CANMET REVIEW 1982-1983

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FOREWORD

The Canada Centre for Mineral and Energy Technology (CANMET) moved into its 76th year of research and development in mining, metallurgy and energy with renewed ministerial guidance for its endeavours.

A discussion paper "Mining, Mineral and Metals Technology, and the Role of CANMET, 1983"/ "Technologie des mines, des minéraux et des métaux, et le rôle de CANMET, 1983" was developed from a series of internal reviews by scientists within CANMET, and from valuable advice given by various subcommittees of the National Advisory Committee of Mining & Metallurgical Research. The past patterns of R & D were analysed and effort was made to recognize emerging techniques and their role in the future work of CANMET.

In simple terms the three principal mission goals of CANMET are identified as Policy R & D, Protection Technology and Productivity Technology. Policy R & D is that portion of the program (about 10 per cent) designed to directly assist government policy making and regulation by other agencies. This includes standards, certification, resource assessments, and R & D such as that related to technologies for the abatement of acid rain.

About one third of CANMET's work is related to protection technologies - health, safety and the environment. This covers mining, treatment of water and effluents, and the quality and integrity of structures.

Over half of the program is specifically directed to the support of industry by means of productivity technologies. These outputs may be processes, either new or incremental improvements, or hardware in the form of instrumentation; all designed to improve the productivity and competitiveness of industrial operations.

The ultimate test of the usefulness of CANMET's work is the way in which research results are used either by industry or other government agencies. The transfer of technology is an integral part of all CANMET activities.

1982 and 1983 marked some of the most depressed market conditions for the mining industry since the 1930's, and Ministers requested that a program of Short Term Aid in Research and Technology (START) be applied to assist the industry. A two year program amounting to $5 million was initiated, mostly in contract work, with some division of research effort from the historic medium to long term research work in the branch.

New research thrusts that may profoundly influence mining metallurgical and energy research are those fields of biotechnology, computerization, plasma technology and the use of robotics and remote controlled equipment. The branch is well equipped with highly qualified scientists, engineers, technical and support staff to meet the research challenges that lie ahead, and to serve the non-renewable resource industries of Canada.

W.G. Jeffery
Director General

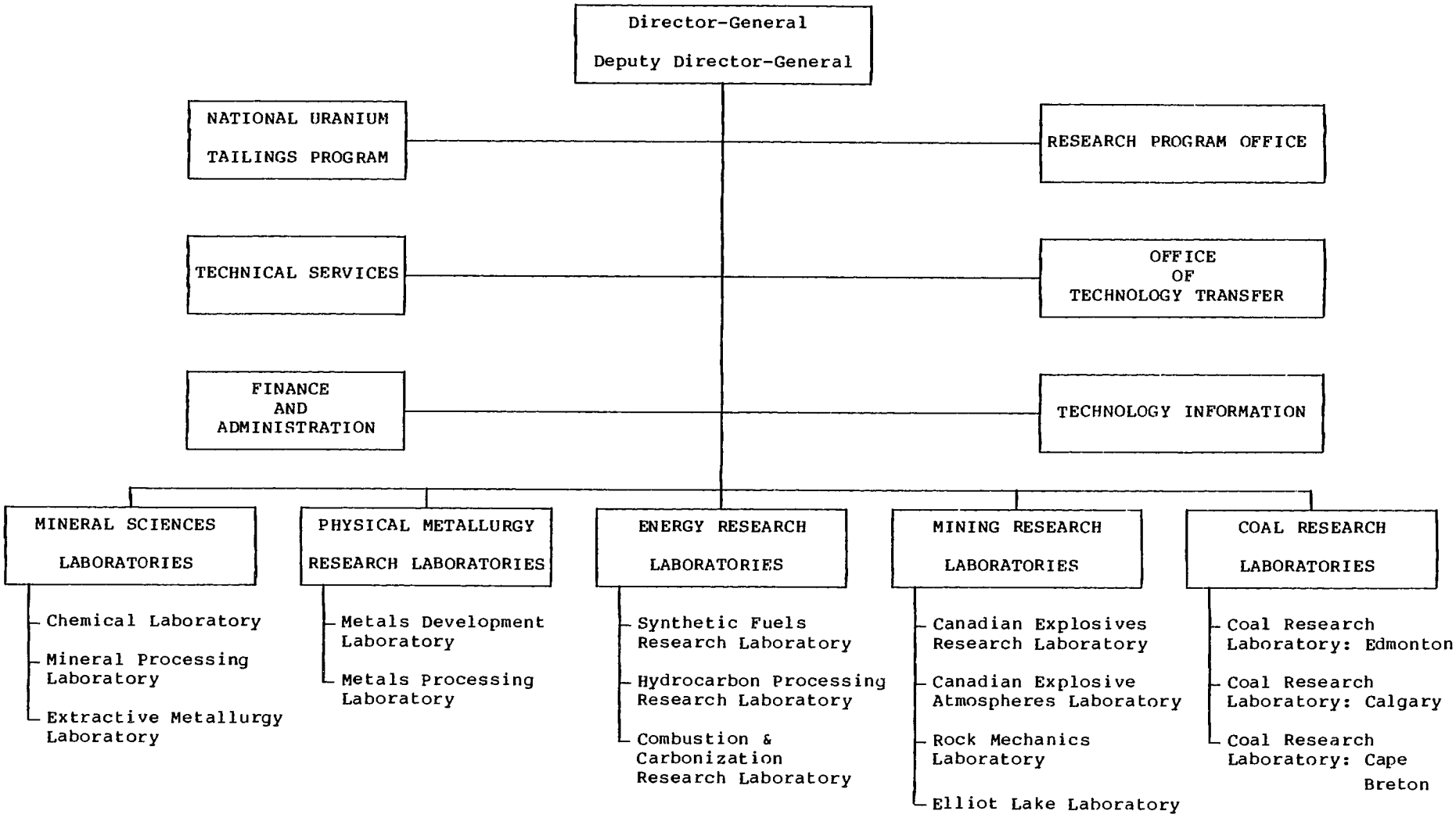
INTRODUCTION

CANMET's mission is to enhance the role and contribution of minerals and energy to the Canadian economy by means of mission-oriented research and development in mining, mineral processing and utilization of metals, industrial minerals and fuels. This

- Provides information to the Minister for making non-renewable resource-related policies;
- Serves government social objectives for health and safety and the environment;
- Is supportive to R & D performed by industry in order to improve the economic performance and productivity of industry.

In addition, technology transfer is an integral part of all CANMET activities. It is CANMET's policy to endeavour to transfer to industry or other appropriate clients (e.g., regulatory agencies) new knowledge and developments as they become available or as soon as users can take advantage of them. A complete range of transfer techniques, from information dissemination to joint R & D projects is used. Moreover, the longer term R & D projects develop expertise which is also of use in shorter term industrial R & D and is made available to industry where appropriate, usually on a cost-recovery basis, through joint projects or through the contracting-out process.

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY (CANMET)



CANMET MANAGEMENT 1982-83

Director-General - W.G. Jeffery

Deputy Director-General - V.A. Haw

RESPONSIBILITY CENTRES

Energy and Minerals Research Program	D.A. Reeve
Energy Research Laboratories	B.I. Parsons
Mineral Sciences Laboratories	W.A. Gow
Mining Research Laboratories	T.S. Cochrane
Physical Metallurgy Research Laboratories ..	W.H. Erickson
Coal Research Laboratories	T.D. Brown
Technology Information Division	J.E. Kanasy
Office of Technology Transfer	J.A. Potworowski

DISTRIBUTION OF RESOURCES

1982-1983

	PERSON YEARS	OPERATING FUNDS $ 000	CAPITAL FUNDS $ 000
ENERGY TECHNOLOGY			7 369
Conservation Technology	6	1 399	
Petroleum Supply Technology	92	6 731	
Coal Technology	146	13 445	
Nuclear Technology	27	1 163	
Renewable Energy Technology	15	749	
Research Program Office (incl. contracts)	5	296	
Information and Library Services	16	945	
Technical (Engineering) Services	33	1 163	
Management and other common services	60	3 685	
Grants and Contributions		491	
MINERAL TECHNOLOGY			1 526
Mining Technology	16	1 760	
Health and Safety in Mining	21	1 338	
Conservation and Resource Management	22	948	
Mineral Processing Technology	44	1 611	
Environmental Technology	24	989	
Materials Development Technology	34	1 619	
Metals Processing Technology	56	1 986	
Standards and Specifications	24	819	
Research Program Office (incl. contracts)	3	1 547	
Information and Library Services	17	824	
Technical (Engineering) Services	31	1 325	
Management and other common services	76	3 108	
Grants and Contributions		46	
ADMINISTRATION OF THE CANADA EXPLOSIVES ACT	12	470	59
TOTAL	780	48 457	8 954

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CONTENTS (Cont'd)

ENERGY TECHNOLOGY ACTIVITY

CANMET's energy research and development is chiefly concerned with the processing and use of Canada's oil, gas, coal and uranium reserves. The main objectives of energy research are directed to fulfilling the goals of the National Energy Program. The expertise which CANMET has built through its many years of research in these areas makes it ideally suited to act as Canada's foremost agent in the research and development of new energy technology.

Reorganization of the Energy Research Laboratories (ERL) took place this fiscal year to improve efficiency and more clearly define the areas of interest for the laboratories involved. The three laboratories are: the Combustion and Carbonization Research Laboratory, the Synthetic Fuels Research Laboratory and the Hydrocarbon Processing Research Laboratory.

This review summarizes the energy-related activities, and describes the progress and achievements during fiscal year 1982/83. CANMET's primary objective in the energy field is to contribute to the availability to Canada of technology for the supply, processing and use of energy to achieve sustained self-sufficiency as soon as possible. Secondary objectives are to assist in strengthening industry's competitive capabilities, and to provide leadership and liaison in dealing with the groups either at the international, provincial or industry levels.

The basic principle guiding the planning foundation at CANMET is that government-sponsored R & D should be accessible to all Canadians and be undertaken to ensure the widest possible dispersion of its benefits throughout Canadian society. Consistent with this assumption, CANMET adopts the stance of a public sector agency with a mission to provide R & D under circumstances where the private sector cannot be expected to perform the services necessary for our society.

One result of this approach is that work under the energy technology activity focuses on those specific technologies essential to achieving Canada's goal of long-term energy self-sufficiency. The research strategy is based on established notions of economic efficiency and environmental protection. It is recognized that public R & D should be conducted only where technology is an effective instrument in addressing a particular energy issue relative to non-technological policies. The essential relationship between private enterprise and public sector management should be maintained, and the least-cost principle should guide the selection of technologies to avoid waste and maximize net benefits.

The review describes research on various scales and in a variety of settings. The projects are selected to be complementary and to represent as comprehensive an effort as possible to meet the essential future energy needs of Canadians. This includes non-discretionary elements which help maintain a core science program. For example, although a sophisticated and indispensable tool exists for chemical analysis, its benefits may not be readily apparent to the casual observer.

At the other end of the spectrum, the review indicates the increased importance of demonstration-scale projects in transferring technology and developing industrial capability to meet urgent needs. Major demonstration projects are underway in fluidized-bed and coal-oil mixture combustion. CANMET scientists also act as technical advisers on demonstration projects coordinated by other government agencies, such as those in conservation and renewable energy.

The importance of public and private sector co-operation through contracting, cost sharing and joint projects is increasingly evident. Currently, 11.6% of the Energy Research Program expenditures is allocated to contracts. CANMET continues to play an important role in providing representation for the International Energy Agency and other international coal activities.

To aid in the development of sound energy policies and effective resource management, CANMET participates in the assessment of reserves derived from geological surveys and exploitation programs, through the application of resource quality parameters and technical and economical criteria. In cooperation with departmental resource economists, CANMET, as a result of many years of experience in coal and uranium and its expertise in mining, has been able to complete major projects on assessment of energy commodities. The assessment of Canada's intrinsic resources of coal, peat, uranium and low-grade petroleum materials, remains as CANMET's main raison d'etre. Through the careful evaluation of these results, priorities are determined which give direction to CANMET's research efforts. Research is centered on low-grade resources which could provide the bulk of Canadian future energy supply, but require specialized techniques for their development.

Technological advances in energy research will be the major factor in providing energy supplies to Canadians.

The implementation of existing improved technology, combined with the advent of new technologies is essential in the transition from Canada's heavy

reliance on conventional energy feedstocks to a more diversified system of supply. Our future energy supplies will probably include sources such as heavy oils, oil sands, coal, nuclear and renewable biomass sources. CANMET's role in the search for a secure and abundant energy source, is to ensure the latest and best technologies are available. To meet this goal the branch has continued its work on fossil fuels, and by placing greater emphasis in such areas as conservation renewable energy sources, and transportation and storage.

CONSERVATION TECHNOLOGY

To meet our national energy goals Canada must make the best possible use of the resources now available to us. CANMET, in an effort to aid in the achievement of these goals, continued its R & D efforts to improve the efficiency of fuel-burning technology. As in the past these efforts are coordinated with energy conservation efforts of many other public and private sector agencies.

RESIDENTIAL AND INDUSTRIAL ENERGY CONSERVATION

A decade ago the major thrust in North America energy usage was to eliminate the use of solid fuels in all but some of the largest installations, where coal was retained to generate electricity. The premium fuels, oil and gas, became predominant. The rapid increase in energy prices, some supply short falls which have occurred since 1973, and the realization that fossil fuels are a finite resource, have caused many users to look to energy conservation to reduce demand.

