The most important factors were:

1. The general presence of an underlying peat layer which was used as a plug in the bottom of the 6.1 m-long Shelby tube.

2. The vacuum applied during extraction.

Full recovery was obtained in most cases and the process was very time efficient.

The core samples recovered were accurate, and more and better samples than expected were obtained by this technique.

APPLICATION AND ONGOING WORK

This sampling technique for extracting tailings material or loose sand can be used wherever a similar investigation is to be conducted. The samples recovered will be used for geohydrochemical interaction studies in addition to the overall chemical and radioisotope balance investigation.

TITLE: MANUAL FOR THE SAMPLING OF A MINE WASTE DISPOSAL AREA

CONTRACTOR: Golder Associates Ltd.	FILE NUMBER: 2-9139	FUNDING	
	BEGIN/END: Nov. 82/March 83	CANMET:	$ 17 230
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: J.L. Dalton	TECHNOLOGY: Tailings	TOTAL:	$ 17 230

OBJECTIVES

Prepare an authoritative manual on the definition and implementation of a sampling program on a waste disposal area of a mineral processing plant. (As far as is known, an authoritative manual on sampling a tailings area does not exist.)

PROCEDURE

Prepared a manual that will describe the necessary factors in the planning of a sampling program and the technology and methodology used to carry out the sampling program.

RESULTS

An authoritative manual on the sampling of a mine waste disposal area was prepared. The manual consists of eight chapters, as follows:

1. Introduction
2. Definition of Sampling Program
3. Preliminary Data Collection
4. Tailings Solids
5. Surface Water and Seepage
6. Tailings Porewater
7. Wind-Blown Dust and Radon
8. Case History - Sampling Programs at Denison Mines, Elliot Lake, Ontario.

APPLICATION AND ONGOING WORK

The manual will be useful for the characterization of mine waste disposal areas, as required for the National Uranium Tailings Program and will also be useful for the sampling of tailings areas in general.

TITLE: DEVELOPMENT OF A FIVE-YEAR RESEARCH PROGRAM FOR THE DISPOSAL OF URANIUM MINE AND MILL WASTES

CONTRACTOR: Lawrence A. Melis	FILE NUMBER: 2-9197 BEGIN/END: March 83/May 83	FUNDING	
		CANMET:	$ 14 625
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Environmental Technology	OTHER:	--
AUTHORITY: V.A. Haw	TECHNOLOGY: Tailings	TOTAL:	$ 14 625

OBJECTIVES

The object of the Melis contract was to develop a broad outline for a five-year research program dealing with the disposal of mine and mill wastes from uranium mining operations in order to achieve safe containment and acceptable environmental conditions into the indefinite future. The contractor was asked to specifically concentrate on the disposal technology component of the National Uranium Tailings Program in proposing the program outline.

PROCEDURE

1. Reviewed present practice of uranium tailings management in terms of current operations and abandoned tailings.

2. Identified all aspects of tailings management, giving attention to the technical and economic features of each in relation to operational performance and indicating problems and gaps in knowledge.

3. Identified promising areas of investigation that may lead to new or improved methods of closing out uranium tailings.

4. Examined special problems of abandoned tailings (e.g., Gunnar, Laredo, and Bancroft) and proposed investigations that would be useful in determining remedial measures.

5. Examined the milling of uranium ores in relation to removal of contaminants from mill effluence.

6. Examined the confinement or treatment of mine wastes.

7. The contractor was to review the literature, interview operating personnel and visit mine sites to obtain such information and prepare a report that would assist the National Uranium Tailings Program to prepare a five-year program, in which objectives would be defined and plans could be formulated.

RESULTS

The contractor prepared a report in which he provided the following information, data, and recommendations:

1. Descriptions were given of all tailings sites in Canada, whether inactive, active, or projected tailings areas, which included detailed maps of locations, characteristics of the tailings, the type of milling operations used and the measures taken to contain the tailings from polluting the environment.

2. An outline of all waste disposal technologies currently being used in Canada was presented in which the following items received attention:
   a) Site selection
   b) Impounding techniques
   c) Use of liners
   d) Sub-surface flow barriers
   e) Effluent treatment
   f) Tailings modifications
   g) In situ leaching
   h) Reclamation
   i) Mine waste rock

3. Specific recommendations were given in the report on the following:
   a) Solids disposal
   b) Seepage
   c) Radionuclide and pyrite removal
   d) Effluent treatment
   e) Modifications to existing practice
   f) In situ leaching
   g) Reclamation

4. Finally, the report contained the author's view of priorities in the light of current economic and technological considerations. The report was considered satisfactory in all respects.

APPLICATION AND ONGOING WORK

The report will be used as a basis for future planning in the National Uranium Tailings Program. The findings of the report will be combined with program proposals received from other contractors to put together a complete five-year research program with all objectives defined.

TITLE: LASER SPECTROSCOPY OF MINERAL PARTICLE SURFACES - PHASE 1

CONTRACTOR:	Carleton University	FILE NUMBER:	2-9134	FUNDING	
		BEGIN/END:	Oct. 82/March 83		
				CANMET:	$ 3 477
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	DSS:	12 340
AUTHORITY:	J.L. Dalton	TECHNOLOGY:	Tailings	TOTAL:	$ 15 817

OBJECTIVES

Explore the use of laser Raman and laser fluorescence spectroscopy as measurement techniques to identify the surface components of small particles (~2 μm). The laser Raman and laser fluorescence spectroscopy will be conducted on pure compounds, mixtures of pure compounds, and on radioactive compounds using a surface dopant and an optical microscope.

PROCEDURE

1. Developed an experimental deposition technique to apply the surface dopant to the appropriate mineral particle.

2. Carried out spectroscopic measurements, both laser Raman and laser fluorescence, on the doped particles, both as individual compounds and as mixtures of pure compounds.

3. Prepared a gypsum sample doped with Ra-226, and carried out spectroscopic measurements on the doped and undoped gypsum.

RESULTS

With the surface dopant, deutroporphyrin XI dimethyl ester, characteristic fluorescence spectra were obtained from the large surface area minerals; silica-gel and gamma-alumina. No fluorescence was observed from alpha-quartz, alpha-alumina or gypsum. Temporal studies showed that the dye molecule was physically absorbed rather than chemisorbed which is necessary to produce characteristic surface spectra. Silica-gel and gamma-alumina particles (~2 μm) were able to be identified in mixtures of these two compounds.

Laser Raman spectra were obtained from small surface area compounds, alpha-quartz, alpha-alumina and gypsum. Particles of these compounds were identified in a mixture of these compounds. The band contours of gypsum doped with Ra-226 and undoped gypsum showed a marked difference, even though the same frequency was observed in all gypsum samples.

APPLICATION AND ONGOING WORK

The application of this technique to the surface analysis of mineral particles requires more research effort before it can be applied to surface analysis of field samples.

TITLE: PRODUCTION AND CONTROL OF OZONE IN THE WELDING OF COPPER/NICKEL ALLOYS

CONTRACTOR:	Welding Institute of Canada	FILE NUMBER:	9-9171	FUNDING	
		BEGIN/END:	May 80/Dec. 80		
				CANMET:	$ 7 992
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	M. Sahoo	TECHNOLOGY:	Pollution Control	TOTAL:	$ 7 992

OBJECTIVES

Ultraviolet radiation emitted during welding processes reacts photochemically with ambient oxygen to produce ozone. The presence of ozone in the welding working environment can cause irritation of mucous membranes, chest congestion, nausea, fatigue, headaches, etc. The requirement, therefore, was to study the factors affecting ozone production in the gas-metal-arc welding of both Nb-modified (ASTM B369-72 alloy C94600) and Cr-modified (IN 768) 70/30 Cu-Ni casting alloys, and to suggest possible methods for reducing the ozone levels as warranted. These alloys are candidate materials for shipboard systems.

PROCEDURE

Flat bead-on-plate welds were made to evaluate the ozone concentration as a function of welding parameters, measuring position, shielding gas composition, arc shielding, travel speed, etc. A weld was also made on a prepared butt joint and on a horizontal fillet to simulate actual welding geometry.

Ozone levels were detected on a direct reading chemiluminescent type monitor. Draeger samples were also taken for comparison in a few instances.

RESULTS

It was concluded that:

1. Highest ozone levels occur during conditions of spray metal transfer. This transfer mechanism is probable at higher voltages.

2. Longer welding arcs enhance ozone production.

3. Helium gas shielding does not significantly reduce ozone levels if the metal transfer characteristics are matched to those apparent during welding with argon.

4. Ozone decay is relatively rapid and should not pose accumulation problems in large welding shops.

5. Levels in excess of the ACGIH (American Conference of Governmental Industrial Hygienists) ceiling exposure for ozone can occur at distances up to 60 cm from the arc.

6. Local air currents (caused by extraction equipment, shielding gas flow, etc.) can affect ozone levels measured at a point.

7. Areas shielded from direct ultraviolet radiation showed dramatic reductions in the concentration of ozone.

8. Ozone levels decrease quite rapidly with increasing distance from the arc.

9. Under similar welding conditions, there is no appreciable difference in the ozone levels produced while welding with the Cr-modified or Nb-modified alloy.

APPLICATION AND ONGOING WORK

Similar studies have been planned for aluminum bronzes which are also used in shipboard systems. In addition, welds will be made in both Cu-Ni and aluminum bronze alloys utilizing the suggestions for reducing ozone levels. The weld quality will be evaluated and compared with those made earlier at PMRL where no attempt was made to reduce ozone levels.