In Canada, the National Energy Program (NEP), has set a goal to reduce the use of oil in each of the residential, commercial and industrial sectors to no more than 10% of the total energy used in those sectors by 1990. To achieve this, NEP is providing incentives for promoting research into greater use of alternative energy options.

Conventional gas-fired heating systems operate at a low seasonal efficiency, between 55 and 60%, well below their steady state efficiency. Changes in technology could offer significant reductions in fuel consumption by improving combustion performance, reducing off-cycle losses, eliminating the need for downstream infiltration through the draft hood and increasing the steady state efficiency to over 90% by condensing some of the water vapour present in the flue gas and regaining latent heat.

CANMET scientists are conducting a research program in domestic gas-fired heating systems to help develop some of the most promising of the new technologies and to determine their performance, both in the laboratory under controlled conditions and in the field under real-life conditions.

The industrial energy conservation effort is concerned with increasing the efficiency of utilization and reduction of consumption of oil and gas in industrial processes. Much of the present industrial equipment, particularly if more than 10 years old, may not be operating nor even operable at maximum attainable efficiency of fuel use; some scope may exist to technically upgrade the installation to attain greater fuel economy. The program is intended to support, at zero cost to the owner, a limited number of specific studies on retrofit of combustion systems in a variety of industrial sectors and regions of Canada. By this means, a fully documented capability for energy conservation will be formulated by the performers, enabling them to subsequently and privately offer such services to industry in general, perhaps even with a guaranteed pay-back.

Five pre-engineering studies, including on-site testing, were carried out, on the following industrial processes: cement kiln; brick kiln; chemical processing boiler; uranium processing boiler and combined solid-gaseous-fuelled food processing boiler.

These studies provided recommendations for efficiency improvements, including the cost effectiveness of various options. The Industrial Energy Conservation Task Force set up by EMR will be one major vehicle for desseminating this information as well as offering seminars to specific industrial sectors, particularly those groups with which CANMET has a close association, such as metals and minerals.

ELECTRICAL ENERGY STORAGE DEVICES

CANMET continued applying its expertise in materials science by developing technology through intramural research for the fabrication and exploitation of various solid state electrolytes in energy storage and conversion systems.

Work continued on the development and exploitation of sodium beta-alumina for use in energy storage and conversion. During the past year, a simple and insensitive spray-drying process was developed which results in single-phase, theoretically dense beta-alumina on conventional processing.

CANMET continued conducting and sponsoring research on other electrolytes used in electrical storage and conversion devices. Work continued on the development of zirpsio ceramic materials, examination of which has shown that the difference in the durability of these materials is related to the composition of residual glass that is present in the sintered product. The more extensive the calcination and sintering, the more durable the structure. In addition to the zirpsios, two other groups of materials known as gasicons and yasicons, are known to be three-dimensional conductors and have conductivities comparable with those of beta-aluminas. These gasicons and yasicons have been produced by spray drying under contract at McMaster University. The durability of the material towards liquid sodium and their application in the sodium-sulphur battery is being evaluated.

Examination of a method for non-destructive evaluation of solid electrolytes established that the limit of detection using ultrasonics was inadequate. Consequently, work was initiated which improved the limit of detection using ultrasonics from 75 to 27 μm. Smaller defects require the development of higher frequency transducers having a so-called "screw-driver" beam for which work has been started.

HYDROGEN BY PHOTOELECTROLYSIS

The objective of this project is to develop low-cost, stable semi-conducting materials for use as electrodes in photoelectrochemical cells to convert solar energy into chemical energy by photoelectrolysis of water to produce hydrogen, or alternatively to convert solar energy into electrical energy.

In-house work, supported by outside contract to McGill Industrial Research has continued during 1982. The previous contracts to Bell Northern Research, and the University of Toronto, and Brock University terminated by the end of the fiscal year 1981/82. However, some follow-up work continues.

PETROLEUM SUPPLY TECHNOLOGY

The primary objective of CANMET's research in petroleum supply technology is to develop new, improved technologies which will overcome technical constraints for the exploitation of Canadian petroleum resources. These new technologies would greately enhance Canada's huge reserves of heavy oils and tar sands in Western Canada. The objective remains to develop improved technology for catalytical conversion of asphaltenes to liquids, and to establish upgrading processes to increase liquid product yields so they can be used as refinery feedstocks.

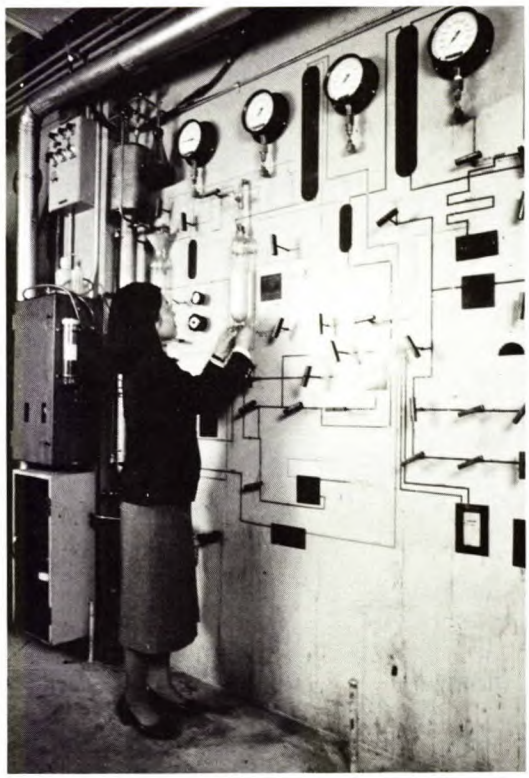
BITUMEN AND HEAVY OIL RECOVERY

Results of preliminary in-house experiments on the use of steam to displace bitumen from oil sands were assessed critically in report format. Also, a literature survey on laboratory techniques and research on steam stimulation were completed. These studies were helpful in developing a program of research and designing apparatus.

The high reservoir viscosity of Western Canadian bitumen and heavy oil requires that about one third of the produced oil or its equivalent in natural gas be used to generate steam. Work was contracted out by CANMET to investigate the possible use of coal as an ancillary feed for in situ oil recovery.

Many of the in situ recovery operations produce effluents containing complex emulsions which restrict the re-use of the water, not only for steam generation but also for release into the environment. While this problem is being addressed with considerable success by the use of demulsifiers, it is believed that there might be more attractive alternatives. One alternative that is being studied is the passing of these effluents through cheap sorbents. Some of these sorbents can remove/recover several times their weight in oil materials and appear to offer substantial advantages. A patent application has been filed and allocations for human and financial resources to continue the work have been requested.

UPGRADING OF BITUMEN/HEAVY OIL (HYDROCRACKING)



Pilot plant operator panel for CANMET hydrocracking pilot plant unit

CANMET support of hydrocracking commercialization during 1982/83 involved two feedstock runs. These were performed with continuous pilot plants to obtain information on yields, conversions, and product properties as a function of operating conditions. One of the feeds, a mixed sour blend pitch from Western Canada, was identified as a potential demonstration plant feedstock. Three experiments were performed with a residual pitch from a light Arabian feed to determine the effect of additive preparation and composition on long term operability. The effect of using an additive prepared by a lower cost route was also investigated to determine whether such a procedure could be used in the demonstration unit. Other runs performed in this period included a series of bench scale feedstock processibility tests to assess feedstock behaviour in the pilot plant. Another series of runs was also conducted in this unit to assess the effect of hydrogen sulphide on processibility.

A total of three runs were conducted in the continuous pilot plants under this project in the fiscal year. One experiment was designed to study the effect of bottom withdrawal and additive composition and concentration on reactor bed behaviour, product yields and properties. The other two were performed with pitch from light Arabian oil using a continuous stirred tank reactor (CSTR).

In addition, a program of autoclave studies was initiated after extensive modifications to equipment to obtain kinetic data. Based on pilot plant data, a mathematical model was developed which allowed the calculation of an overall rate constant from which pitch conversions can be predicted from process conditions for Cold Lake feedstock. These studies are aimed at elucidating the chemical and physical changes occurring in heavy oil and its components during hydrocracking, and studying the effect of additive composition on coke inhibition.

An in-house study was carried out using microscopic techniques to examine solid samples from the reactor bed, product and deposits. This work is needed to elucidate the coke inhibition mechanisms occurring in the process which in turn will greatly aid in additive improvements and development.

Characterization studies of hydrocracked products have been performed to support hydrocracking technology development. By examining a variety of feedstocks and products obtained at several operating severities, a better understanding of the reaction can be obtained. These studies also concern the assessment of the utilization qualities of the products. The characterizations require the development of new/improved analytical methods that are suited to bitumen/heavy oils/residuals and their products.

Liquid chromatograph used to operate hydrocarbon types in synthetic fuels on a preparative scale

During the past year the effect of hydrocracking on the compound type distribution in products from Light Arabian crude residues was studied and a report prepared. Also, a detailed compositional study of the polynuclear aromatic components in various heavy (as well as conventional) feedstocks and hydrocracked Cold Lake samples was completed under contract. These components have the potential to play significant roles in coke deposition during processing, and therefore data from this study will provide a better understanding of the mechanism of coke formation.

Most characterization studies as well as routine analysis involve the determination of asphaltenes. The conventional methods are very slow and cumbersome. In addition, the reproducibilities are poor. A method using thin layer chromatography-pyrolysis has been developed for these determinations. This method decreases the time by a factor of ten and provides much better reproducibility than conventional methods.

LECO sulphur analyzer used to determine sulphur levels in liquid and solid fuels

A proposal "Resource characterization on in situ recovery heavy oils - the effect of recovery methods on composition", was presented for consideration at the meeting of the executive committee for Canada-US cooperative tar sands projects. This proposal is being considered and discussions will be held with the Americans during the preparation of formal work statements.

UPGRADING OF BITUMEN/HEAVY OIL (NOVEL CONCEPTS)

A fixed-bed system was used to investigate fundamental aspects of catalyst surface acidity by adding chemical components to commercial-type hydrotreating catalysts. Another experimental study, conducted by CANMET which was completed in 1982, assessed the effect of the presence of carbon monoxide in hydrogen feed on the hydrocracking of bitumen. This assessment is important in determining the economics of hydrogen utilization in hydroprocessing. Two reports and 1982 conference presentations communicated the results of these two studies.

The formulation of catalysts having large mean pore diameters has been a concern at CANMET for a number of years, coinciding with its overall objective to develop an economical technique for processing heavy feeds. Previous work had indi-

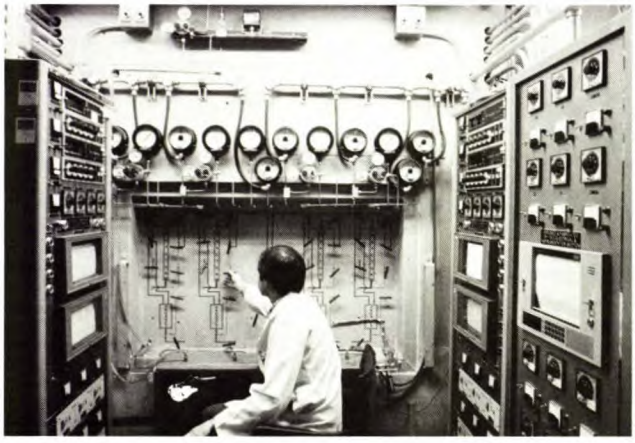
cated the usefulness of certain pre-treatment procedures in increasing the porosity of the catalyst support. This year work was directed toward a detailed analysis of the effects of parameters such as alumina content, concentration of acid, drying temperature and mode of drying on the total pore volume of the support.

One problem associated with pitch utilization is caused by its high sulphur content and the environmental effect of the release of sulphur dioxide during combustion. As stack gas scrubbing implies additions of costly equipment, less capital-intensive options are sought. Hydrodesulphurization (HDS) of pitch appears to be one possible option. The work on HDS of hydrocracked pitch was done by two contractors. One approach using a combination of microwave irradiation and metal hydride catalysts was found promising and a patent application covering this new method was prepared.

Previous work has shown that the use of catalysts in the pyrolysis and gasification of pitch provides increases in both reaction rates and yields, and produces more useful products. The program for 1982/83 was a continuation of the primary study to design and construct a fluid-bed reactor. The components of the reaction system were assembled and tested. The results have been promising. A test run with commercial alumina catalyst produced over 20% liquid at a rather low temperature.

UPGRADING OF SYNTHETIC CRUDES TO TRANSPORTATION FUELS

Canadian synthetic crudes are not ideal refinery feedstocks for the production of transporation fuels and much research is needed to develop the required processing technologies. Characterization of the problematic as well as desirable components is needed to obtain better insight into the problems and to support upgrading technology developments. The middle distillates from the various synthetic crudes including hydrocracked products are being characterized to determine the desirable and undesirable components for the production and utilization in diesel and jet engines.



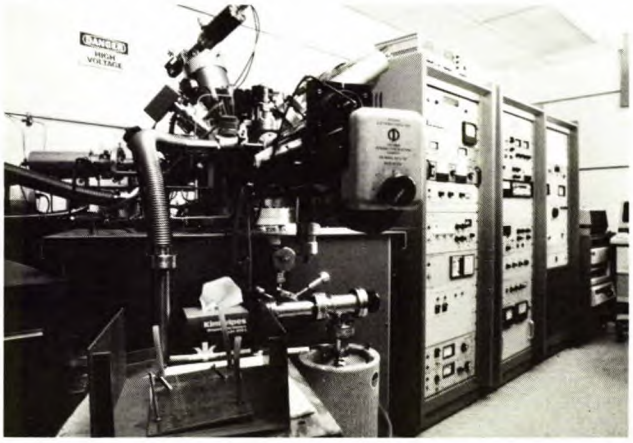
Control panel for the catalyst-life testing facilities

The ignition qualities for diesel fuel is a significant factor in these studies. However, the quality of the naptha as a feedstock for gasoline and petrochemical production was also assessed.

Work continued on the hydrotreating of CANMET distillates in 1982/83. The objective was to assess the performance of CANMET distillates under hydrotreating conditions using commercial hydrotreating catalysts. These evaluations were carried out in cooperation with Petro-Canada. This study was completed and the results, which will be used as a basis for choosing the optimum upgrading route for the CANMET hydrocracked product, are documented in a confidential report.

Middle distillate fractions from Athabasca oil sand syncrudes were upgraded by high severity hydroprocessing in a continuous-flow reactor system using conventional pre-sulphided hydrotreating catalysts. The catalyst activities were evaluated and a model for the hydrogenation kinetics was derived.

In-house and contract projects were designed to probe the mechanism by which the catalyst functions and the factors which optimize performance using available Canadian feedstocks. This year a catalyst testing system, composed of a 1-L bolted-closure pressure reactor with associated gas handling capability was designed and construction initiated. The reactor is designed to allow catalyst reduction, sulphiding, reaction with model compounds, and later in situ surface analysis of the catalyst by XPS/Auger spectroscopy without air exposure. During 1982, Auger electron spectroscopy capabilities were added to the surface spectrometer.



X-ray photoelectron spectrometer used in the analysis of sulphur characteristics

The evaluation of processes for segregating problematic compounds showed that selective removal of the catalyst deactivating nitrogenous and sulphurous components would obviate the need to hydrotreat the naphtha fractions before reforming. Removal of these components from the middle distillates would allow the use of more active hydrogenation catalysts at lower temperatures. Economically feasible separation of aromatics in the naphtha fractions would allow the isolated reform-

ing of the saturates and thus reduce degradation. In the middle distillates such separation would allow isolated treatment of the aromatics and thus decrease degradation. Selective separation of major fractions of aromatics would improve the quality of diesel fuels.

MATERIALS FOR PRODUCTION AND PROCESSING

Attention is being focused on high temperature/high pressure testing techniques for wear resistance evaluation of materials suitable for in situ oil recovery processes. Laboratory testing and evaluation of experimental data on wear resistance performance were completed for various candidate materials suitable for a Syncrude tailing pipeline. The data demonstrate that using various resistant alloys for transport of Syncrude tailings would be more beneficial than abrasion resistant steels because of the overwhelming contribution by corrosion to the total wear rates.

In-house work on the assembly of an ultrasonic wave system for detection of defects in heavy section welds continued. The previously developed system is being improved with particular respect to the capability of accurately sizing defects. An acoustic emission system, which will be used to detect defects during welding, is being developed under contract.

The need for pressure vessels in processing plants involved in the hydrotreatment of tar sands and heavy oils as well as the liquefaction and gasification of coal has encouraged CANMET to develop specific technologies dealing with the fabrication and inspection of heavy wall pressure vessels. In addition, the problems associated with in service deterioration of pressure vessel materials are being investigated.

In-house work on welding pressures focused primarily on the evaluation of the mechanical properties and microstructure of weld overlays produced by the strip overlay submerged-arc process. Work is also being continued on the development of technology required for in-shop welding of heavy section pressure-vessel steels. The major portion of this work is being carried out by two contractors. A submerged-arc narrow-gap-welding system was assembled as part of the in-house program which complements the two contracts.

MATERIALS FOR OIL AND GAS PIPELINES AND OFF-SHORE STRUCTURES

Previous work on this project involved evaluating sections of linepipe from different manufacturers. While this evaluation of commercial linepipe is complete, the interpretation of the data continues to yield useful metallurgical insights. Recently, observations of delamination frequency shown by Charpy tests in two modern grade 483 linepipe steels were correlated with shelf energy and shown to be a maximum in the transition between cleavage and ductile fracture. Studies of the micromechanisms of cleavage in these steels indicate that fracture initiates at the levels of non-polygonal phases and propagates along with the interfaces between these phases and the polygonal ferrite phases.

The development of high-strength low-alloy (HSLA) linepipe is an ongoing process with a continuous trend towards higher strength, leaner alloy chemistries, thicker gauges and lower processing temperatures. An examination of possible routes to the production of higher strength pipeline of similar or superior toughness and weldability has been initiated in order to support the Canadian pipemaking industry. Work has just started on the effect of accelerated cooling on the mechanical properties of a current Canadian steel. Trials have produced cooling rates in a quench tank that will adequately simulate these experiences during on-line accelerated cooling.

The effect of controlled rolling on microstructure development was studied previously. A series of rolling experiments was conducted to study the effects of a range of roughing reduction practices, combined with a fixed finish rolling schedule, on austenite recrystallization and final microstructure in a simple Nb-base composition. Microstructures were examined on samples quenched from reheat and from the early and end stages of roughing. Similar austenite grain sizes at the completion of roughing were attributed to partial recrystallization and the accumulation of strain during light reductions.

Research is being done to address the main controllable pipeline failure mechanisms, mechanical damage from installation or during service, the several electrochemical degradation mechanisms and mechanical overload as a result of lack of subsoil support. Mechanical damage in the form of dents and gouges can be produced in pipe during the pipelaying process by rocks and debris in the trench or by earth moving equipment. The elastic-plastic analysis of the stress state of a pipeline with a dent was completed. The plastic collapse failure mode of flattened specimens containing machined, pressed or gouged notches has been studied both experimentally and analytically. The effective stress-effective strain relationship has been applied to determine the maximum nominal stress for the specimens. The analytical predictions are consistent with the experimental results. Pipe specimens with gouged notches have been pressure tested. Preliminary results indicate that the present acceptance standards are safe but quite conservative.

The longitudinal stresses on a pipeline can change because of earth movement caused by washouts or frost heaving. In extreme cases the pipe can be plastically deformed. Monitoring the stress changes during the life of a pipeline gives the opportunity of pinpointing problem areas before failure occurs. This is particularly important in remote areas where earth movements are often not noticed and environmental damage is potentially serious. CANMET and NRC/IMRI are jointly sponsoring research at Queen's University to correlate magnetic measurements with stress level. Initial results on a grade 414 linepipe steel indicate that within the range of stresses studied the change in flux density was approximately pro-

portional to the applied stress and there was no Villari reversal.

Pipelines are subject to two types of electrochemical attack during service that subsequently lead to failure. Internal attack by hydrogen can occur in pipes transmitting wet H_2S containing (sour) oil or gas. External attack can occur in "Holidays" in the external pipeline coating from soil-borne mild corrodents. Two forms of H_2S-induced cracking are under investigation at CANMET, sulphide stress cracking (SSC) and stepwise cracking (SWC). The evaluation by standard methods is largely complete and attention has turned to other test methods and to determining the operative cracking mechanisms. Currently, the effects of stress and temperature upon SWC are under investigation.

Stress corrosion cracking (SSC) from external attack by soil-borne ions is another failure mechanism, particularly in older pipelines with poor coatings. Crack initiation and propagation during slow strain-rate SCC testing a grade 483 line-pipe steel in a CO_3/HCO_3 environment was investigated. Crack initiation was found to be associated with pits, which act as stress concentrators.

The assessment of the properties of mill welds in commercial linepipe and the field weldability of these steels were completed. The emphasis of this project in the past year was directed towards overcoming the problem of reliably producing large-diameter linepipe fittings to grade 414 and above. In particular the objective is to improve the strength and toughness of the seam weld.

Research activity on offshore structures focused on precipitation effects on strength and toughness in Ti-N steels, on the effect of sea water temperature on corrosion fatigue, and on the development of a program on the fracture toughness of welded joints. The work on strengthening mechanisms in HSLA steel for linepipe applications has provided a starting point for the detailed evaluation of grain-boundary pinning of austenite by Ti-N particles. An experimental program on the effect of sea water temperature on corrosion fatigue crack-growth rates in structural steel was completed. Results demonstrated that the enhancement of fatigue crack-growth rate by corrosion decreases with decreasing temperature.

Work on the identification of welding consumable and process variables to produce fracture tough weldments at -50°C was initiated. It was shown that residual stresses affect fatigue crack propagation rates and can be accurately accounted for using a fracture mechanics analysis when the residual stress source is remote from the crack tip. The residual stress fields across welds of T-joint configuration are being examined by conventional strain gauge and X-ray stress analysis techniques.

In a cost-sharing research program, four Canadian companies initiated work on aspects of steel production, fabrication and testing technologies relevant to Arctic and offshore applications. The program represents an initial evaluation of present domestic capability to produce steel for welded structures displaying fracture toughness characteristics equivalent to 40 J Charpy V-notch at -60°C. Other aspects that are being evaluated include the formability of these particular steels in tubular joint manufacture; the mechanized flux-cored welding system for on-site fabrication; and methods for ultrasonic inspection of large girth welds.

CONVERSION OF NATURAL GAS TO LIQUID FUELS

The objective of this research is twofold: first, to identify the major operating variables (temperature, pressure, residence time, etc.) which affect liquid product yield and, second, to assess operating difficulties with the flow apparatus. Small quantities of liquids were obtained and work on this project continues.

Studies were also initiated to promote and develop a novel and improved Fischer-Tropsch catalyst which will make the process more selective and more economically attractive. Extensive literature searches and visits were used to assess the state of knowledge relevant to Fischer-Tropsch synthesis of liquid fuels. Based on this, the design of a fully automated high pressure flow system with a computerized data acquisition station was completed.

COAL TECHNOLOGY

EMR is the leading agency for R & D in coal in the federal government. In response to federal initiatives to achieve oil independence and energy security, Canadian utilities and private industries are converting from premium liquid fuels to indigenous, often low grade coals. As a result of this expanded interest in coal CANMET has been able to maintain a high profile in coal R & D. The resulting technologies, both new and improved, are diversified and include topics such as coal mining, processing and utilization.

RESOURCE AND RESERVE ASSESSMENT

The objective is to assemble data and develop methodologies for assessing recoverable reserves of coal, production capability and coal quality in Canada. The acquisition of coal reserves data is an on-going activity with results published biennially. Under preparation is a report "Coal mine production, constraints and potential: an initial assessment". Several computer programs were created to select, analyze and process data. Geostatistical techniques are being used to evaluate operational variables, and a report evaluating two major coal zones in the Estevan coalfield is being prepared.

Refinement of existing methodologies and propagation of new analytical techniques are required in the development of technologies related to conventional and alternative fuel sources. Analytical techniques such as X-ray fluorescence, inductively coupled plasma emission spectroscopy, direct

coupled plasma emission spectroscopy, and atomic absorption spectroscopy are being utilized to assess the technical, and environmental constraints imposed by the unique profiles of Canadian fuel sources.

MINING

CANMET's Western Office in Calgary continued to assist industry to study and improve coal mining methods. This was done through a specialized R & D program which emphasized technologies that would be applicable to Canadian geological environment.

The Cape Breton Coal Research Laboratory is a new facility and is geographically remote from all other CANMET facilities. In this fiscal year, major efforts were made to recruit staff and establish research and development activities.

Underground mining methods used in coal seams of moderate thickness and gradient when applied in thick and steep seams of the Rocky Mountains have resulted in serious mining and strata control problems. Development of hydraulic mining technology was found effective with regard to safety and productivity but the knowledge base with respect to strata control and subsidence control is limited.

Working with B.C. Coal Ltd., CANMET has developed a unique remote sensing system for measuring subsidence-induced surface movements. The system uses tiltmeters to sense ground movement and radio telemetry to transmit data. In addition, techniques are being developed to assess subsidence using aerial photogrammetry. The two systems were compared and validated during a two-year experimental program. Photogrammetry proved to be accurate to within ±8 cm and progress was made in perfecting the interpretation techniques.

Internationally, longwall is the method-of-choice for mining coal from underground. In the correct geological environment it is notable for safety, high output, high labour productivity and economy. The method is not presently being used in Western Canada. Its chief disadvantages are that it lacks flexibility, requires a high initial capital investment and requires considerable skill to apply it successfully. All work on this project has been done under two contracts. The first was a feasibility study of a proposal to establish a demonstration site at McIntyre Mines Grande Cache property. The study concluded that suitable sites were available and identified issues to be dealt with in a detailed engineering study. The second study provided for engineering and system design for a specific site at Grande Cache. It concluded that a series of longwall panels be mined over a period of 5 years at the Steely site. Initial capital cost of the installation is estimated to be $12.5 million and, at current sales prices, would provide an attractive return on investment.

Surface mining methods account for the bulk of coal production in Western Canada and all commercial oil sands production is based on surface mining systems. CANMET research on surface mining technology in the past has been limited; surface mining has been extensively studied and is seen to be an activity requiring systematic research and review to ensure effective application of widespread technologies and predictive techniques. A major opportunity for development of computer based mine planning and mine management systems is developing as a consequence of a CANMET/NRC/industry program.

CONTROL OF EXPLOSION HAZARDS IN COAL MINES

The Canadian Explosive Atmospheres Laboratory (CEAL) continued to study the hazards associated with fire and explosion in coal mines in terms of ignition source control. CEAL also continued to participate in the development of suitable codes and standards for the effective control of these hazards.