TITLE: PRODUCTION AND CONTROL OF OZONE IN WELDING COPPER-BASE ALLOYS FOR SHIPBOARD SYSTEMS

CONTRACTOR: Welding Institute of Canada		FILE NUMBER:	1-9000	FUNDING	
		BEGIN/END:	July 81/March 82		
				CANMET:	$ 15 510
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY: Dr. M. Sahoo		TECHNOLOGY:	Pollution Control	TOTAL:	$ 15 510

OBJECTIVES

Ultraviolet radiation emitted during welding processes reacts photochemically with ambient oxygen to produce ozone. The presence of ozone in the welding working environment can cause irritation of mucous membranes, chest congestion, nausea, fatigue, headaches, etc.

The objective of this study was to compare the levels of ozone generated during gas-metal-arc welding (GMAW) of copper-nickel and nickel-aluminum bronze (NAB) alloys which are commonly used in construction of marine components. In addition, the effects of changes in welding parameters on ozone production and practical methods of reducing ozone were investigated.

PROCEDURE

Four types of wire electrodes were used:

1. Cuprotrode 521 for Nb-modified 70/30 Cu-Ni
2. Monel 451 for Cr-modified 70/30 Cu-Ni
3. Ampcotrode 10 (high aluminum, no nickel)
4. Ampcotrode 46 (complex Ni-Al bronze) for Ni-Al bronze alloys.

Several bead-on-plate welds were made using each of the four electrodes and the ozone level was simultaneously measured. The variables which were investigated to assess their influence on ozone concentration included; current, voltage, type of shielding gas and the placement of opaque barriers around the arc. If a procedure to minimize ozone was determined, then a constrained butt weld was made using this procedure.

Ozone levels were detected on a direct reading chemiluminescent-type monitor. Drager samples were also taken for comparison in a few instances.

RESULTS

1. Ozone concentrations well above the TLV can occur within a distance of 60 cm with any of the Cu-Ni or NAB electrodes when the arc conditions are such that metal transfer occurs in a fine droplet spray mode.

2. Combinations of welding parameters which comprise a relatively low voltage and an excess current are conducive to lower ozone formation but generally such conditions are not optimal for welding.

3. Ozone concentration can be reduced substantially with the use of an opaque shielding material placed in close proximity around the welding arc.

4. Ozone levels in operator breathing zones can also be controlled by a sufficiently strong cross-flow of air which effectively replaces the ozonated air with air drawn from an uncontaminated source.

5. Exhaust ducts up to 1700 m^3/h . capacity operating through a 20 cm diameter orifice are relatively ineffective in reducing the high ozone concentrations.

6. Helium additions to the shielding gas suppressed ozone formation by altering the arc characteristics, however, high ozone levels can be re-established by increasing the arc voltage.

7. Ampcotrode 10 electrode appears to produce approximately twice the level of ozone as the other electrodes.

APPLICATION AND ONGOING WORK

In addition to the production of ozone gas during metal inert gas (MIG) welding, particulate emissions in the form of metal oxides are inevitable reaction products from the welding arc.

The work can be extended to measure the fume generation rate and to analyze the fume. This would help identify circumstances which result in excessive airborne concentrations.

TITLE: COST ESTIMATES FOR FLUE GAS DESULPHURIZATION PROCESSES WHICH MAY BE USED TO TREAT OFF-GASES FROM NONFERROUS SMELTERS AND WHICH DO NOT PRODUCE SULPHURIC ACID OR LIQUID SO_2 AS END PRODUCTS

CONTRACTOR:	Acres, Davy, McKee Ltd.	FILE NUMBER:	O-9051	FUNDING	
		BEGIN/END:	Dec. 80/May 81		
				CANMET:	$ 89 242
CANMET			MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	C.A. Hamer	TECHNOLOGY:	Control of Noxious Pyro-metallurgical Emissions	TOTAL:	$ 89 242

OBJECTIVES

Prepare capital and operating cost estimates for a flue gas desulphurization (FGD) process to treat off-gases from nonferrous smelters. Eight cases were to be covered:

Gas Flow (m^3/min)	SO_2 Concentration (vol %)
420	10
7 000	0.5, 1.0, 4.0
14 000	1.0
28 000	1.0
112 000	0.5, 1.0

PROCEDURE

1. Calculated heat and material balances.
2. Prepared flow diagrams.
3. Compiled equipment list - description, type, capacity, materials of construction.
4. Plotted plans.
5. Estimated capital cost.
6. Estimated operating cost.
7. Prepared comprehensive report.

RESULTS

Two document reports were received; one being confidential because it contained proprietary information on equipment and material balances, and the other, with slightly less detail in those areas, for public use.

The study indicated that FGD is an expensive method of removing SO_2 from smelters. The average capital cost was $829/annual tonne sulphur removed, and the average operating cost was $312/annual tonne sulphur removed.

APPLICATION AND ONGOING WORK

Reports were distributed to the smelting industry and to provincial and federal government departments involved in SO_2 abatement. The data was used in various studies of abatement technology and costs. There is no ongoing work now at CANMET.

TITLE: STUDY OF THE COPPER-CATALYZED AIR OXIDATION OF THIOSALTS

CONTRACTOR:	University of Waterloo	FILE NUMBER:	0-9084	FUNDING	
		BEGIN/END:	Dec. 80/Feb. 81		
				CANMET:	$ 10 710
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Environmental Technology	OTHER:	--
AUTHORITY:	J. Dutrizac	TECHNOLOGY:	Pollution Control	TOTAL:	$ 10 710

OBJECTIVES

Obtain basic data on copper-catalyzed air oxidation of thiosalts to demonstrate the technical feasibility of the process and to provide the necessary data for a cost analysis of a hypothetical process for catalyzed air oxidation of thiosalt-bearing effluents. Previous work by the university staff has shown the potential utility of this method on the laboratory scale.

PROCEDURE

Heterogenized polyvinyl pyridine Cu complexes in both the quaternized and unquaternized states were prepared. These catalysts were then employed for thiosalt oxidation under continuous conditions in a two-stage slurry reactor for several test campaigns of two-weeks duration. Temperatures and pH were controlled, and a range of reactor variables were studied to try to optimize the reactor operation. Thiosalt concentrations and base demand were measured under all conditions.

RESULTS

For 2% (w/w) slurries of the poly (4-vinyl pyridine) $Cu(II)_2$ catalyst, effective oxidation of ~700 ppm $S_2O_3^{2-}$ influent to an effluent of <100 ppm total thiosalts can be carried out continuously for at least one month when operating at 20 to 30°C with solution flow rates of ~1 L/h and aeration of 1300 L/h using a two-stage reactor system comprised of 12 L reactors. At higher thiosalt influent levels (i.e., >1600 ppm), increased reaction temperatures enable depletion to <100 ppm thiosalt effluent levels for up to one week of continuous operation. The catalysts deactivate much more readily at these higher influent levels as a result of greater copper losses and appreciable adsorption of $S_2O_3^{2-}$ by both catalysts.

The quaternized poly (4-vinyl pyridine) Cu(II) catalyst has good long-term stability, and copper losses are very low. The poly (4-vinyl pyridine) Cu(II) catalyst, however, is susceptible to appreciable oxidation of the polymer matrix on long-term usage. This oxidation of the polymer matrix results in a substantial reduction in the activity of the regenerated catalyst.

The expected behaviour of the continuous slurry reactors employed in the experimental studies was mathematically modelled successfully.

APPLICATION AND ONGOING WORK

CANMET is currently undertaking a preliminary cost analysis of this approach. The results of the contract were recently presented as a seminar to industry personnel.

MINERALS TECHNOLOGY

MATERIALS DEVELOPMENT

TITLE: SURVEY REPORT ON THE STATUS OF THE CORROSION-IN-SOILS PROBLEM IN CANADA

CONTRACTOR:	J.D. Palmer Associates Engineering Ltd.	FILE NUMBER:	9-9116	FUNDING	
		BEGIN/END:	April 80/March 81		
				CANMET:	$ 7 740
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	W. Revie	TECHNOLOGY:	Failure Control	TOTAL:	$ 7 740

OBJECTIVES

1. Provide a survey report on the status of the corrosion-in-soils problem in Canada, with emphasis on gaps in existing knowledge and problem areas where R & D is needed.

2. Make specific proposals for a long-term testing program to obtain base data on corrosion of alloys of technological importance in typical Canadian soils.

PROCEDURE

1. Reviewed literature.

2. Interviewed persons concerned with control of corrosion in Canadian soils.

3. Prepared report that includes proposals for the testing program.

RESULTS

Soil corrosion mechanisms, control measures, and the occurrence of soil corrosion problems in Canada are summarized in the final report. The single most significant soil corrosion problem in Canada is reported to be the corrosion of municipal ductile iron water mains, which entails annual expenditures of millions of dollars. The main recommendations for future soil corrosion studies are:

1. Municipal soil resistivity maps should be prepared, and the effects of deicing salt should be studied.

2. A ductile iron corrosion control program should be implemented.

3. Regional soil corrosion test centres should be established.

4. A reliable, permanent, reference electrode needs to be developed for potential measurements in cathodic protection systems.

5. Equipment for remote potential measurements requires development.

6. Instrumentation and procedures for in situ corrosion rate measurements should be developed.

7. The effects of induced AC voltages and telluric currents on pipeline integrity need to be defined.

8. A soil corrosion information centre should be established to ensure rapid technology transfer.

APPLICATION AND ONGOING WORK

The information generated in this contract will form part of a technological base at CANMET to be used in formulating future R & D on corrosion in soils.

TITLE: MATERIAL AND DESIGN FOR RESISTANCE TO CRACK GROWTH BY CREEP - PHASE 1

CONTRACTOR:	McMaster University	FILE NUMBER:	9-9122	FUNDING	
		BEGIN/END:	July 80/March 81		
				CANMET:	$ 7 940
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	W. Tyson	TECHNOLOGY:	Failure Control	TOTAL:	$ 7 940

OBJECTIVES

Assess the applicability of fracture mechanics methodology to the control of creep crack growth in pressure vessels operating at high temperatures and pressures.

PROCEDURE

1. Summarized and evaluated existing fracture mechanics methodology for control of creep crack growth.

2. Collected and reviewed information on microstructure and creep crack growth in pressure vessel steels, especially as it relates to weld microstructures.

3. Identified critical weaknesses in existing methods and knowledge emerging from the above items 1 and 2, with a view to designing an experimental program to improve the reliability of pressure vessels operating under creep conditions.

RESULTS

A review of data in the literature and information obtained by a visit to a leading laboratory was completed. A report "Material and Design for Resistance to Crack Growth by Creep" and a supplement outlining implications for Canadian industry was completed. The reports present an authoritative survey of the subject, and are being circulated to industries in the petrochemical and pressure vessel field for reaction.

APPLICATION AND ONGOING WORK

The results of the work were presented at an open CANMET/PMRL seminar, followed by a discussion of the implications. Phase 2, an experimental study to follow up on ideas in the report and apply them to Cr/Mo pressure vessel steels, began in July 1981.

TITLE: CREVICE CORROSION SUSCEPTIBILITY OF STAINLESS STEEL

CONTRACTOR:	Dearborn Environmental Consulting Services	FILE NUMBER:	0-9096	FUNDING	
		BEGIN/END:	Jan. 81/March 81		
				CANMET:	$ 20 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	R. Brigham	TECHNOLOGY:	Failure Control	TOTAL:	$ 20 000

OBJECTIVES

Evaluate the effect of different materials on the crevice corrosion susceptibility of stainless steel in an aggressive oxidizing acid chloride environment.

PROCEDURE

One thousand coupons of MONIT stainless steel were prepared from commercial wrought sheet. Groups of 100 coupons were exposed in 10% $FeCl_3$ with crevices consisting of elastic pieces to metal, teflon to metal, glass to metal, delrin to metal, nylon to metal, metal to metal and wood to metal. For each group, 24 h exposures were started at 30°C and raised in a step-wise fashion by 2.5°C until 55°C was reached. The number of coupons on which crevice corrosion was observed to initiate at each exposure temperature was recorded and plotted.

RESULTS

Different materials were found to exhibit different degrees of effectiveness in initiating crevice corrosion. This is a significant observation which would not be predicted by classical crevice corrosion theory. This work on low-interstitial ferritic stainless steel augments earlier preliminary observations using austenitic stainless steel and confirms that elastic bands are the most effective initiators of the materials tested to date.

APPLICATION AND ONGOING WORK

Work is continuing by contract to evaluate Avesta 254 SMO stainless steel.

TITLE: CREVICE CORROSION SUSCEPTIBILITY OF AN AUSTENITIC STAINLESS STEEL

CONTRACTOR:	Dearborn Environmental Consulting Services	FILE NUMBER:	0-9180	FUNDING	
		BEGIN/END:	July 81/March 82		
				CANMET:	$ 19 916
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	R. Brigham	TECHNOLOGY:	Failure Control	TOTAL:	$ 19 916

OBJECTIVES

Evaluate the crevice corrosion susceptibility of Avesta 254 SMO high-alloy stainless steel.

PROCEDURE

Coupons of stainless steel containing crevices of different materials were exposed to step-wise increases in temperature in 10% $FeCl_3$. Go/no-go crevice corrosion behaviour, as a function of temperature, was recorded.

RESULTS

1. This contract confirmed that different materials exhibit different degrees of effectiveness in nucleating crevice corrosion in stainless steel.
2. Temperature was again shown to be a reliable criterion for evaluating crevice corrosion initiation.
3. Crevice corrosion initiation is a statistical phenomenon.

APPLICATION AND ONGOING WORK

This work supported a core program at CANMET. The results are directly applicable to industrial technologies such as materials for in situ recovery of heavy oil.

TITLE: DETERMINATION OF THE REPRODUCIBILITY OF A CONCRETE TESTING PROCEDURE

CONTRACTOR:	Laboratoire de Béton Ltée.	FILE NUMBER:	9-9112	FUNDING	
		BEGIN/END:	March 80/May 80		
				CANMET:	$ 12 952
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G. Carette	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 12 952

OBJECTIVES

Determine the reproducibility of a new strength test for in situ testing of concrete, the Split-Sleeve Assembly Pull-Out Test.

PROCEDURE

A series of concrete mixes covering a wide range of mix proportions were prepared at the Laboratoire de Béton in Montreal. Specimens cast from each mix were tested using both the new pull-out technique under investigation, and the standard compression test. Results were analyzed to determine the correlation between the two methods and to develop a precision statement for the new technique.

RESULTS

The within-test variation for the new technique was found to be about 8% and the correlation with the standard test was satisfactory with a coefficient of correlation exceeding 0.90.

Based on the above, the new pull-out technique appears promising as a method for in situ testing of concrete strength.

TITLE: DEVELOPMENT OF HIGH-STRENGTH CONCRETE USING FLY ASH AND SUPERPLASTICIZERS

CONTRACTOR:	Ontario Hydro Research Laboratories	FILE NUMBER:	7-9027	FUNDING	
		BEGIN/END:	Nov. 77/July 79		
				CANMET:	$ 10 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 10 000

OBJECTIVES

Develop high-strength concrete incorporating a large percentage of fly ash and superplasticizers.

PROCEDURE

The test program consisted of an evaluation of non air-entrained concrete containing Type I Portland cement and fly ash in combination with three commercially available superplasticizers. The following series of concrete mixes were made.

1. Trial mixes - to establish the water to cement + fly ash ratio and maximum percentage replacement of the cement by fly ash for a reference concrete mix to have a 28-day compressive strength in the order of 40 MPa.

2. Reference mix - to determine the mechanical properties of concrete made with the reference mix.

3. Water-reduced mixes - to determine the mechanical properties of concrete made by reducing the W/C ratio of the reference mix. The loss in slump of the concrete due to a 20% water reduction is to be restored using superplasticizers.

RESULTS

It was concluded that satisfactory high strengths can be achieved with concrete incorporating a large percentage of fly ash and superplasticizers.

The mechanical properties of the water-reduced, superplasticized fly ash concrete are superior to those of the reference fly ash concrete though the creep strains of the former are somewhat higher. The shrinkage strains of the two types of concrete are comparable.

The workability of the water-reduced, superplasticized fly ash concrete may impose a limitation on its use for cast-in-place construction; however, it appears satisfactory for the production of high-strength structural elements in a precast concrete plant.

Concrete made with combinations of other cements and fly ashes may or may not perform as indicated above.

TITLE: DEVELOPMENT OF HIGH-STRENGTH CONCRETE USING LESS ENERGY INTENSIVE MATERIALS

CONTRACTOR:	University of Calgary	FILE NUMBER:	0-9083	FUNDING	
		BEGIN/END:	Jan. 81/March 81		
				CANMET:	$ 23 770
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	V.M. Malhotra	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 23 770

OBJECTIVES

Develop high-strength lightweight concretes using fly ash and superplasticizers.

PROCEDURE

A series of concrete mixes were made using 350, 400, 450 and 500 kg/m^3 of cement. The amount of fly ash added varied from 0 to 100 kg/m^3. Air content was maintained at 5 ± 1% and superplasticizers were used to maintain the slump.

RESULTS

The test results obtained indicate that the procedure adopted did yield high-strength concrete (40-50 MPa compressive strength at 28 days). The limiting factor was the nature of lightweight aggregate.

TITLE: MARKET STUDY OF THE BENEFICIATED PRODUCTS FROM FLY ASH

CONTRACTOR:	Genstar Conservation Systems Ltd.	FILE NUMBER:	1-9083	FUNDING	
		BEGIN/END:	March 82/Jan. 83	CANMET:	$ 14 979
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	H.S. Wilson	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 14 979

OBJECTIVES

Carry out a comprehensive literature and patent survey of the beneficiation of Canadian fly ashes. Also, study the potential markets for the beneficiated products.

PROCEDURE

The contractor visited various locations where beneficiation is being done and surveyed available literature on the beneficiation procedures publicized. The potential markets were examined and economics studied.

RESULTS

The contractor prepared a report: "Market Study of the Beneficiated Products from Fly Ash". A CANMET Report (82-17E) has also been prepared.

APPLICATION AND ONGOING WORK

This work would be a basis upon which further studies could be made in anticipation of marketing the components of fly ashes.

TITLE: ANALYSES DES VIDES DANS LE BETON DURCI

CONTRACTOR:	Université Laval	FILE NUMBER:	1-9100	FUNDING	
		BEGIN/END:	Dec. 81/Feb. 82		
				CANMET:	$ 1 800
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 1 800

OBJECTIVES

Study the air-void characteristics of concretes incorporating silica fume in order to explain their behaviour under freeze-thaw cycling.