With respect to ignition source control, CEAL is the only facility in Canada that tests explosion proof equipment for use in coal mines and other hazardous gas locations. Therefore, efforts have been directed to identify design criteria for such equipment to disseminate this information to Canadian industry.

A study to provide design criteria for flameproof diesel water scrubbers based on the resistance to deformation by flat stainless steel plates was undertaken and a report describing the experiments carried out for the study will be published in 1983. Further work on stiffened plates is in progress.

A new ASTM apparatus for determining the flammability limits of gases and vapours was constructed and is being commissioned for use on request by outside organizations.

Investigations of such unusual occurrences as an exploding coupler on a power line in a Nova Scotia coal mine are an example of the responsibilities resting with CEAL in this sub-activity.

METHANE/DUST EXPLOSIONS

The Canadian Explosives Research Laboratory (CERL) continued to promote the means of maintaining safety in underground coal mines involving potential methane/coal dust explosions. This is being accomplished by characterizing the explosibility of coal dust in order to assess the risk of explosion of methane/coal dust in the atmosphere of underground Canadian coal mines and the establishment of fundamental parameters for assessing the explosibility of the coal dust, methane and air mixtures.

Two major characteristics of Canadian coals which contribute to the severity of unexpected coal dust or methane gas explosions have been determined experimentally. The explosion severity was measured in terms of both the maximum explosion pressure and maximum rate of pressure rise. The effect on spark-initiated coal explosions of low concentrations of methane (0 to 5%) in air was

also investigated. The results indicated that coal dust from the Harbour seams in Nova Scotia were more hazardous than those from Western Canadian mountain seams and that small amounts of methane increase the explosion pressure and the rate of pressure rise. The results will be presented at the 20th International Safety in Mines Research Conference, Sheffield, U.K., October 1983.

A contract to study the development of equipment and techniques to evaluate boundary effects of methane/coal dust explosion was awarded to McGill University and most of the effort to date was devoted to the design of dust dispersion techniques to achieve a reasonably uniform dust-air mixture in a vertical combustion tube.

A probe to indicate coal dust concentration was built and calibrated using encapsulated standardized dust clouds.

The ignitability and explosibility of Cape Breton coal dust and the effect of stone dust were studied and some of the results were included in "Spontaneous combustion of Canadian coals" which was presented at the 1982 Combustion Institute (Canadian Section). A Quantimet 720 image analyzing system with "Zetopan" large research microscope was purchased and installed so that the surface area and volume of dust particles can be determined by observing and measuring the projected image.

Calibration of a high-voltage capacitive discharge system to produce sparks of known magnitude and duration as the ignition source in a Hartman apparatus was undertaken and is still ongoing. This apparatus will allow researchers to control spark characteristics during ignition tests.

At the request of Kilborn Engineering and Denison Mines, coal dusts from Babcock, B.C. were tested to determine ignition sensitivity and explosion severity to provide data for the design of a methane/coal dust explosion protection system for coal storage silos.

PREPARATION

The application of processes to upgrade coal mine product to improve utilization efficiency is defined as coal preparation. CANMET research involves developing methods to remove impurities such as sulphur, ash and other mineral matter, to adjust the water content, and to turn out consistently a product uniform in size and quality. The objective of coal preparation is to produce the optimum recovery of required coal quality at a minimum cost/time. The approach to achieve this depends on available processing methods and coal characteristics.

The pilot plant serves the research programs in fine coal beneficiation by providing for testing of computer control systems, on-line monitoring instruments and generating data for computer modelling of coal behaviour during processing. The plant will also serve the Canadian coal industry for evaluating new equipment before industrial application. The plant is designed to permit the choice of several circuit options to help the industry solve problems at existing washeries and to provide data for resource evaluation and the design of new plants.

With financial support from the coal industry, a bottom-feed thickener was installed to complete the Edmonton pilot plant circuit. Three coals were washed in the Batac jig this year, and evaluation of the Batac jig in washing metallurgical and thermal coal was made along with recommendations concerning its application to these three specific coals. For two of the coals, results indicated that the Batac jig can be used economically in cleaning instead of a more expensive option such as a heavy medium system. A new system for controlling the separation cut point in the Batac jig was tested and proved reliable.

Funding has been made available through the NEP to build two mobile fine coal treatment plants. The plants are intended for field application and to upgrade the existing pilot facilities.

Western Canadian coals with high proportions of fines are subject to high losses of fine coal to the reject and hence to a low overall recovery of saleable coal. Eastern Canadian coals with high amounts of sulphur often require crushing to fine sizes to liberate and separate pyrite. The mobile fines cleaning plant with its ability to operate at existing coal preparation plants across Canada, and with its flexibility in both implementing flowsheet options and monitoring of fine coal circuit variables, is suited to these fine coal cleaning problems. The mobile plant objectives are to design and optimize flowsheets, evaluate and improve fine cleaning circuit operations and to test new process monitoring and control equipment. The mobile dewatering unit is intended to identify optimum dewatering practices.

A large portion of the water treatment R & D work dealt with fundamental and applied research in properties of water soluble polymers used as coal washery flocculation additives. Low angle laser light scattering was used to obtain information about molecular weights and molecular sizes of polyacrylamides. The effect of added ions on the size of polymer molecules in solution was studied. A differential refractometer was used to measure the chain in refractive index of a polymer solution with concentration. This work was conducted to elucidate the mechanism of flocculation. With the aim of helping to reduce costs of coal drying and water treatment associated with the washing operations, two literature surveys were initiated in preparation for projects dealing with fine coal dewatering and clarification thickening processes. The objective of this year's field testing was to optimize performance of the solid bowl centrifuge. The variables were bowl speed, differential speed, retention time, feed rate and addition of flocculants on cake and concentrate quality. Results have shown that a substantial improvement in concentrate quality and solids recovery can be obtained by selecting a suitable flocculant.

CARBONIZATION

Coking coal is tradionally the most valuable of all grades of coal and is used by the world's steel industry to make metallurgical coke to fuel its blast furnaces. CANMET is Canada's leading research centre for conducting comprehensive R & D activities into high temperature carbonization and coke evaluation to support Canada's metallurgical coal producers and Canada's integrated steel industry. CANMET works closely with industry as a member of the Canadian Carbonization Research Association and provides the experimental facilities and scientific and technical personnel for assisting in planning and carrying out research. CANMET scientists also plan and conduct in-house research activities often of more national interest.

At CANMET, four pilot-scale ovens, 1 m high and 1 m long but with similar widths and hence heat transfer rates as conventional ovens are needed to satisfactorily evaluate coking coals and blends. The ovens have moveable walls connected to load cells to monitor pressures created during coking. A sole heated oven is also used to measure expansion and contraction properties of coals and blends. Laboratory methods such as chemical, thermo-rheological, and petrographic analyses are also done to completely characterize coal and coke properties.

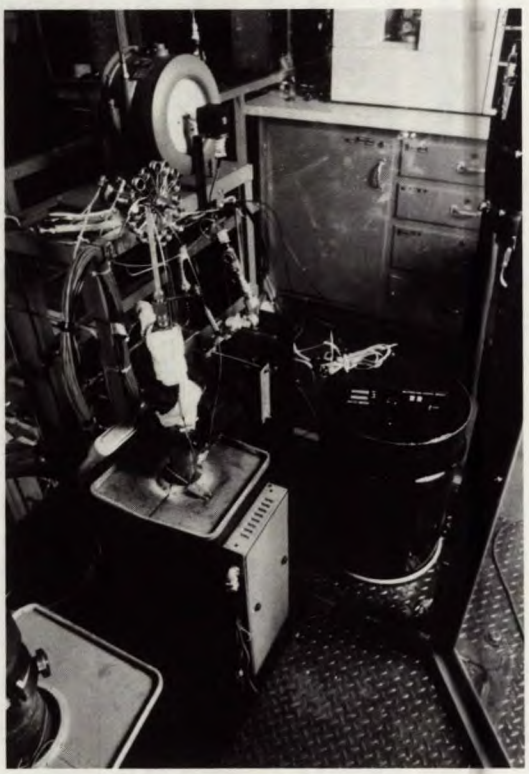
In recent years CANMET scientists have correlated coke properties from CANMET test ovens to those of Canadian industry. Although operating practices of the various steel companies vary and some differences in coke quality exist, coke from CANMET technical-scale ovens is generally comparable to that produced by Canadian industry. An international roundrobin investigation of coke quality was initiated this year by exchanging Japanese and Canadian steel company blends with Nippen Kokan Keihin of Japan to compare coke quality and analytical methods from Canadian and Japanese research centres. Investigations showed that certain experimental pitch materials are more effective than others in increasing the thermal rheological properties of coals from Western Canada and for steel company coal blends. Technical-scale oven studies showed that improvements to rheological properties of Western Canadian coals by pitch additives translate into improved coke strength parameters. Similar improvements were not found for steel company blends. Current studies in which different pitches are being added to three ranks of poor coking medium-volatile coal indicate that all additives tested are most effective with the coals of higher rank.

Coke used in blast furnaces must be strong and show relatively little variability in ash or moisture contents. Large swings in the moisture content of coke will upset the carbon to iron loading in the blast furnace and result in large changes to hearth temperature and difficulties in controlling sulphur and silicon contents of the casts. CANMET scientists are studying the effects of quenching rates and water temperature on coke moisture contents and coke quality and have found that coke moisture can be controlled by changing the water temperature and quenching rates.

Partial briquetting of coke oven charges using Western Canadian coals improves coke quality from conventional ovens by introducing briquets into the charge to increase its bulk density. Preliminary investigations with medium- and low-volatile Western Canadian coals suggested these coals are particularly well suited to partial briquetting technology and showed large improvements to coke strength parameters compared with those of the conventional charges.

The work in the chemistry of coal oxidation using ^{13}CNMR and FTIR is in progress. The characterization of the oxidized coal depends on functional group and Fourier Transform Infrared Spectroscopy (FTIR) plays an important role to determine these functional groups precisely. A study of the influence of oxidation/weathering on the nature and distribution of pyrolysis products of the Eastern and Western Canadian coals was completed. The effect of the oxidation on yield of products, chemical composition of gases, liquid and chars produced during low temperature pyrolysis was investigated. It was observed that mild oxidation resulted in a decreased liquid hydrocarbon yield whereas severe oxidation increased the proportion of aromatic carbon as well as oxygen content in the liquid product.

The restoration of coking properties and upgrading of poor coal for different industrial utilization using the water-gas shift reaction ($CO + H_2O$) continued. A logical and important extension of this



Top view of a gasification unit used in the gasification of coals

work to improve the liquefaction yields of oxidized coals by reducing the tendency to form coke residues was successfully achieved.

GASIFICATION

Screening of Canadian coals with respect to their gasification reactivities continued in the fixed bed reactor. Several coals have been identified as being preferable feedstocks for gasification processes. The lack of information on particulate matter and corrosive components in gasification products was recognized and addressed. Steps were taken to develop in-house facilities for obtaining such data. Construction of the continuous fluidized bed reactor was completed. This included modifications to study both gasification and pyrolysis.

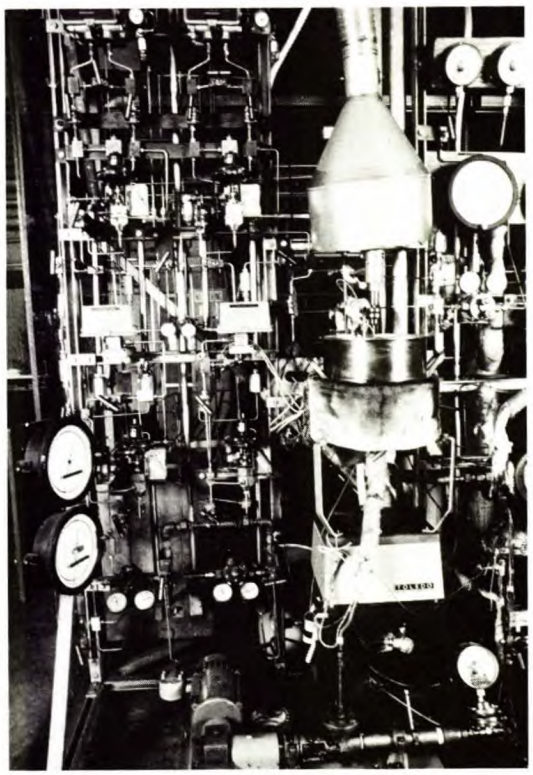
LIQUEFACTION

CANMET has embarked on a program aimed at developing Canadian interest and expertise in coal liquefaction as a future source of liquid fuels. To accomplish this a database on the liquefaction behaviour of various coals using different processing approaches was generated by an in-house and contracting-out program. A few of these programs will be investigated in this review. In the current fiscal year three person years and $150 000 capital and operating funds were allocated to the in-house R & D program, most of which is being carried out in the Coal Liquefaction Section.

After a lengthy delay before the Contracts Approval Board the contract for the design, construction and commissioning of a bench-scale hydrogenation unit recommenced in January 1983. Some design changes were made and modules for the unit are being assembled. The delivery and the commissioning of the unit are planned for mid-1983. The unit will be used for solvent preparation studies related to coal-bitumen co-processing and two-stage coal liquefaction research.

A rapid pyrolysis-gas chromatography technique was developed to assess coals with respect to yields of hydrocarbon products from pyrolysis. Thirteen Canadian coals of different ranks were evaluated. Several correlations between various properties of coals, yields of liquids and properties of these liquids were developed. These correlations can be used to predict the suitability of a particular coal as a feedstock for pyrolysis. Three technical reports were published based on this work which was carried out in the Coal Gasification Section.

A new research project on the solubilization of low-rank coals in bitumen fractions at atmospheric pressure was started. Preliminary laboratory results indicated that significant coal conversions were obtained at temperatures below 400°C. A new batch autoclave system was constructed and commissioned for this project. The study was extended to include autoclave experiments where pressures of up to 7 MPa can be tested.



CANMET Continuous Coal Liquefaction Unit

The development of international cooperation in coal liquefaction research continued. A number of Canadian coals were tested in Japan with scientists participating in the test program. Negotiations were started with West Germany on joint projects of interest as part of the overall science and technology agreements. A CANMET Coal Liquefaction Contractors' Review meeting was held with international attendance and participation. Further negotiations were held with UK Department of Energy representatives about possible Canadian participation in the National Coal Board's liquid solvent extraction pilot plant program. During the past year an agreement was negotiated whereby Canada through CANMET may join the International Energy Agency's coal pyrolysis project for the final phase.

In the contract program approximately $1 500 000 and two person years were allocated for a wide variety of contracted R & D using coals from the Maritimes to British Columbia. CANMET scientific authorities played a major role in the development and operation of this contract program which resulted in a significantly better understanding of the contribution coal resources can make to future liquid fuels production. The objectives of this contract research are to develop Canadian interest and expertise in coal liquefaction and to generate a national database on the liquefaction behaviour of different Canadian coals. The principal priority areas for the program are the co-processing of coal with bitumen or heavy oil, flash hydropyrolysis, pyrolysis and supercritical gas extraction of low-rank coals.

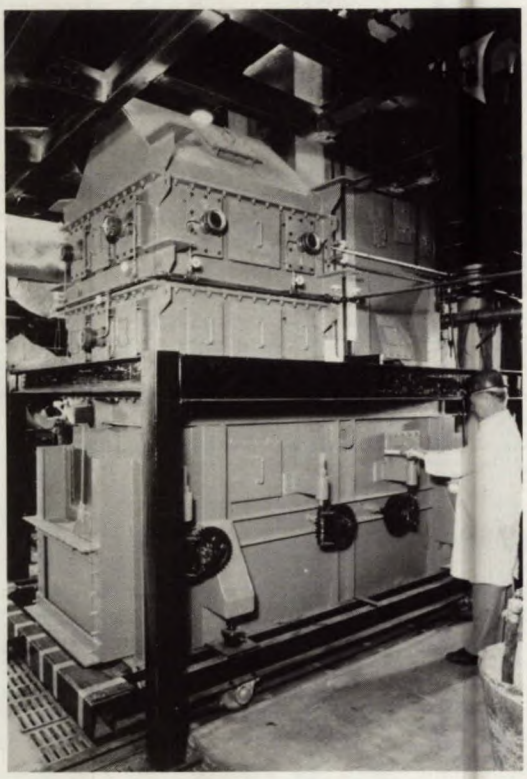
COMBUSTION

Current conventional combustion activities reflect the increasingly important contribution that coal is expected to make in meeting our future energy requirements and reducing our dependence on foreign oil. In addition, Canadian coal companies are vigorously working to secure a reasonable share of the world market, often with newly developed thermal coals of unknown quality and performance. These activities have resulted in collaborative government/industry combustion research projects under the CANMET Minerals and Earth Sciences Research Program, Energy Technology Activity. The objectives of the conventional coal combustion research group at CANMET are:

1. To develop new or improved techniques for efficiently utilizing pulverized coal and renewable fuels as a substitute for oil in industrial processes;
2. To define and optimize the combustion performance of low-grade coals from new mines or waste materials in pulverized-fired combustion systems;
3. To promote the development and, where feasible, the implementation of coal-liquid mixtures (CLM) as a substitute fuel for oil in existing oil-fired equipment and as an alternative to direct coal firing in other combustion equipment;
4. To conserve and improve the use of fuel oil through operational and design modifications to industrial combustion systems;
5. To keep abreast of domestic and foreign combustion R & D and, where appropriate, to participate in joint R & D projects relevant to Canadian needs;
6. To minimize the environmental effects of the increased use of coal in industrial and utility combustion systems; and
7. To develop and promote new or improved techniques for measuring and defining the combustion reactivity of fuels.

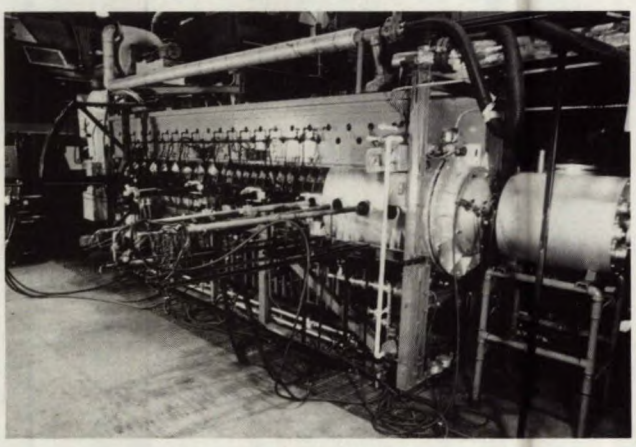
During 1982/83, the conventional combustion group replaced the existing pilot-scale pulverized-coal-fired utility boiler with a new facility. This new rig was designed to study low-quality fuels and is capable of increasing the adiabatic combustion chamber residence time by a factor of five. In addition, a controlled history mixing reactor (CHMR) was designed and is in the last stage of construction. The conventional combustion group is also building up its capability in the area of non-intrusive combustion measurement procedures, through the utilization of laser diagnostic equipment.

Various thermal coals were investigated by CANMET scientists to characterize the flame and heat transfer properties of raw, beneficiated and blended thermal coals, as well as washery rejects for use as substitute fuels in industrial process kilns currently fired with oil or gas. These tests were done in collaboration with or on behalf of coal companies or utilities and were carried out in CANMET facilities. The variables studied included ignition and combustion stability, burnout and heat flux rates.



Pilot scale calorimetric tunnel furnace used for basic combustion research

CANMET is continuing its studies on the expanded use of low-grade coal in electrical utility boilers. The overall objectives of this project are to evaluate the combustion, slagging and fouling properties of coals from newly opened deposits for use in power utility boilers; and to minimize emissions from conventional coal combustion through control of flame properties, chemical additives, burner design, flue gas cleanup and atmospheric dispersion.



Pilot scale research boiler used in low grade combustion studies

CANMET has made a commitment to develop non-intrusive diagnostic techniques for flame environments. These techniques will be used to measure the

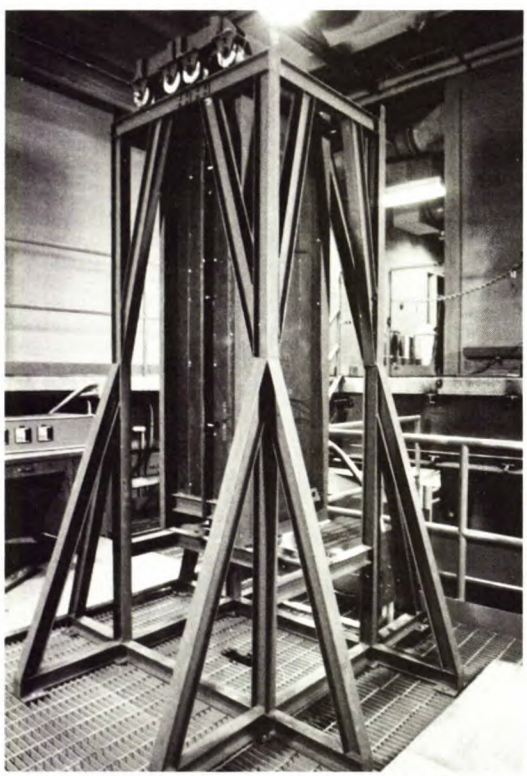
temperature, composition and velocity of gases and the particle size distribution in a flame. Flow utilization techniques will be developed at the same time. The need to develop these non-intrusive techniques arises from the requirement to make measurements in constricted geometries. Furthermore, the extent to which the existing probes disturb the velocity and temperature yields and the availability of in situ technology, have encouraged the adoption of this technology by CANMET.

Because of the variability of the burning characteristics of coals - even of a coal taken from different locations in the same mine - a quick and simple method for the evaluation of coal reactivity would be useful. To this end, a controlled mixing combustion history furnace (CMCHF) was designed and installed at the combustion laboratory. Some of the volatilization and combustion mechanisms of coal can also be studied in this furnace. By allowing optical access to the interior of the ceramic tube, the laser probes can be used to study the flow characteristics and species concentration on a much smaller scale than is permitted with the existing cooled probe. By taking these optical measurements at various axial locations, a comparison can be drawn between the important reactions early in combustion and those at a later stage. Furthermore, by using flow visualization techniques, coal volatilization can be studied first hand. The furnace was installed and some preliminary start-up tests were run.

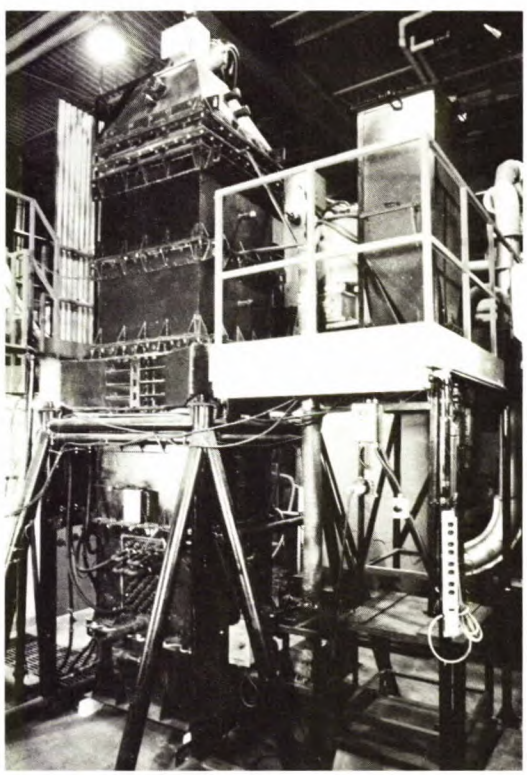
Eastern Canada is the only region of the country where electricity is generated from oil and it is the region which is most dependent on imported oil. In addition, natural gas is not yet generally available and local coal tends to be high in ash and sulphur and in need of upgrading. This scenario has prompted Energy, Mines and Resources Canada, in collaboration with the New Brunswick Electric Power Commission (NBEPC) and the Cape Breton Development Corporation (CBDC) to undertake a major collaborative initiative in Eastern Canada under the NEP to develop coal-liquid mixture technology for utility boiler application.

The perceived benefits of fluidized bed combustion (FBC) technology are:

- The ability to burn high-sulphur coal with convenient control of SO_2 emissions by means of limestone injection. This is important when using Eastern Canadian coals;
- The ability to burn fuels, having combinations of high moisture content, high ash content and low reactivity such as coal washery rejects and coke byproducts from oil sands extraction and wood waste;
- An economic means of burning solid fuels cleanly in small as well as in large installations, thus providing a means for utilizing coal or wood waste to replace oil and natural gas in the commercial and industrial markets;
- A potential means to achieve more efficient coal-to-electricity cycles, through the utilization of a combined cycle, based on pressurized FBC.



Entrained flow furnace used for coal reactivity studies



CANMET Pilot Plant Fluidized Bed Combustor

Designers of full-scale FBC equipment have a continuing requirement for detailed information which can often be generated in pilot-scale equipment. To meet the need, CANMET began in 1975 to develop

pilot-scale FBC research facilities, with the objective of building a bank of performance data for various Canadian fuels and sulphur sorbents. CANMET uses contracting-out to accomplish a significant amount of R & D, as a supplement to the in-house program and with the same general objective. One such contract was awarded to Queen's University in 1978 and subsequently extended. This extension specifies an R & D program to evaluate the performance of various mixtures of coal and limestone and to clarify factors affecting the efficiency of sorbent utilization. This work will complement the database being built by the CANMET in-house program.

Atmsopheric Recirculating Fluidized Bed Combustion (ARFBC) is a second generation FBC technology with applications including the combustion of unreactive and high sulphur fuels, whereby rejects, wood wastes and solid fuels with a high percentage of fines can be utilized. After reviewing the potential for this technology, CANMET decided to complement its present bubbling mode FBC facilities and awarded a contract for a conceptual design of an ARFBC to Moneco Ltd. The conceptual design was completed in September 1982.

The Summerside Heating Plant is a demonstration project co-sponsored by EMR and DND, by which the first atmospheric FBC boilers in Canada are being installed in a heating plant addition at CFB Summerside in Prince Edward Island. The design fuels are a Cape Breton coal containing 5% sulphur and wood chips. The wood chips are a supplementary fuel, which can be co-fired with coal on a demonstration basis, at a fuel rate of up to 30% of the total heat input. A detailed design and firm price proposal was completed in early 1981 when two companies submitted tenders for construction of the plant addition. This turnkey plant contains two FBC boilers rated at 18 000 kg/h each, fuel storage and handling equipment, and other auxiliaries. Foster Wheeler Ltd. was awarded the contract in February 1981. Because of technical problems encountered during construction the original schedule was not met. Foster Wheeler Ltd. intends to complete the combustion trials and instrument calibration before the end of 1982/83 heating season after which the efficiency tests involving CANMET and Environment Canada will be performed.