PROCEDURE

Air parameters such as air content, specific surface and spacing factor were determined for 12 samples of concrete containing up to 30% silica fume. The modified point-count method (ASTM C457) was used.

RESULTS

The study has shown the following:

1. Air content of the hardened concrete is in close agreement with that determined for the fresh concrete.

2. The incorporation of 10% or more of silica fume in the concrete affects the characteristics of the air system.

3. The poor performance of concretes incorporating 20 and 30% silica fume cannot, however, be fully explained by the changes in the air-void characteristics.

4. The behaviour of concrete under freeze-thaw conditions appears to be related to the incorporation of large percentages of silica fume and large dosages of superplasticizers.

TITLE: DURABILITY OF CONCRETE IN MARINE ENVIRONMENT - PHASE 5

CONTRACTOR:	University of New Brunswick	FILE NUMBER:	2-9001	FUNDING	
		BEGIN/END:	Jan. 83/March 83		
				CANMET:	$ 29 410
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	G.G. Carette	TECHNOLOGY:	Performance & Durability of Concrete	TOTAL:	$ 29 410

OBJECTIVES

1. Study the long-term durability of concrete incorporating up to 80% pelletized blast furnace slag under extreme exposure to seawater, including freezing and thawing, salt water attack, and wetting and drying.

2. Study the long-term durability of concrete incorporating up to 20% silica fume under the above environment.

3. Study the strength development of concrete incorporating 50% pelletized blast furnace slag and up to 15% silica fume.

PROCEDURE

1. Twelve air-entrained concrete mixes were prepared. These incorporated up to 80% slag as a replacement for cement and covered water/(cement + slag) ratios of 0.40, 0.50 and 0.60. A total of 12 large prisms and 48 cylinders were cast for field and laboratory studies. The large prisms, after curing, were transported to Treat Island, Maine, for long-term exposure to seawater attack. The cylinders were tested in compression and for modulus of elasticity at U.N.B.

2. Twelve air-entrained/non-air-entrained concrete mixes were prepared. These incorporated up to 20% silica fume either as an addition to, or a replacement for, cement and were made with a water/cement or water/(cement + silica fume) ratio of 0.60. The casting and disposal of specimens was as above.

3. Fifteen non-air-entrained concrete mixes were prepared. These incorporated up to 50% slag as a replacement for cement and up to 15% silica fume as an addition to cement and slag. A total of 90 small prisms and 180 cylinders were cast for laboratory studies which included compressive and flexural strength and modulus of elasticity determinations at various ages.

RESULTS

The work for Parts 1 and 2 involves long-term studies and no results are available yet.

Results of Part 3 basically indicate that any reduction in the early-age strength of concrete due to the incorporation of 50% slag as a replacement for cement can be overcome, in general, by the addition of about 10% silica fume to the mix.

TITLE: DEVELOPMENT OF ABRASION RESISTANT CERAMICS - PHASES 1 AND 2

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	9-9081	FUNDING	
		BEGIN/END:	Jan. 80/Dec. 80		
				CANMET:	$ 24 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	K. Bell	TECHNOLOGY:	Abrasion Resistant Ceramics	TOTAL:	$ 24 000

OBJECTIVES

1. Survey the literature and identify candidate materials exhibiting polymorphic changes with temperature that may be recommended for use as crack-growth inhibitors in ceramic bodies.

2. Prepare composites of polymorphic ceramic materials (SiO_2) in glasses and investigate their abrasion resistance.

PROCEDURE

1. Literature survey.

2. Much difficulty was experienced in sintering various glass/silica polymorphic systems to sufficient density to develop significant abrasion resistance. Finally, some specimens were hot-pressed. Those few specimens showing good abrasion resistance were examined by SEM, which showed a clear relationship between crack inhibition and crystalline content, but whether or not polymorphism was involved could not be determined.

3. A test method for determining relative abrasion resistance, using a Minimet polisher, was developed to replace the expensive and time-consuming Taber abrasion test. The latter was then reserved only for samples of most interest.

RESULTS

1. A limited number of polymorphic materials has been identified from the relatively sparse data available. Specific recommendations for further in-house investigation include: SiO_2 in silicate glass, Ca_3SiO_3 in silicate ceramic systems, and PbO in enamel-type coatings.

2. Quartz and crystobalite additions were made to soda-lime, borosilicate and lead silicate glasses. The results were largely inconclusive, due to low and variable densities of the specimens. Among the better specimens, there was a trend indicating improved abrasion resistance with 10% silica additions, decreasing at the 20% addition level.

3. Sintered glass is clearly not a prime candidate material for this purpose; it was selected for test because it is amorphous to X-rays, enabling ready identification of the crystalline phases.

4. The quick abrasion resistance test method will be adopted for in-house studies for preliminary selection of samples for further study.

APPLICATION AND ONGOING WORK

In-house studies will examine silica and calcium silicate (and possibly TiO_2) in high-alumina ceramic formulations, which are expected to sinter more satisfactorily.

A contract was issued to ORF (File No. 9-9081-1) to examine the abrasion resistance of glass ceramics, in which the polymorphic phases were developed in dense, recrystallized bodies obtained from the melt (rather than by sintering).

TITLE: DEVELOPMENT OF ABRASION RESISTANT CERAMICS - PHASE 3

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	9-9081-1	FUNDING	
		BEGIN/END:	April 81/March 82		
				CANMET:	$ 38 800
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	K. Bell	TECHNOLOGY:	Abrasion Resistant Ceramics	TOTAL:	$ 38 000

OBJECTIVES

1. Develop new glass ceramic compositions (crystallized from the melt) that show abrasion resistance.
2. Investigate the inherent crack inhibition of these materials.
3. Measure the relative abrasion resistance of these materials.

PROCEDURE

Fifteen compositions were prepared in the alumina-silica, basalt and slag systems, and their nucleation and crystallization behaviours were studied under various heating conditions. Ten of these compositions showed extensive recrystallization and were evaluated further for abrasion resistance (using an ASTM procedure) and for fracture behaviour (by microscopy).

RESULTS

All of the recrystallized materials showed increased abrasion resistance over the parent glasses, indicating validity of the assumed criteria. None, however, showed abrasion resistance approaching that of high-density alumina (commercial standard); this is attributed to the observed transgranular fracture of the specimens rather than intergranular fracture. Further work may be merited to seek development of crystalline phases that cause local stressing which promotes intergranular fracture.

APPLICATION AND ONGOING WORK

This work is complementary to in-house work to develop conventional abrasion resistant ceramic materials for linings of materials handling systems subject to abrasion and corrosion.

TITLE: FIELD EVALUATION OF CANCOAT ABRASION-RESISTANT DRAGGER SHOES

CONTRACTOR:	IMP Group Ltd.	FILE NUMBER:	O-9025	FUNDING	
		BEGIN/END:	Oct. 80/March 82		
				CANMET:	$ 6 804
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	Dr. K.G. Davis	TECHNOLOGY:	Cost Recovery and Technology Transfer	TOTAL:	$ 6 804

OBJECTIVES

1. Evaluate the use of ductile iron dragger shoes with a layer of CrC applied by an in situ technique.

2. Compare service life of CANCOAT dragger shoes with standard steel dragger shoes.

Background

a) The CANCOAT Process. A process has been developed, called CANCOAT, whereby a cast part can be produced with a layer of abrasion-resistant material bonded to a designated surface during casting. A layer of powdered abrasion-resistant material is held on the mould wall by suction while the metal is poured. The liquid metal alloys with the powder forming a metallurgically bonded layer. In addition to holding the powder in place, the suction facilitates infiltration of the molten metal and removes any gases formed during the casting operation.

b) Dragger Shoe Castings. Dragger shoes are attached to the steel doors which weigh down trawl nets. In bottom trawling, the steel doors are dragged across the sea bed causing rapid abrasion of the dragger shoes. Each door requires three shoe castings, one each for the leading, middle and trailing sections. These castings generally weigh between 30 and 34 kg each for a total shoe weight per door of about 90 kg.

PROCEDURE

CANCOAT middle dragger shoe castings were supplied. They were attached to one of the two doors used in a trawl, while other door was equipped with standard shoes from a single source to a specified composition. The shoes were not removed until either of the two doors was no longer serviceable, and data, such as time of test and test dates, distance covered, condition of sea bottom trawled, etc., was recorded. At least four such tests were performed. All test shoes and the standard shoes used for comparison were returned to CANMET suitably labeled, for subsequent examination.

RESULTS

The shoes were made in a commercial foundry. They were field tested in fishing trials on the east coast. The results were disappointing. Wear rates were similar to the standard shoes. Also, the degree of shock loading involved was underestimated.

APPLICATION AND ONGOING WORK

Some tests of CANCOAT castings in other applications are planned. This work is part of a demonstration project to transfer the CANCOAT process to industry.

TITLE: DETERMINATION OF ABRASION RESISTANCE OF EXPERIMENTAL PLATE STEELS

CONTRACTOR:	Falconbridge Nickel Mines Ltd.	FILE NUMBER:	0-9182	FUNDING	
		BEGIN/END:	July 81/March 82		
				CANMET:	$ 19 953
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	R.F. Knight	TECHNOLOGY:	Cost Recovery and Technology Transfer	TOTAL:	$ 19 953

OBJECTIVES

Perform abrasion resistance evaluations on seven experimental, direct-quenched, microalloyed steels and on three commercial, abrasion-resistant steels.