In 1979, EMR's Energy Policy Sector - Coal and the Nova Scotia Power Commission (NSPC) initiated a project aimed at demonstrating an AFBC boiler for generating electricity from high-sulphur coal. CANMET serves the Policy Sector, now the Coal Branch, Conservation and Non-Petroleum Sector, as technical adviser on the project. Studies by a consultant identified NSPC's Point Tupper plant as a suitable location for a demonstration. A detailed risk analysis identified the potential for high-temperature corrosion of superheater tubes immersed in the bed as the most technological obstacle. To reduce the risk factor a joint project has been initiated under which selected alloys will be tested at temperatures up to 650°C, for periods up to 10 000 h. CANMET has provided substantial consultation in the design of the combustor.

Although pressurized FBC is not nearly as close to commercial application as atmospheric FBC, it has a greater potential for increased fuel efficiency and reduced emissions, particularly when applied to combined power generation cycles. At present, the only Canadian activity in PFBC is being carried out by B.C. Hydro which, with previous financial support from EMR, has been working towards a 70 MW demonstration project.

Work continued in 1982 on a bench scale fluidized bed apparatus, using synthetic flue gas, to investigate the sulphation behaviour of limestones and dolomites. Limestones from Nova Scotia, New Brunswick, Alberta and some foreign samples from Norway, Sweden and Japan were tested. A complete program was developed to graph and analyze test data and to give the mathematical equation of the sulphation curve. This equation was used in a model to predict limestone performance in large scale fluidized bed units.

In view of the wide range of coals available in Canada for which little or no information relative to performance in FBC systems is available, a means of rapid ranking in terms of thin relative reactivity is highly desirable. To this end CANMET has undertaken a project to develop a bench-scale FB combustor and a procedure whereby many coals can be quickly and economically evaluated with respect to their suitability for use in FBC systems. This will be complementary to the present pilot-scale database program which provides more detailed information, but at a slower rate and a higher cost.

CO-PROCESSING OF COAL WITH BITUMEN, HEAVY OILS AND RESIDUALS

This project is concerned with the fundamental research effort at the Energy Research Laboratories (ERL) in the simultaneous processing of coal and bitumen or heavy oils. This co-processing concept has generated a large amount of national interest. In Eastern Canada, the combination of Nova Scotia coals with conventional crude residuals or imported heavy oils has potential for large scale applications. In Western Canada, the low rank plains coals of Alberta or Saskatchewan lignites are prime feedstocks in combination with tar sand bitumens or heavy oils. Much greater liquid yields are anticipated in comparison to a normal type of direct coal liquefaction process, due to elimination of the large recycle stream.

In the current fiscal year, an increase in both personnel and capital was allocated to the program with most being utilized in the Coal Liquefaction Section. New projects on short contact time co-processing and liquid and solid product characterization were begun. The examination of operating variables using the bench-scale continuous-flow unit was continued and initial results warrant further experimental testing.

The construction of a short contact time batch co-processing unit was completed. The micro-autoclave was constructed in support of the continuous unit presently in operation and will be used to carry out short time co-processing studies. Research programs using this batch facility are

underway to establish the hydrogen donor ability of pitches and coal solubilization under co-processing conditions.

Work was done under contract to determine the possibility of using FTIR for quantitative analyses of coal in the presence of coke. The preliminary results using FTIR indicated that there are substantial differences between FTIR of altered coal and coke which would allow quantitative analyses of each component.

In the characterization of the solids, the major concern is the determination of the proportions derived from coal and from bitumen to establish the degree of coal liquefaction. A method to characterize the coal residue was developed by correlation of the H/C ratio of different standards with samples.

MATERIALS FOR COAL HANDLING AND UTILIZATION

On line with the federal government "off oil" energy policy, the NSPC under the instruction of their provincial government is to establish a full-scale coal-fired fluidized bed combustion facility for electricity generation. An assessment of the technical problems in such an undertaking revealed that one of the greatest concerns is the capability of in-bed heat exchanger materials to survive 15-25 years of service. During 1982/83 CANMET expressed its views on this topic, including materials-testing requirements for the positioning of samples in a fluidized bed combustor, exposure duration and temperature ranges, design of specimen probes and the monitoring of oxygen potential in the bed. In addition, an in-house research element directed toward an understanding of the mechanism of corrosion of boiler materials is underway.

SLURRY TRANSPORT

The potential for transportation of coal through pipelines appears favourable where coal is mixed with approximately an equal mass of water. Economic studies estimated that the cost of pipeline transportation could be half that of rail transport by the year 2000. The R & D work on coal slurry pipelining is carried out jointly by Transport Canada, Saskatchewan Research Council and CANMET. A steering committee reviews and evaluates work progress. The main activities in 1982/83 were:

- A slurry pipeline test was carried out on a metallurgical coal. Carbonization results before and after pipelining indicate no change in the coking quality, although previous tests showed some deterioration in coking quality;
- A link was established between ΔP index and the amount of minus 0.6-mm fines generated during the pipeline tests of coarse coal. The relationship is linear and can be used in predicting size degradation during pipelining. Results also indicated that coals with higher ΔP indices showed greater amounts of minus 0.1-mm material being produced during pipelining;
- A Canadian-German coal slurry pipeline workshop was held in Edmonton. Several papers were presented and discussions included the possibility of cooperation and exchange of technical information;
- A work statement was established for a future contract on dense coal slurry transportation with CANMET acting as the scientific authority on the contract.

EQUIPMENT SAFETY CERTIFICATION

The Canadian Explosive Atmospheres Laboratory (CEAL) continued to provide cost recovery services to industry including certification and testing of: electrical equipment, diesel-powered equipment, fire-resistant and anti-static materials, gas detection systems, fire-resistant hydraulic fluids; and, in general, cost recovery research and testing where CEAL is the sole Canadian facility; and to supplement the certification service for equipment and materials used in underground Canadian coal mines, by increased safety of activities in explosive atmospheres, by carrying out related equipment development, and by participation in standards-writing activities.

A total of seventy-nine certificates were issued, however, these do not include non-certification contract testing figures related to work on behalf of other certification and governmental agencies, and private industry applicants. The overall demand for certification and testing work by CEAL has escalated to the point where procedural changes are being implemented to obviate any backlog of certification or test work.

CEAL is developing and coordinating standards for underground flameproof diesel powered equipment, fire-resistant conveyer belting and fire-resistant hydraulic fluids, which, when finalized, will be published as National Standards by the CSA. Work also continues on a number of CSA standards related to hazardous locations.

A training course was given for representatives of the Canadian General Electric Company related to flameproof electric motors for use in coal mines.

NUCLEAR TECHNOLOGY

Work undertaken by the Mining Research Laboratories (MRL) of CANMET includes the assessment and potential production capabilities of uranium ore reserves, as well as the technology for the disposal of high level nuclear waste material by deep burial underground.

URANIUM RESERVES AND PRODUCTION

This ongoing program began in 1974. MRL continued to provide a comprehensive internal annual report to the Uranium Resource Appraisal Group (URAG) EMR, based on a continuing assessment of measured and indicated uranium reserves and associated inferred resources in Canada. It also establishes mineability and productive capability of existing and projected Canadian uranium producers, as well

as the viability of potential new operations, by means of engineering and economic evaluations. An additional role involves improving existing methodologies for assessing uranium reserves and resources and developing new and more sophisticated methods. These are designed to effectively utilize the large quantities of primary data made available to the MRL Mine Evaluation Group on all economic uranium deposits in Canada.

Based on a continuation of special studies of Elliot Lake uranium reserves and resources, an interim assessment report on the north limb of the Elliot Lake Syncline was completed and distributed in May 1982. Its objective was to determine reserves and resources for a wide range of economic parameters.

The remainder of 1982 was required to complete a detailed study of the north limb, using the newly developed global multiple cut-off methodology. The final report was completed in December 1982 and distributed in the first quarter of 1983.

In parallel with the special project evaluating Elliot Lake deposits, interim assessments were being made for all significant uranium deposits in Canada at the end of 1981. Such assessment results were compiled in a regular annual report, which was completed and distributed to EMR URAG members in January 1983.

The next URAG assessment exercise to establish reserves, resources and production details, as of 1982, was commenced in January 1983. This is scheduled for submission to URAG in June 1983.

For improved technical mineability and economic viability evaluations, studies of current mining technologies, mine equipment and methods are pursued, in conjunction with the development of mining cost databases and economic mine evaluation methodologies.

UNDERGROUND NUCLEAR WASTE REPOSITORY

As part of the Fuel Cycle Waste Management Program (FCWMP), EMR is carrying out a geotechnical program with geological, geophysical and geomechanics components to investigate the possibility of disposal of high level nuclear reactor waste in the plutonic structure of the Canadian Shield. CANMET is participating in EMR's geotechnical program in the areas of rock mechanics and rock properties with respect to research areas located in typical plutonic structure and in the planned underground research laboratory located on the Lac du Bonnet batholith near Pinawa, Manitoba. Earlier research by CANMET on sealing technology for nuclear waste disposal was completed with review reports on the subject and a report outlining a research program on sealing technology to meet the needs of the FCWMP.

CANMET is using access to research area rock formations through surface and core samples to develop the field and laboratory techniques to assess the concept of high level waste disposal in plutons in terms of rock matrix thermal, mechanical and ion transport properties and rock mass joint properties. At the same time data are being gathered on a generic basis for future use by Atomic Energy of Canada Limited (AECL) in its geosphere modelling studies. Rock property research on underground research laboratory (URL) formations is directed at serving experimental design requirements related to the use of the facility.

In 1982/83, the experimental phase of the more fundamental property studies of three research areas was completed at Chalk River and Atikokan, Ontario and Pinawa, Manitoba; the analytic phase will be completed by the end of 1983. A candidate model was selected to describe joint mechanical/hydraulic properties and is being developed under contract. It will initially be applied and evaluated at the underground research laboratory site on the Lac du Bonnet batholith before use elsewhere.

Also in 1982/83 triaxial thermal/mechanical studies were continued on Pinawa research area and URL rock formations. The studies were expanded to include special investigations on the functional dependence of thermal mechanical properties on temperature, pressure and time to meet AECL modellers' requirements.

High temperature and pressure permeability were modified so that thermal expansion studies on rock formation can be carried out under confined conditions. New temperature and pressure control units were designed and constructed to provide more precise control over specimen test conditions. A new multi-purpose temperature and pressure unit was added to existing equipment which will permit fracture permeability studies at elevated temperatures.

In 1983/84 the basic studies and analysis of the above mentioned three research areas will be completed with the exception of joint property studies. Similar studies on East Bull Lake should be completed by 1985/86. Major effort in terms of laboratory and field studies over the next three years will be concentrated on the special requirements of the URL. It is still planned to proceed with a field heater study at the URL.

URANIUM EXTRACTION CONVENTIONAL TECHNOLOGY

Ongoing research continued to aim at maximizing the recovery of uranium from conventional, low-grade and complex ores; to recover all valuable byproducts such as thorium and rare earths; and to provide process technology with minimum environmental impact.

Pressure leaching studies using Elliot Lake type ore were initiated last year and produced very promising results in simultaneously tackling the problem of high uranium and radium dissolution.

Specific projects undertaken in the review period were rejuvenation of a silica "poisoned" anion exchanger in uranium processing; mixing characteristics and mass transfer optimization in sol-

vent extraction; the influence of the physical parameters as well as the effect of humic acid on crud in solvent extraction circuits; optimization of precipitation of uranium from purified leach solutions; development of a novel precipitation process for the hydrolyses of a high purity uranium product from acidic strip to eluate solutions; infrared studies on precipitation products; the recovery of thorium from Elliot Lake uranium barren solutions; development of analytical methods for the rapid determination of the individual rare-earth elements and thorium in ores; and application of high-performance liquid chromatography to the separation and determination of small amounts of rare-earth elements.

URANIUM EXTRACTION ALTERNATIVE TECHNOLOGY

CANMET continued to pursue the research program to effect minimum environmental impact and maximize resource conservation by developing economic alternatives to conventional sulphuric acid technology such that the recovery of uranium, thorium and rare earths will be increased, radionuclides solubilized for subsequent isolation and disposal, and minimum sulphides disposed in the tailings.

Hydrochloric acid leach tests were conducted on the preconcentrates and small pilot-scale leaching of Elliot Lake uranium ore and its preconcentrates was conducted to verify the optimum leach conditions obtained from bench-scale tests, to obtain leach liquor for solution treatment, and to select the most suitable process flowsheet for the uranium ore.

Two-stage hydrochloric acid leaching of Key Lake uranium ore provided satisfactorily high extraction of uranium, nickel, arsenic and radium-226, and a caustic roast-aqueous leach procedure was employed on a complex uranium ore from Saskatchewan to extract arsenic separately from uranium. Preliminary tests removed approximately 80% of the arsenic while leaving the uranium essentially unreacted. Tests are underway to extract uranium and radium-226 from the low-arsenic residue by HCl leaching. Follow-up investigations included continuous caustic roasting in a twin-screw kiln and methods to improve the arsenic extraction.

A solvent extraction process was developed to treat the uranium chloride solution resulting from the HCl leaching of uranium ores. The process has been run successfully on a continuous circuit and a technical paper on the process was presented at the International Solvent Extraction Conference in 1983.

Screening of many possible extractants for thorium and rare earths separation from chloride solution is continuing. The thorium circuit will be tested during 1983/84. Much more work is required on the rare earth separation to produce pure products.