PROCEDURE

The contractor designed procedures and modified equipment for determining the abrasion resistance for two types of applications, i.e., low-stress, scratching abrasion (ASTM Standard Practice G65-80, procedure B), and high-stress, grinding abrasion (loaded sample dragged along a sand-covered, steel track). Four samples of each steel were tested for two intervals each in the low-stress test and three intervals each in the high-stress test. Abrasion resistance was determined by weight loss as compared with a mild steel reference sample.

RESULTS

The experimental steels had similar low-stress and high-stress abrasion resistance as compared with conventional low alloy steels with similar hardness levels. The low-stress results were directly proportional to the hardness of the samples. The relative abrasion resistance of the commercial steels, as indicated by the low-stress test, was identical to the reported performance of these steels in the field. The abrasion resistance indicated by the high-stress test was independent of the hardness level over the hardness range involved.

APPLICATION AND ONGOING WORK

The results of abrasion testing were incorporated into the final report on the project.

TITLE: POTENTIAL DEMAND FOR DIRECT-QUENCHED PLATE STEEL RELEVANT TO THE CANADIAN STEEL INDUSTRY

CONTRACTOR:	Price Waterhouse Associates	FILE NUMBER:	O-9181	FUNDING	
		BEGIN/END:	Oct. 81/Oct. 82		
				CANMET:	$ 23 592
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	J.D. Boyd	TECHNOLOGY:	Cost Recovery and Technology Transfer	TOTAL:	$ 23 592

OBJECTIVES

Forecast future demand for high-strength plate steels, having yield strengths in the range 345-690 MPa (50-100 ksi) and thicknesses of 13-38 mm (0.5-1.5 in.). Evaluate the potential of direct-quenched plate.

PROCEDURE

Interviewed Canadian steel companies, pipeline companies, petroleum companies, steel service centres, steel fabricators and ship builders. Presented results in a seminar at Physical Metallurgy Research Laboratories (PMRL) and prepared a report.

RESULTS

It was concluded that:

1. There is a trend toward higher strength steel plate with improved toughness.
2. The resource project demand for steel plate to 1995 is estimated to be 3 300 000 tonnes for linepipe and 1 800 000 tonnes for ship plate.
3. There is little interest in direct-quenched steels because of capital costs, but there is considerable interest in on-line accelerated cooling of plate.

APPLICATION AND ONGOING WORK

Information is being used in the planning of PMRL research on plate steels.

TITLE: ASSESSMENT OF LONG-TERM RESEARCH AND DEVELOPMENT REQUIREMENTS IN CANADA'S NONFERROUS METALS MANUFACTURING INDUSTRY

CONTRACTOR:	Dr. P. Chollet	FILE NUMBER:	2-9091	FUNDING	
		BEGIN/END:	July 82/Dec. 82		
				CANMET:	$ 15 154
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Materials Development	OTHER:	--
AUTHORITY:	D. White	TECHNOLOGY:	Cost Recovery and Technology Transfer	TOTAL:	$ 15 154

OBJECTIVES

Characterize the current state of the nonferrous metals manufacturing industry and its future prospects and identify any obstacles and problems of major, or national, dimensions amenable to improvement by research and development.

This work will necessitate visits to company offices and laboratories in Montreal, Toronto, and Fort Saskatchewan, discussions with Federal officials in Ottawa, as well as library research.

PROCEDURE

Held discussions in the head offices of the principal manufacturers of nonferrous metal semi-fabricated products and carried out supporting library search.

RESULTS

Among the metals considered in this study, aluminum and copper provide the greatest returns in terms of value added to Canadian metal commodities. They also still present good opportunities for fabricating process and product improvements. This is due to market competition in the areas of cost and product quality.

Technological opportunities for wrought-nickel and its alloys are not as obvious. This is probably due to the rather limited, though lucrative, markets for the fabricated metal in Canada and to the strong U.S. fabricating base.

With regard to lead and zinc, only major new markets can foster increased fabricating activity in Canada, and it seems that the corresponding technological requirements would be already largely on hand due to significant R & D anticipation by Cominco and Noranda.

Finally, magnesium appears to stand out as the most promising Canadian metal commodity from the point of view of expansion of its fabricating (wrought product) prospects. Magnesium refining and fabricating costs present the greatest technological challenges.

PMRL/CANMET has a distinct role to play in providing the necessary backup to the Canadian nonferrous metals fabricating industry, in that its physical and human resources can be used to augment industrial R & D efforts. Suggestions for R & D topics have been formulated in this report, mainly on the basis of consultation with industry.

APPLICATION AND ONGOING WORK

The results of this study will be useful in identifying and defining topics for R & D in nonferrous metal semi-fabrication manufacturing.

MINERALS TECHNOLOGY

METALS PROCESSING

TITLE: EXTRACTING GASES EVOLVED FROM CORES DURING THE SAND CASTING OF MAGNESIUM ALLOYS

CONTRACTOR:	Haley Industries Ltd.	FILE NUMBER:	7-9069	FUNDING	
		BEGIN/END:	Jan. 78/April 78		
				CANMET:	$ 5 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	B. Lagowski	TECHNOLOGY:	Metal Casting	TOTAL:	$ 5 000

OBJECTIVES

1. Develop a suitable pumping system and a suitable method of applying reduced pressure to cores for extraction of gases produced during pouring of magnesium alloy castings.

2. Assess the ability of the core coating to prevent metal penetration.

3. Evaluate the effectiveness of the application of reduced pressures to the cores to eliminate the defects caused by gases evolved during pouring of magnesium alloy castings.

PROCEDURE

The project was divided into three parts:

1. Low level reduced pressure (~ 5 - 7.5 cm of mercury) was obtained from available compressed air and high level reduced pressure (~ 66 cm of mercury) from a modified mechanical vacuum pump.

2. The cores were coated with Foseco N.825 mould wash composed of zircon flour and suitable inhibitors to seal the surface to avoid metal penetration into the core.

3. The effectiveness of the application of low level reduced pressure (compressed air) to vented cores and high level reduced pressure (vacuum pump) to unvented cores to prevent "core-gas" defects was tested on magnesium aircraft castings which previously yielded up to 90% rejects.

RESULTS

It is important to coat the cores to prevent metal penetration and to apply the reduced pressure to the cores without leakage to eliminate the "core-gas" defects. This is of paramount importance in the case of solid cores (unvented) which use high level reduced pressure (66 cm of mercury). The low level reduced pressure (compressed air) method is being used in the commercial production of five casting designs, and more designs are expected to be switched over to this method. It is believed that the application of this method results in the elimination of excessive scrap and will keep the company in a more competitive position in the export markets.

TITLE: DESIGN OF A SERVO-MECHANISM AND CONTROL SYSTEM FOR THIN-WALL ELECTROSLAG CASTING PRODUCTION

CONTRACTOR: Davis Engineering Ltd.	FILE NUMBER: 1-9087 BEGIN/END: Nov. 81/Feb. 82	FUNDING	
		CANMET:	$ --
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	DND:	$ 18 268
AUTHORITY: R.K. Buhr	TECHNOLOGY: Metal Casting	TOTAL:	$ 18 268

OBJECTIVES

Design a servo-mechanism for the production of thin-wall cylindrical castings of variable thickness using the electroslag casting process and devise a control system for the efficient operation of the machine using multi-strand electrodes.

PROCEDURE

A mechanism for the controlled withdrawal of a metallic water-cooled mandrel for thin-wall cylindrical castings of variable section thickness was to be designed. A control system was also required to regulate:

1. The feed rate of up to four individual wire electrodes for production of the castings
2. The rate of slag additions
3. The rate of addition of alloy powder and deoxidants.

RESULTS

The design concept was completed along with schematics of the proposed layout and a list of all equipment needed. A report was also submitted, detailing the anticipated operation of the equipment for the production of thin-wall cylindrical castings using the electroslag process.

APPLICATION AND ONGOING WORK

The design concept is being applied to the development of necessary apparatus to produce thin-wall cylindrical castings by the electroslag casting process for the Department of National Defence.

TITLE: DEMAND SITUATION FOR IMPORTED AND DOMESTIC MOULDING AND CORE SANDS USED BY CANADIAN FOUNDRIES AT PRESENT AND FOR THE PAST FIVE YEARS AND NEXT TEN YEARS

CONTRACTOR:	Robert Shnay & Associates Ltd.	FILE NUMBER:	2-9039	FUNDING	
		BEGIN/END:	July 82/Dec. 82		
				CANMET:	$ 19 600
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	R.K. Buhr	TECHNOLOGY:	Metal Casting	TOTAL:	$ 19 600

OBJECTIVES

Determine the demand situation for both imported and domestic moulding and core sands used by Canadian foundries at present and for the past five years and next ten years.

PROCEDURE

Produced a summary of current production and trade statistics with significant comment regarding perceived supply shortages, security of supply, urban encroachment, transportation problems, etc. The report included the following:

1. A list of Canadian foundries and their silica-sand consumption, grouped by foundry type (ferrous or nonferrous) and by province.
2. Current foundry sand consumption by company and location, with dollar values and supply source. Also, consumption for the past five years and estimated consumption for the next ten years.
3. Sand type and specifications, including grain sizes used and chemical analysis, if possible.