The solid residue discharged from current uranium milling operations retains the bulk of the radium-226. With the acidic chloride leaching technology, the radium-226 is practically all dissolved and investigations are in progress to remove this from the acidic chloride leach liquors by precipitation with conventional barium chloride.

An optical emission spectrochemical method was developed for the determination of 20 to 500 µg/g of beryllium in residues obtained from the leaching of pyrochlore.

RENEWABLES TECHNOLOGY

Because knowledge gaps exist in the performance of newer large wood refuse-fired boilers, a major field test program has been initiated with the Canadian Boiler Society, as part of the Canadian Government's ENFOR program. This program was established in 1978 to promote substitution to forest biomass for non-renewable fuels. Detailed experimental programs will be carried out on bark-fired and refuse-fired boilers at five selected Canadian pulp and paper mills. The major objectives will be to improve design and operation criteria to optimize efficiency while minimizing environmental impact. Results will be available to designers and operators of similar units to carry out effective hardware and operating condition changes to achieve significant fuel savings.

Renewables, particularly wood, are projected to provide 6% of Canada's total energy budget by 1990. One of the major areas where wood can contribute significantly is in residential heating. To prevent this new energy from seriously impinging on the environment, consideration must be given to the flue gas emissions from residential wood combustion. To ensure the wide-spread acceptability of wood-fired appliances, these emission levels must be such as not to dramatically influence ambient air quality levels. This is particularly true if wood is to be used as a heating fuel in populated areas. The eligibility of wood-fired appliances for rebates under the Canadian Oil Substitution Program is making it very attractive for many people to convert to systems using potentially renewable fuel. Scientists at CANMET's Combustion and Carbonization Laboratory are applying their expertise in solid fuel to study the technology of wood combustion.

Controlled combustion wood stoves have been shown to have a significant degree of incompleteness of combustion and corresponding high emissions. CANMET is continuing to address this problem as well as other problems associated with the burning of wood.

MATERIALS FOR ADVANCED ENERGY CONVERSION SYSTEMS

The purpose for this project is to develop solutions to a series of materials problems identified as potential inhibiting factors in high temperature energy systems. In the second year of this NEP project, two in-house support research elements were initiated to supplement the external R & D contracts undertaken during fiscal year 1981/82.

The first of these two in-house research projects addresses potential problems in the area of high

temperature corrosion. The work includes characterization of Nova Scotia limestones and their influence on alloy corrosion in fluidized-bed combustion of coal. Development of alloys that will resist high temperature oxidation under cyclic conditions will also be investigated.

The second in-house project is the study of sulphate corrosion of metals and the formation of pseudo-scale deposit. The thermoanalyzer for use on this project was acquired in late 1982 and has just become operational.

MINERAL TECHNOLOGY ACTIVITY

This activity encompasses EMR's responsibility for performing, funding and coordinating mineral research and development in Canada as well as acquiring foreign technology and transferring it to industry. CANMET is a major contributor to this function as it represents the department's centre for research and development related to mining and mineral processing, and the conservation and utilization of mineral-based materials.

MINING TECHNOLOGY

This subactivity pursues and furthers the advance of technology necessary for increasing the efficiency and safety of underground and open pit mines.

DIAMOND DRILLING

CANMET continued to provide technological support to the diamond-drilling industry and thus, indirectly, to Canadian resource development.

Major research needs of the industry have been identified for several years and include the development of hardware items, such as a carrier for improved drill mobility, data logging instrumentation for improved drillhole monitoring and a waterline-heater for improved drilling efficiencies, as well as studies involving the problem of hole-deviation and that of excessive noise at the drill sites. During 1982/83, work was again concentrated on the latter problem. A contract was awarded to Noranda Research Centre of Pointe-Claire, P.Q., for continued study of the technical and economic aspects of noise suppression on diamond drilling equipment. This contract called for: upgrading the listing of currently available diamond drilling (DD) equipment; identification of noise suppression work already being undertaken by the drilling industry; establishment of an order of preference for retrofitting existing DD equipment; recommendations for totally achieving noise attenuation to meet the legal limits; and the production of prototype designs for enclosing diesel power units used with DD equipment.

STABILITY IN DEEP HARD ROCK MINES

This project has been ongoing for several years and continues to focus on investigating interrelated mining technologies that are capable of improving safety and economics of mining hardrock orebodies at depths in excess of 1000 m. On the advice of NACMMR sub-committee on mining, research is being concentrated on the rock mechanics aspects of deep mining.

Mine closures during the severe recessionary period in 1982 precluded continuation of significant portions of the deep mining project. Closure of the Onaping mine of Falconbridge Ltd. delayed the mining trial of a blasthole stoping method at 1300 m. However, all development openings, support systems, instrumentation and engineering studies were completed and are the subject of a contract report. A cooperative study with INCO Metals Co. on a blasthole stoping block at the Copper Cliff South mines was also delayed by mine shutdowns between May 1982 and April 1983. However most of the planned numerical modelling, laboratory and field geotechnical investigations were completed.

MODEL DEVELOPMENT

Computer modelling to develop and upgrade numerical procedures for stress analysis of mine structures and other mining-oriented applications, together with field trials in various Canadian mines, continued throughout the period under review.

The cooperative research project initiated in 1981 between INCO and the Mining Research Laboratories (MRL) was completed. One of the primary objectives was to examine, develop and assess the predictive capabilities of numerical modelling applied to ground behaviour in the case of blasthole open stoping operations. As a result of this study, a number of enhancements were incorporated into a displacement discontinuity stress analysis program and this program has been used sucessfully in modelling INCO's Copper Cliff South mine using measured field stresses and in situ rock strength. Preliminary results indicate that the comparison between the measured and predicted pillar stresses are in reasonably good agreement and therefore this technique should provide mining engineers with an alternative means of predicting pillar stresses for open stoping operations, provided the orebody is relatively thin, uniformly dipping and free from major weakness planes.

Another major effort during the year was the re-evaluation of MRL's computer requirements for numerical model development and other associated mining applications. For years software packages had been developed at MRL for a large mainframe computer, however, with the resulting installation of a VAX 11/750 mini-computer unit, conversions of some of these packages for use on mini-computer are now in progress. As a consequence, the mining engineering community involved in operations will have better access to MRL's advanced structural analysis routines and programs.

REGIONAL STABILITY

Research and development work continued to provide operators with the technical ability to assess regional stability in existing room-and-pillar recovery operations and to effectively plan new mine layouts, particularly those at greater depths.

After a lapse of 20 years rockbursts again occurred in the Elliot Lake mines. CANMET scientists assisted Rio Algom Ltd. Quirke Mine in the installation of a microseismic monitoring system which is used to locate the sources of the rockbursts. Computer programs were developed so that rockburst locations could be immediately viewed or printed on digitized mine plans. Convergence stations were installed around the rockburst affected area to measure roof/floor closure. Present research is aimed at correlating seismic activity, convergence and energy. Studies were also done on the effect of rockbursts on support systems (rock bolts, split sets and grouted rebar). It was found that repeated impact loading was causing the rock bolts to fail in fatigue. Haulage drifts reinforced with grouted rebar, split sets and wire mesh survived rockbursts in the drift walls with little damage.

Also at Elliot Lake, numerical techniques were used to model the widening of a shaft especially where a steeply dipping weak dyke entered the shaft. Zones of potential failure in the shaft walls were identified which assisted in design of the support system. When two small rockbursts occurred in the shaft the shape of one wall was modified based on the model results.

Research was initiated into stability in shallow mines and especially where there was a potential problem with surface crown pillars. The interaction between cemented rockfill and stope walls is being investigated both in situ and by laboratory tests.

LOCAL STABILITY

CANMET, Denison Mines Ltd. and Rio Algom Ltd. were involved in a joint study to evaluate instrumentation of roof falls. Two test stopes at Denison and Quirke Mines were instrumented with extensometers, convergence meters, rock bolt load cells, rock permeability and microseismic devices. The heads of the roof bolts were sequentially blasted off with especially designed shaped charges to try and initiate a roof collapse. Unfortunately in both test stopes removing the roof bolt support did not result in a roof collapse. However techniques for measuring open fractures in the roof were developed and in particular the rock permeability measurements using a vacuum were able to detect very small fractures 0.1 mm wide.

MATERIAL PROPERTIES AND SUPPORT SYSTEMS

An increasing portion of Canadian underground mining operations will take place under high stress, deep mining conditions where the post-failure strength and deformational properties of the rock must be taken into design consideration. The effectiveness and limitations of present underground support systems are currently being studied and established. Further investigations will have to be undertaken for the development of new methods of support. This will require close cooperation with industry.

The development of test procedures that can be used by industry for the determination of residual strength and deformation properties of brittle rocks was completed using preliminary laboratory test equipment. The design and test trials of this equipment, based on the double-shear principle were also completed. A prototype version is now being manufactured in-house. Development of the multi-shear equipment was started.

The study on current practices of design, installation and stability evaluation of rock bolting in underground mines was completed. Based on the results of this study, a parametric analysis is being conducted to define the interaction between the rock mass properties, the geometry of underground openings, and the field stresses, with respect to the comparable stability of unsupported and bolted underground openings.

A test program, to determine the strength and deformation properties of rock strata that significantly influence the roadway stability of Devco's Prince Mine in Nova Scotia, was established and the program is now being executed. The cooperative study in INCO's Copper Cliff south mine at Sudbury had to be temporarily postponed due to the prolonged mine closing.

HEALTH AND SAFETY IN MINING

Rigorous controls on the working environment and on liquid and gaseous effluents from mining and metallurgical operations have imposed serious constraints on industry. Because research funds for these environmentally related issues seldom provide a return on investment, industry tends to minimize such expenditures and to develop short-term remedies. Long-term technology development to ensure proper resolution of environment, health and safety issues is therefore dependent on government initiatives. CANMET, in cooperation with other federal and provincial agencies, is a major contributor to these developments.

RESPIRABLE DUST

Dust is a significant factor affecting the comfort and long-term health of the workforce in all mining operations. Not only can excessive amounts of air-laden dust be a "nuisance" problem in the confined areas of a mine, dust from certain minerals can lead to lung diseases such as silicosis, asbestosis and also malignancies, such as lung cancer. Lubricating oil mists and diesel exhaust carry noxious dust and gases and in uranium mines all dust particles can carry solid radon daughters into the lungs and stomach where the alpha and beta radiation emitted internally may give rise to malignancies.

Instrumentation for determining individual exposure to respirable dust has long been in use.

However, there is a need to develop measurement techniques and programs, particularly involving continuous measurement, to predict personal exposure when there are large statistical fluctuations in concentrations, size distribution and dust composition. These and other factors must be known to determine effective control measures and to guide and interpret epidemiological studies, and this work requires the development of an extensive database through sampling in mines in cooperation with radiation and diesel emission scientists.

Control measures depend on improving breakage and rock handling techniques to minimize dispersion of dust into the air, filtration of airborne dust, wetting techniques, and optimizing mine layout and ventilation. Ultimately, optimum control requires appropriate dust suppression and control methods to be built directly into mine equipment.

The combined occupational, ambient and medical study in the Labrador West Iron mines has been completed and the report published by the Newfoundland and Labrador Department of Mines and Energy.

A contract has been let for the commercial production of a dust sensor suitable for use as a continuous monitor and this is approaching its final stages. It is expected that further development of this unit will facilitate the measurement of mineral and diesel exhaust particulates. Work is starting on the development of asbestos dust cloud generation techniques and associated asbestos measurement equipment. Development of X-ray diffraction techniques for free silica assessment in mine air is complete and development of infrared techniques is in progress with the objective of finalizing a suitable method for immediate use by mines.

S. Hardcastle – developing IBM-PC computer programs for dust program

Assistance continues to be given to industries and universities in maintaining gravimetric sampling programs (Rio Algom, Denison, Quebec, Cartier and Eldorado) and in developing capability of X-ray diffraction (XRD) analysis.

The possibility of determining quartz quantitatively in mine dust using infrared spectroscopy to examine deposits of dust on filter membranes is under continuing investigation.

RADIATION

Research and development continued to concentrate on the development of monitoring instrumentation; radiation measurement of the in-mine environment and personal exposures; and health impact studies.

A contract was awarded to EG & G Canada for the development of a passive Radiation Data Acquisition System (RDAS) capable of monitoring underground and surface environments for alpha, beta and gamma radiation. The system is particularly suitable for gamma-logging in underground situations and at tailings sites.

A contract was awarded to Alpha-NUCLEAR Ltd. for the development of a personal alpha dosimeter of the passive type using diffused-junction (DJ) detector technology. Phase 1 is now complete and the prototype was tested in the laboratory with satisfactory results.

An underground technical evaluation of a modified version of the Alpha-NUCLEAR personal alpha dosimeter was initiated at Denison Mines Ltd. and is being conducted in conjunction with Terradex track-etch detectors for personal dosimetry. A long-term research program aimed at investigating seasonal changes and long-term trends in the emanation of radon gas from tailings piles is being carried out at the Stanrock tailings site (Denison Mines Ltd., Elliot Lake) by the staff of the Elliot Lake Laboratory.

Three Working Groups were established to address the technical questions arising from the establishment of practical reference standards for calibration purposes in Canada for external radiation, airborne contaminants and bioassay.

A. Frattini and M. Grenier measuring radioactivity

DIESEL EMISSIONS CONTROL

Controlling toxic diesel emissions is of paramount importance to the betterment of the health and safety of workers in underground mines. Research and development work continued to concentrate on providing a diesel machinery emissions certification service that would be applicable to all underground mines and other confined locations, and also to effect the transfer of diesel emission reduction technology to industry by 1985/86 by demonstrating the improvement of the underground environment as a result of using the reduced emissions prototype machine.