RESULTS

Data on past, present, and future consumption was collected by means of questionnaires, visits, and meetings. Information from foundries was supplemented with data from sand suppliers and government sources. During the past five years, the estimated average annual sand consumption was 648 000 tonnes. This dropped to about 425 000 tonnes in 1982, and it was estimated that the average annual sand consumption for the next ten years will be 508 000 tonnes. The decrease is attributed to reduced automotive and agricultural needs, fewer megaprojects, reduced railroad casting needs, and increased sand reclamation.

About 97% of the sand consumed in Canada is imported from the U.S.A. Transportation adds more to the cost than any other factor. This results in costs of sand ranging from $43.70/tonne in Hamilton to $81.90/tonne in Vancouver.

The sand requirements from Ontario to Newfoundland are more than tenfold those in the West. Thus, if Canadian sand deposits are to be exploited, they should be close to cheap transportation such as the St. Lawrence Seaway.

APPLICATION AND ONGOING WORK

The information gathered in this survey has been sent to the Mineral Policy Sector, EMR, to augment their work on a survey of the industrial mineral requirements of Canadian industry.

It was recommended that high priority be given to the development of commercial sources of Olivine in Canada either from the Quebec deposit or from asbestos byproducts. In either case, the U.S. market should be considered. Also, the feasibility of developing chromite deposits in Manitoba and/or Newfoundland should be studied.

TITLE: PREVENTION OF DUPLEX GRAIN STRUCTURES IN CONTROLLED-ROLLED HSLA STEEL PLATE - PHASE 1

CONTRACTOR:	McGill University	FILE NUMBER:	0-9179	FUNDING	
		BEGIN/END:	June 81/March 82		
				CANMET:	$ 28 342
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	G.E. Ruddle	TECHNOLOGY:	Metal Working	TOTAL:	$ 28 342

OBJECTIVES

Conduct, on behalf of CANMET, experimental research to determine the causes of the undesirable duplex grain structure which develops during controlled rolling of microalloyed high-strength steels, and examine processing methods to prevent or minimize the duplexing of the steel microstructure.

Phase 1 - Microstructural Characterization of Simulated Rolling Deformation

In a base microalloyed steel composition, examine and characterize the development of austenite microstructure and the austenite-to-ferrite transformation in simulated rolling deformation. Determine the conditions under which grain coarsening and grain refinement occur during the deformation of austenite at high temperatures. Delineate the roles of coarsening and refinement mechanisms in controlling grain size in recrystallized austenite.

PROCEDURE

Simulations of controlled rolling of plate were developed by hot torsion testing of a Nb-microalloyed steel. The tests were designed to thermomechanically produce a small uniform austenite grain size. Test specimens were reheated at 1220°C, given roughing deformation in the 'full recrystallization' temperature regime down to 1075°C, cooled without deformation to 875°C, and finished to large strains in the 'no recrystallization' regime below 875°C.

A model was developed to explain the mechanism of dynamic recrystallization in austenite in terms of the initial grain size relative to the equilibrium recrystallized grain size. This 'critical grain size' model was tested by hot compression experiments which examined:

a) the effects of varying initial grain size in the range 65-300 μm and deforming at fixed temperature and strain rate conditions,
b) the effects of varying microalloying composition and fixing the initial grain size and deformation conditions such that the equilibrium recrystallized grain size was varied as a consequence of the microalloying elements in solution and in precipitates.

RESULTS

Hot torsion testing of an Nb-microalloyed steel was started to simulate plate rolling schedules which will obtain uniform fine-grained ferrite after transformation.

A newly developed 'critical grain size' model describes dynamic recrystallization characteristics in the homogeneous compression (rolling) deformation of austenite, where the classical 'critical strain' model based on torsion testing does not apply. For $D_o/D_s > 2$, (D_o, D_s are the initial and equilibrium austenite grain sizes, respectively), which is generally the case in industrial conditions of austenite processing where reheating produces coarse initial grain size, an unsynchronized dynamic recrystallization achieves equilibrium grain refinement in one recrystallization cycle, i.e., single-peaked stress-strain behaviour. Conversely, in fine-grained austenite, when $D_o/D_s < 2$, dynamic recrystallization is synchronized in several cycles leading to equilibrium grain coarsening.

Experiments in which D_o was varied and deformation conditions were fixed, and in which D_o was fixed and D_s was varied, verified the 2:1 grain refinement criterion.

Grain refinement is achieved through 'cascade' (unsynchronized) recrystallization proceeding from the outermost to the innermost parts of the deforming material. Considerable strain, e.g., 0.5-1.0 true strain at rolling strain rates, is required before refinement is complete in all parts of the material. Lower strain results in a mixed grain structure.

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.

TITLE: CHARACTERIZATION OF TiN PARTICLES IN HSLA STEELS FOR THE CONTROL OF GRAIN GROWTH

CONTRACTOR: University of Toronto	FILE NUMBER: 9-9061	FUNDING	
	BEGIN/END: Jan. 80/March 80	CANMET:	$ 7 995
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: M.J. Godden	TECHNOLOGY: Metal Working	TOTAL:	$ 7 995

OBJECTIVES

Characterize TiN particles with respect to size, morphology and chemical composition for four high-strength low-alloy (HSLA) steels in three specified conditions:

1. As cast
2. As rolled
3. As rolled and thermally cycled in the coarse grained heat affected zone (HAZ)

PROCEDURE

Electron microscopy of carbon extraction replicas.

RESULTS

Particle sizes and morphologies were determined for all three conditions, but chemical compositions could not be successfully determined. This is because the lattice parameters of the precipitates could not be used to unambiguously determine the composition of the particles due to the extensive solid solution of niobium, titanium, nitrogen and carbon in the precipitates.

Dendrite-like particles in the as-cast materials were unexpected and were absent in the as-rolled product. Their large volume fraction suggests they have a major influence on the fine precipitates of the as-rolled steels, and further study of these is suggested.

APPLICATION AND ONGOING WORK

This work is part of a joint project between Stelco and CANMET designed to develop better HAZ toughness. A subsequent contract for FY 80/81 further examined the Ti, Nb(C,N) particles using STEM techniques.

TITLE: IDENTIFICATION OF PRECIPITATE PHASES IN MICROALLOYED STEELS BY SCANNING TRANSMISSION ELECTRON MICROSCOPY

CONTRACTOR: University of Toronto	FILE NUMBER: 9-9120	FUNDING	
	BEGIN/END: May 80/Feb. 81	CANMET:	$ 11 159
CANMET	MINERALS TECHNOLOGY ACTIVITY	CONTRACTOR:	--
SCIENTIFIC	SUB-ACTIVITY: Metals Processing	OTHER:	--
AUTHORITY: D. Boyd	TECHNOLOGY: Welding	TOTAL:	$ 11 159

OBJECTIVES

1. Characterization of precipitate phases in TiN steels in the as-cast, as-rolled and as-welded conditions.

2. Determination of the kinetics of precipitation reactions during reheating.

PROCEDURE

1. Samples of experimental steels supplied by CANMET were examined using a scanning transmission electron microscope (STEM), and all precipitate phases were characterized by energy dispersive X-ray analysis and microdiffraction.

2. Precipitation kinetics were studied by reheating as-cast material for varying times at 1200°C, quenching, and analyzing the precipitates present by STEM.

RESULTS

All precipitate phases were analyzed for Ti and Nb, as well as Mo and V where appropriate. Electron energy loss experiments on analyzing for C and N were not completed. A complex precipitation sequence was identified as follows:

1. Nb-rich dendrites (as-cast)

2. Ti-rich cuboids (as-reheated)

3. Ti-rich cuboids + Nb-rich precipitate (as-rolled)

4. Ti-rich cuboids, 500-1000 A° (weld HAZ).

The dispersion of fine TiN particles which persists in the heat affected zone (HAZ) controls the grain size and produces a higher weld HAZ toughness.

APPLICATION AND ONGOING WORK

Further STEM work is being done under another contract to complete the electron energy loss experiments and to examine four other experimental steels.

The results have contributed significantly to a PMRL-Stelco co-operative research program on the development of linepipe steel with improved weld HAZ toughness.

This work was a continuation of Contract No. 9-9061.

TITLE: TRANSMISSION ELECTRON MICROSCOPY OF NIOBIUM AND VANADIUM CARBONITRIDE PRECIPITATES IN LOW-ALLOY EUTECTOID STEELS FOR PREMIUM RAIL

CONTRACTOR:	Nova Scotia Technical College	FILE NUMBER:	9-9117	FUNDING	
		BEGIN/END:	May 80/March 81	CANMET:	$ 11 000
CANMET SCIENTIFIC AUTHORITY:	D.M. Fegredo	MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
		SUB-ACTIVITY:	Metals Processing	OTHER:	--
		TECHNOLOGY:	Materials for Transportation	TOTAL:	$ 11 000

OBJECTIVES

Examine the size, spacing and distribution of niobium and/or vanadium carbonitride precipitates in thin foils of a current chromium-niobium premium rail steel made by SYSCO Steel Co., as well as in experimental steels containing niobium and/or vanadium, being investigated by PMRL.

PROCEDURE

Thin foils and extraction replicas of various steels, in different conditions, were examined by transmission electron microscopy. Scanning electron microscopy was used when precipitates were not observed in transmission. Optical microscopy was used in the preparation of extraction replicas. All thin foils were prepared and supplied by PMRL.

RESULTS

In general, only three steel specimens appear to contain a significant number of fine precipitates. Histograms detail the size-frequency distribution.

The premium rail steel contains a sufficient number of large precipitates to account for all the niobium content. No countable number of precipitates was seen in a number of steels in which they were expected. This can be explained by the processing conditions in a few cases. However, since a lower size detectability limit of ~ 2-3 nm exists, it is possible that some increases in hardness observed in steels with vanadium additions may be due to very fine, undetected precipitates. Alternatively, the interlamellar spacing may decrease sufficiently to account for hardness changes. This latter possibility will be checked.

APPLICATION AND ONGOING WORK

The results are useful in assessing the advantages of niobium or vanadium additions to eutectoid steels. It appears that alloying with niobium does not have any particular merit from the point of view of producing an adequate number of fine precipitates to substantially improve the hardness and strength, or significantly reducing the prior austenite grain size. Vanadium, however, can increase hardness to an extent that depends on the processing conditions.

Experiments to produce very hard and strong rail steels are continuing.

TITLE: HIGH-INTEGRITY CUPRO-NICKEL CASTINGS FOR TECHNOLOGY DEMONSTRATION AND SUBMARINE SERVICE EVALUATION - PHASE 1

CONTRACTOR:	Burnstein Castings Ltd.	FILE NUMBER:	0-9090	FUNDING	
		BEGIN/END:	March 81/March 82		
				CANMET:	$ 98 115
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Metals Processing	OTHER:	--
AUTHORITY:	Dr. M. Sahoo	TECHNOLOGY:	Materials for Transportation	TOTAL:	$ 98 115

OBJECTIVES

Provide technical support to Burnstein Castings Ltd. to produce a six-valve chest casting of niobium-modified 70/30 Cu-Ni alloy weighing about 318 kg. It was also required that the associated valves and rigging be made from this alloy, that the castings be radiographically sound, and that the assembly pass a pressure test of 2760 kPa.

PROCEDURE

Patterns and core boxes for the castings were not available and had to be made from drawings and a similar corroded casting which had been removed from a naval vessel. CO_2-sand moulds and oil-sand cores (baked) were used for all the castings. The cores were vented. Moulding was done in three stages. A special pouring box was used to facilitate pouring.

The melting practice developed at PMRL was used to prepare the alloys.

RESULTS

1. Use of a two-level non-pressurized gating system together with copper chills and a three-level risering system using insulated sleeves produced a radiographically sound six-valve chest casting of niobium-modified 70/30 Cu-Ni alloy.

2. The casting required only minor weld repairing in two non-critical areas and passed the 2760 kPa water pressure test. The casting yield was about 70%.

3. The production of the auxiliary components was routine and did not require any special precautions.

4. All the melts conformed to the composition limits and mechanical properties specified for alloy C96400 in ASTM B369-78.

APPLICATION AND ONGOING WORK

The project represents a successful exchange of experience between a commercial foundry and a government research laboratory, to the benefit of both. The six-valve chest casting will be used in a Canadian submarine and performance in seawater will be evaluated.

In the event that the Canadian Navy becomes interested in making other castings for ships and submarines of either niobium or chromium-modified 70/30 Cu-Ni alloy, technical assistance would be provided by PMRL to the Canadian brass and bronze foundries.

MINERALS TECHNOLOGY

STANDARDS AND SPECIFICATIONS

TITLE: EFFECT OF LIGHT ON CADMIUM RELEASE FROM GLAZES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	8-9081	FUNDING	
		BEGIN/END:	Jan. 79/Dec. 79		
				CANMET:	$ 30 660
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	K.E. Bell	TECHNOLOGY:	Ceramic Standards	TOTAL:	$ 30 660

OBJECTIVES

1. Study the kinetics and mechanisms of cadmium release from glass.

2. Study the kinetics of cadmium release from glazed articles.

PROCEDURE

1. Conducted kinetic studies on the leachability in weak acid of a glass melted from a typical Canadian glaze formulation containing cadmium and selenium stains. Studies encompassed the effect of temperature and the influence of exposure before and during leaching to no light, daylight, infrared and ultraviolet light.

2. Theoretically, the cadmium crystallizes in the fired glaze as cadmium sulfo-selenide, which is photosensitive. The above glaze was fired on ceramic bowls and tiles, and the kinetics of Cd release were examined as before.

RESULTS

1. It was concluded that cadmium release from glass is not affected by exposure to light of various wavelengths. The cadmium leaching kinetics in the glass showed a linear dependence with respect to time$^{1/2}$, indicating that cadmium release is a diffusion-controlled process; probably H^+ and Cd^{2+} ions counterdiffusing. The rate of cadmium release is strongly temperature dependent.

2. Considerable difficulty was experienced due to crazing of the glazes, which led to considerable scatter of the results. On a comparative basis, there was no significant difference between the glazes which were leached in darkness and those which were exposed to different wavelengths of light, indicating that it is possible to compound cadmium glazes that are essentially insensitive to light.

APPLICATION AND ONGOING WORK

This work is complementary to in-house studies on lead release from ceramic glazes. Both aspects contribute to the knowledge base necessary for national and international standards governing release of toxic materials from ceramic ware in contact with food. The results obtained under this contract influenced Canada's position with respect to the need for controlling lighting conditions when testing for Cd release under the test method being developed by ISO/TC 166 - Canada contending that it is not necessary to test in darkness.

TITLE: EFFECT OF HEAT TREATMENT AND CRYSTALLIZATION UPON LIGHT-INDUCED CADMIUM RELEASE FROM CERAMIC GLAZES

CONTRACTOR:	Ontario Research Foundation	FILE NUMBER:	0-9024	FUNDING	
		BEGIN/END:	Aug. 80/Aug. 81		
				CANMET:	$ 25 000
CANMET		MINERALS TECHNOLOGY ACTIVITY		CONTRACTOR:	--
SCIENTIFIC		SUB-ACTIVITY:	Standards & Specifications	OTHER:	--
AUTHORITY:	K.E. Bell	TECHNOLOGY:	Ceramic Standards	TOTAL:	$ 25 000

OBJECTIVES

1. Study the effect of crystallization of cadmium-bearing phases on cadmium release from glaze frits.

2. Determine the relationship between firing parameters and cadmium release from glazed ceramic articles.

PROCEDURE

1. The frits were melted and cast as rectangular bars, which were then heat treated in a temperature gradient furnace at various temperatures and times. Crystallization was examined using a laser light-scattering apparatus, by X-ray powder diffraction and by thin-section microscopy. Cadmium release from these glasses into acetic acid was determined using sized grains, in the presence and absence of light.

2. Glaze slips were prepared from the cadmium-bearing frits and applied to ceramic tiles. The tiles were fired at various temperatures, soak times and cooling rates. Cadmium release into acetic acid was determined under various light conditions.

RESULTS

It was concluded that:

1. Cadmium release from the glasses is independent of light conditions.

2. Crystallization increases cadmium release.

3. Cadmium release continues to increase above the crystallization range, probably due to separation of a cadmium-rich glass phase.

4. Contrary to the results for glasses, cadmium release from the glazes is sensitive to light, likely owing to compositional changes due to glaze/body reaction. Other workers have postulated a mechanism of photo-oxidation of CdS to more-soluble $CdSO_4$; further work in this area is underway at ORF, supported by NRC/IMRI (Montreal).

5. Rapid cooling of the tiles increased cadmium release, probably due to locked-in inhomogenous structures.

6. Crystallization (desired colours) occurs in a narrow temperature range; overfired ware, in addition to colour problems, may release excessive amounts of cadmium.

Unfortunately, the methods available to ORF failed to quantify the crystallization, therefore, the extent of the crystallization and optimum crystallization temperature could be interpreted only qualitatively.

APPLICATION AND ONGOING WORK

The results are being communicated to the Canadian Advisory Committee on release of toxic materials from ceramic ware in contact with food, where they will be used in support of Canada's position on International Standard Test Methods and Limits.

MINERALS TECHNOLOGY

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

TITLE: INVESTIGATION AND REPORT ON THE FIRE AND EXPLOSION HAZARD OF AMMONIUM NITRATE - PHASE 1

CONTRACTOR: Queen's University

FILE NUMBER: 8-9137
BEGIN/END: May 79/Dec. 79

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT
SUB-ACTIVITY: Explosives Testing and Research

CANMET SCIENTIFIC AUTHORITY: J.A. Darling

FUNDING

CANMET:	$ 15 000
DOT:	5 000
ITC:	5 000
CANADIAN FERTILIZER INSTITUTE:	25 000
TOTAL:	$ 50 000

OBJECTIVES

1. Obtain an improved understanding of the hazards presented by ammonium nitrate (AN) in its various commercial forms and environments with particular attention to fire and detonation phenomena.

2. Draw up test specifications to differentiate those grades of AN which may confer an unacceptable degree of hazard.

3. Apply risk analysis techniques in an attempt to quantify the risks involved.

PROCEDURE

1. Developed an equation of state for molten AN.

2. Determined minimum pressure requirements for shock initiation.

3. Investigated plausible means for progression from deflagration to detonation.

RESULTS

1. The critical impact pressure was found to vary from 125 kilobars at 235°C to 6.5 kilobars at 260°C. This latter value may be too high to permit initiation of detonation by the shock of collapsing structures during a fire.

2. Surface burning reactions appear to be ineffective in initiating a deflagration to detonation transition (DDT) in molten AN. This conclusion may not apply to molten AN contaminated with a metal such as copper or zinc. Also, contrary to Result 1 above, moderate dynamic pressures from weak explosions such as from black powder or from exploding pipes can initiate detonations.

APPLICATION AND ONGOING WORK

1. The elucidation of the DDT mechanism would enable specific cures to be developed for the hazard of detonation of AN during accidental fires. Isolation of bulk storage facilities for AN fertilizers is becoming increasingly difficult, and the continued use of AN as a fertilizer is imperative.

2. Research work at Queen's continued for another year.
   a) DDT characteristics were determined for AN solutions used in manufacturing.
   b) Critical impact pressures of these solutions were determined.
   c) Projectile impact tests were carried out on these products.

SUPPORTING DOCUMENTS

A. King and A. Bauer, "Shock Initiation Characteristics of Ammonium Nitrate" including Appendix I "A Proposed Mechanism for the Deflagration to Detonation Transition of Molten Ammonium Nitrate" (Summary Paper). Serial No. OSU79-00007.

TITLE: INVESTIGATION AND REPORT ON THE FIRE AND EXPLOSION HAZARD OF AMMONIUM NITRATE - PHASE 2

CONTRACTOR:	Queen's University	FILE NUMBER:	9-9172	FUNDING	
		BEGIN/END:	July 80/Nov. 82		
				CANMET:	$ 10 000
CANMET		ADMINISTRATION OF THE CANADA		DOT:	10 000
SCIENTIFIC		EXPLOSIVES ACT		ITC:	5 000
AUTHORITY:	R.R. Vandebeek	SUB-ACTIVITY:	Explosives Testing and Research	CANADIAN FERTILIZER INSTITUTE:	25 000
				TOTAL:	$ 50 000

OBJECTIVES

Determine the deflagration to detonation transition characteristics of ammonium nitrate (AN) in practical situations involving fire and impact accidents with solutions, liquors, blended fertilizers and explosive liquors, containing AN.

PROCEDURE

1. Determined the critical diameter and shock sensitivity of mixed fertilizer and AN solutions, and two explosive sensitizer liquors.

2. Determined the projectile impact sensitivity of the above solutions and sensitizers.

3. Determined the effect of contaminants on AN decomposition rate.

RESULTS

1. a) Without aeration, the solutions tested in 25-30 cm diameter containers were found to be shock insensitive.
   b) With aeration, the AN/ammonia/H_2O solution, as well as the two explosive sensitizer liquors, were found to be shock sensitive.

2. a) The solutions tested above could not be initiated by projectiles impacting the solutions at velocities of 325-425 m/s.
   b) Molten AN at 260°C could be detonated with a projectile velocity of 190 m/s.

3. a) Molten AN at 260°C could be detonated by a deflagrating 200 g black powder charge, showing that reasonably low pressures can initiate this material.
   b) It was shown that copper, as a contaminant in molten AN, could cause detonation.

APPLICATION AND ONGOING WORK

1. This study has increased the knowledge of how AN and its solutions react to fire and impact.

2. Results of this study could affect legislation and practices that exist for the transportation and storage of AN.

3. Possible effect on AN manufacturers' handling of hot AN solutions as the hazards of these solutions are recognized.

4. There is no ongoing work.

This was a continuation of Contract No. 8-9137.

TITLE: MODELLING OF IGNITION AND BUILDUP TO DETONATION IN SLURRY EXPLOSIVES - PHASE 1

CONTRACTOR: University of Ottawa	FILE NUMBER: 8-9140	FUNDING	
	BEGIN/END: Aug. 79/Aug. 80	CANMET:	$ 24 610
CANMET	ADMINISTRATION OF THE CANADA	CONTRACTOR:	--
SCIENTIFIC	EXPLOSIVES ACT	OTHER:	--
AUTHORITY: K.K. Feng	SUB-ACTIVITY: Explosives Testing and Research	TOTAL:	$ 24 610

OBJECTIVES

Investigate the hazardous properties of explosives by developing a model to describe the ignition and buildup process in bubble-sensitized slurry explosives under dynamic loading.

PROCEDURE

1. Evaluated the equations of state of gas bubbles in slurry explosives during dynamic loading.
2. Developed a computer program for computing the temperature profile in slurry explosives subject to dynamic loading (impact).
3. Reviewed the theory of the buildup process from ignition to detonation in slurry explosives.
4. Proposed a model to describe the ignition and buildup to detonation in slurry explosives.

RESULTS

1. A computer model has been developed for computing the temperature profile in slurry explosives subject to dynamic loading.
2. The model indicates that the temperature-time curves obtained by treating air as an ideal gas and those obtained from the Becker-Kistiakowsky-Wilson (BKW) equation of state are different, with the latter indicating higher maximum temperature. It also indicates that the value of γ (specific heat ratio) is very significant.
3. The theory of the buildup process from ignition to detonation in slurry explosives has been reviewed. The Forest Fire model was considered as a possible means to describe the buildup process.

APPLICATION AND ONGOING WORK

1. The computer model could be used to predict the hazards associated with low-pressure impact on slurry explosives.
2. Modelling of Ignition and Buildup to Detonation in Slurry Explosives - Phase 2 and Phase 3 were completed.

TITLE: MODELLING OF IGNITION AND BUILDUP TO DETONATION IN SLURRY EXPLOSIVES - PHASE 2

CONTRACTOR: University of Ottawa	FILE NUMBER: 0-9065 BEGIN/END: Sept. 80/Aug. 81	FUNDING	
		CANMET:	$ 28 014
CANMET	ADMINISTRATION OF THE CANADA	CONTRACTOR:	--
SCIENTIFIC	EXPLOSIVES ACT	OTHER:	--
AUTHORITY: Dr. K.K. Feng	SUB-ACTIVITY: Explosives Testing and Research	TOTAL:	$ 28 014

OBJECTIVES

Investigate the hazardous properties of slurry explosives by developing a model to describe the ignition and buildup process in bubble-sensitized slurry explosives under dynamic loading.

PROCEDURE

1. Made detailed examination of available experimental data for quantitative evaluation of the Forest Fire Model together with the critical energy concept.
2. Determined test conditions for obtaining desirable experimental data for slurry explosives.
3. Developed a suitable mathematical model to describe the buildup from ignition to detonation for slurry explosives.
4. Developed a computer model to predict sensitivity of slurry explosives.

RESULTS

The Phase 1 study of the formation and distribution of hot spots in slurry explosives under projectile impact was extended. The volume of air in the slurry explosive was varied from 2.5 to 30%, and two additional solid to liquid ratios were considered. Furthermore, the effect of gases other than air, as well as the effect of the initial temperature of the slurry explosive were investigated. The results obtained were presented at the Seventh International Symposium on Detonation, Annapolis, Maryland, U.S.A.

The FORTRAN computer program of the Forest Fire Model for calculating the rate of decomposition of explosives was modified. In order to take advantage of the Forest Fire Model for studying the behaviour of slurry explosives under various projectile impact conditions, Pop Plot data of slurry explosives are required. It is suggested that the Wedge technique be used for generating the required data.

APPLICATION AND ONGOING WORK

1. The computer model could be used to predict the hazards associated with low-pressure impact on slurry explosives.
2. Modelling of Ignition and Buildup to Detonation in Slurry Explosives - Phase 3, was conducted.

TITLE: MODELLING OF IGNITION AND BUILDUP TO DETONATION IN SLURRY EXPLOSIVES - PHASE 3

CONTRACTOR: University of Ottawa	FILE NUMBER: 1-9072 BEGIN/END: Sept. 81/Aug. 82	FUNDING	
		CANMET:	$ 29 974
CANMET	ADMINISTRATION OF THE CANADA	CONTRACTOR:	--
SCIENTIFIC	EXPLOSIVES ACT	OTHER:	--
AUTHORITY: K.K. Feng	SUB-ACTIVITY: Explosives Testing and Research	TOTAL:	$ 29 974

OBJECTIVES

Investigate the hazardous properties of explosives by developing a model to describe the ignition and buildup process in bubble-sensitized slurry explosives under dynamic loading.

PROCEDURE

1. Investigated the critical impact velocity of cylindrical projectiles on nitromethane under various physical conditions.
2. Prepared a numerical simulation of initiation to detonation of nitromethane under the impact of a cylindrical projectile.
3. Conducted further research for a code, better than the TENSOR CODE, for refining the calculations, with and without chemical reaction (burning process).

RESULTS

1. The volume percentage of air plays an important role in the generation of high temperatures in slurry explosives. At identical projectile velocity, the volume percentage of air must be within a certain range to generate the temperature required to initiate the decomposition of the liquid explosive component of the slurry.
2. The decomposition of the hypothetical slurry explosive studied is caused either by the first peak pressure caused by the impact of the projectile, or by the rarefaction pressure wave.
3. The dimensions of the explosive container play a role in the starting time for decomposition of nitromethane due to the variation of the rarefaction pressure waves from the bottom and the walls of the container.
4. At high projectile velocity (600 m/s), the decomposition of nitromethane took place in all the cases studied, regardless of the inert solid-to-liquid explosive ratio.
5. At a constant amount of air present in the slurry explosive, the impact velocity must be increased as the inert solid-to-liquid ratio increases to ignite the liquid explosive nitromethane.
6. When a solid explosive (PBX 9404) instead of an inert material was used in the hypothetical slurry explosive considered in this study, the liquid explosive component (nitromethane) decomposed before the solid explosive (PBX 9404).

APPLICATION AND ONGOING WORK

The computer model could be used to predict the hazards associated with low pressure impact on slurry explosives. The work is complete.

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Comments_____

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