The mining industry has shown increasing interest in both the Air Quality Index (AQI) and the development of diesel exhaust emissions reduction devices, and it is now being recognized that the AQI is a powerful economic analysis tool as it provides the ability to widen the choice of engines and the incentive to apply emissions reduction systems on a cost/benefit basis in regulatory jurisdictions where ventilation requirements are regulated to be proportional to the concentration of the toxic emissions (pollution).

The dawning awareness of the importance of AQI is accelerating R & D outside the CANMET programs. However, there is still need for further R & D work within the umbrella of the USBM/CANMET/MOL collaborative agreement, and in preparation for the formal environmental impact demonstration scheduled in 1985/86.

A project was undertaken to develop sensors and monitoring systems to provide a comprehensive pollutant measuring system compatible with the application of the Air Quality Index (AQI formerly HEI-Health Effects Index), and establish it as a comprehensive environmental toxicity assessment criterion.

Development of diesel exhaust emissions reduction strategies has been underway for five years and three types are approaching the demonstration stage: water-in-oil diesel fuel emulsification, venturi-type water scrubbing systems and total exhaust filters.

CANMET acquired a CONSPEC continuous monitoring system that is currently being evaluated particularly from the point of view of sensor performance. In addition a "Portable Analysis System" was purchased during 1982/83. Its first use will be underground at INCO to evaluate total filter life tests in January 1984. Further, a B.C. hard rock company is interested in collaborating on a "spot monitoring project" to evaluate the AQI in dieselized headings.

Under the auspices of the collaborative agreement five health-related contracts were pursued in 1982/83.

Progress was made in the difficult task of separating and identifying the acid mists that emanate from diesel fuel sources and which collect on particulate samples used for proper evaluation of the impact of catalysts. One surprising finding is that ammonia from blasting seriously complicates this acid quantifying problem. This acid/soot discrimination work is continuing.

Underground levels of polynuclear aromatic hydrocarbons (some carcinogens) for a number of dieselized mines have been compared and this work will provide the basis for an assessment of the health risk to underground miners from this source.

Mutagen levels in dieselized mines have been shown to correlate well with laboratory dynamometer studies, and thereby provide a solid foundation to relate Canadian underground exposure to the multi-million dollar U.S. diesel health effects program.

An exhaust treatment purifier in widespread use in Canadian underground mines has been shown to produce gross (200 times) increases in mutagen levels, which may indicate greatly increased exposure to carcinogens.

Extra quality and low grade diesel fuels have been shown to have a relatively minor effect on underground carcinogens and mutagens.

Several developments in the diesel emissions reduction aspect of the work also occurred during 1982/83. Preliminary mutagenic assessment of exhaust gases indicated that filtered exhaust produces less mutagens than raw exhaust giving more encouragement to continued development of this concept. Jarvis Clark was able to deliver part of the equipment for a recirculating water system for the CANMET venturi scrubber, however, finalization of this work will have to wait until 1983/84. Successful adaptation of the Exhaust Gas Recirculation system, and the Corning exhaust filter to the Jarvis Clark JS500 Scooptram, was achieved.

As a result of three certification studies on engines in connection with the Beaver/Donkin project in Cape Breton, some depth has been added to the knowledge of emissions from engines currently used in the mining field.

NOISE AND VIBRATION

Intensive R & D in Canadian mines on personal noise protection and audiometric tests has been in progress for over ten years. Noise measurements have become a routine health and safety feature in many mines and the most up-to-date technologies and experience are being continuously transferred to Canadian mines through publications, demonstrations and in-mine assistance programs, by CANMET scientists.

The main effort is now being made in personal noise dosimetry and it is believed that therein lies the future of noise exposure index measurements in mines. The new generation of dosimeters automatically give statistical data and integrate the amplitude, distribution histograms and noise level graphs to indicate the noise exposure index measurement. The system exemplifies the important

role of the computer programs and the completion of this project in 1983/84 will represent an important, as well as historical, milestone.

Occupational exposure to vibration may reach and affect the worker at intensities which may disturb comfort, efficiency and safety or health. The effects of vibration on workers in mines and mills have not been accurately defined, due to insufficient standards. However, vibration, and particularly localized vibration of the hand due to powerful pneumatic rock drills, has been cited as a potential hazard.

Experimental work is being conducted at the University of British Columbia under contract, entitled "A study of vibration sources affecting mine workers", and so far the results obtained relating to vibration isolation indicate that further work in this area would be desirable. At present, there is an International Standards Organization (ISO) guide for evaluation of human exposure to whole-body vibration (ISO Standard 2631/1978, amended 1980), and it is anticipated that the results of the work sponsored by CANMET will enhance this ISO standard which is currently being redrafted.

ENVIRONMENTAL TECHNOLOGY

CONTROL OF URANIUM TAILINGS

Research continued to produce new operative technical methods for the practical removal or segregation of environmental pollutants from leach residues resulting from uranium mill processing. The purpose is to facilitate the discharge of these residues to a tailings area with a minimum emission of pollutants to the surrounding environment.

A study to compare the results of the preconcentration - leaching of low grade uranium ore with conventional leaching was completed in 1982.

Hydrochloric acid leach tests were conducted on the Elliot Lake uranium mill tailings, and also on the radium-contaminated soil of Scarborough, Ontario.

The study on the principal reactions involved in the natural microbial cellulose-wood-degradation process that decreases water acidity was completed and the information generated in this study is being utilized in a simulation of field conditions.

An apparatus for heavy-metal separation, using differential-sorption properties of cellulose from wood waste materials, was designed and is under construction by the Technical Services Division.

Laboratory studies of tailings, using various types of lysimeters, are being compared with on-site hydrogeochemical measurements to determine if a relation exists between laboratory and field results, and whether chemical and physical predictions of occurrences in the abandoned and current tailings are valid. In simulated weathering-time cycles, correlations are made with measurements on actual tailings.

An unknown organism, present in sawdust, reduced the concentration of radium-226 in solution. Subsequently, different species of fungi which grow on wood, were tested for their capability to remove radium from tailing solutions and experiments are in process: to quantify radium sorption, to determine contact time necessary, and to ascertain radium-226 loading of organism. Work is planned to scale up and design an apparatus for large-scale use.

DISPOSAL OF URANIUM TAILINGS

There is an urgent need to develop methods to reduce the detrimental effects of inactive tailings areas so that they will require little or no intervention by man in the future.

The minimization of the environmental impact of mine/mill wastes involves three main approaches: the removal of the more highly radioactive components of the waste for separate disposal; the reduction of the effects of weathering and other natural forces; and the stabilization of tailings by vegetative cover.

CANMET's role consists of the demonstration and evaluation of methods for treating the tailings pile surfaces, for monitoring their effectiveness, and identifying and evaluating the mechanisms which tend to promote release of environmental contaminants.

To develop and evaluate the technology of tailings disposal, work has been conducted on abandoned tailings to determine their impact on the environment. This included hydrological and hydrogeochemical investigations, contaminant migration in the surrounding aquifers (plume study) and solid phase distribution profiles of the chemical and radioisotope constituents of tailings. Further investigation is planned to study migration of contaminants in fractured bedrock.

Column leaching tests under aerobic and anaerobic conditons are being conducted on various mixtures of crushed rock taken from surface tailings areas to determine the leaching characteristics and to develop a management strategy for waste produced from surface heap leach operations.

Alternative technology of pyritic tailings disposal under deep water burial is being evaluated in laboratory scale lysimeter tests.

VEGETATIVE COVER OF TAILINGS

Surface disposal of uranium tailings can be expected to result in the long-term leaching of environmental contaminants due to the action of acid rain and other weathering processes. Presently the effect of vegetative covers and oxygen interceptors (such as saw dust and peat) are being

evaluated as a means of minimizing the impact of various radionuclide emanation rates and to improve the quality of seepage and surface runoff.

Radionuclide uptake in food chains - some revegetated tailings areas, surrounded by natural ecosystems, have become invaded by neighbouring natural species of plants and animals. The uptake of radionuclides by vegetation, vertebrates and invertebrates present on those tailings is now being investigated (blueberries, grasses, trees, grasshoppers and field mice). The aim of these investigations is to design a mathematical model of radionuclide transfer from the tailings into the food chain.

EFFLUENT TREATMENT FOR CONTAINMENT, REMOVAL OR STABILIZATION OF TOXIC WASTES

Mining and metallurgical operations throughout Canada discharge waste liquid and solid effluents containing gangue materials and metals such as arsenic, antimony, zinc and lead to tailings. These metals are present in small quantities and are not economically recoverable at present. However, they constitute an environmental problem, particularly with a change in pH from the alkaline neutralized effluent to the acid range, which can be produced by acid rain or by oxidation of sulphides in the tailings to sulphuric acid. With acid conditions, leaching of the trace metals in the tailings results in the contamination of natural watercourses. The presence of thiosalts in flotation mill effluents is also undesirable because they are a source of belated acidity in tailings ponds and water streams.

A study was made to identify the optimum conditions which would yield the minimum processing costs for the oxidation of a solution of thiosalts by molecular oxygen under conditions of elevated pressure and temperature.

NOXIOUS PYROMETALLURGICAL EMISSIONS

The emissions of noxious elements and their compounds during pyrometallurgical processing of Canadian ores and concentrates is an area of concern to federal and provincial health and environmental protection groups as well as private industry. Of particular concern are non-ferrous roasting operations which result in the production of sulphur dioxide (SO_2) as well as the emissions of arsenic and mercury, and in many cases small quantities of other toxic elements such as cadmium, selenium, tellurium and lead.

The objective of this research work was to define and characterize sources of noxious elements encountered in pyrometallurgical processes and to evaluate and, where feasible, develop methods for their control.

A report on the distribution of mercury and arsenic in the Afton smelter has been released for presentation at the AIME Annual Meeting, and a contract study is underway to evaluate the technical and economic feasibility of removing zinc and lead from electric arc furnace dusts produced during steelmaking.

SULPHUR DIOXIDE (SO_2) ABATEMENT TECHNOLOGY

CANMET is researching the technology to develop, on a laboratory scale, possible methods for capturing SO_2 in a stable form from smelter off-gases. Preliminary studies on the interaction of pyrrhotite with SO_2 were carried out using differential thermal analysis (DTA), optical microscopy, electron microprobe analysis and X-ray diffraction.

A separate series of DTA experiments was conducted to establish a decomposition pattern for pyrite with the present sample geometry. The results, which agreed with the literature, indicated a complex trend for the decomposition which occurred in the temperature range 530-700°C. Future work will include isothermal studies of the reaction kinetics.

MATERIALS DEVELOPMENT TECHNOLOGY

The general objective of this subactivity is to improve the properties of materials derived from minerals and to expand their applications. Their enhanced utilization is seen as the important final link in the chain of minerals exploitation, having high impact on the previous steps of exploration, mining, extraction, processing and production for end use. Research is underway to improve the performance of metals in corrosive and abrasive environments, improve the weldability of metals, develop methods for measuring the fracture resistance of ductile materials, for measuring residual stress levels in structures and to elucidate relationships between microstructure and physical properties in engineering alloys. Also, research is being conducted to develop concretes for aggressive environments and for specialized applications, particularly through incorporation of waste or marginal materials, and to improve the performance of refractories for the steel industry.

CORROSION MECHANISMS

Work for this project was carried out in three separate phases: localized corrosion of stainless steel, abrasion corrosion, and slow strain rate tests of carbon steel in H_2S solutions.

The localized corrosion resistance of 904 L stainless steel was determined. The work showed that this high-molybdenum stainless steel behaved as expected and the relative influence of various crevice materials was similar to that determined previously for other stainless alloys.

A test procedure that allows the relative contribution of corrosion and abrasion in aqueous media to be determined is being adapted to experiments in a high temperature autoclave so that the effect of temperature on corrosion and abrasion can be studied.

Research on the use of the slow strain rate test to study the stress-corrosion cracking of carbon steel in H_2S solutions concentrated on developing procedures to allow the experiments to be carried out at temperatures up to 100°C. In addition, a series of experiments at room temperature confirmed that the reduction in area remained less than 15% at strain rates in the range 10^{-6}, 10^{-7}.

CORROSION OF MUNICIPAL WATER PIPING

A survey of corrosion problems in Canadian soils, commissioned by CANMET, emphasized that underground corrosion failures of municipal water piping was reaching epidemic proportions. The problem is national in scope and of considerable consequence.

A contract was let to study the water pipe problem in the city of Calgary, as an example of municipal experience. An in-house interpretive history was prepared for the period 1956-1980 that analyzes 13 561 pipe failures and classifies them according to pipe size, material, time of year and failure mechanism. A detailed analysis of 10 recent failures of grey (cast) and ductile iron pipes is nearing completion.

The contractor will prepare a final report that will be distributed to the waterworks maintenance departments of Canadian cities. He will also disseminate the findings and recommendations at regional conferences across Canada.

PLASTIC FLOW, FRACTURE AND STRESS ANALYSIS

The objective of this project is to develop and maintain state-of-the-art expertise in technologies essential to fracture control in metals.

Work continued on elastic/plastic toughness testing and residual stress measurement. A novel approach to the estimation of crack length by the unloading compliance technique was developed. The validity of a hole-drilling method for measuring residual stress using a high-speed drill was established.

The practical experience gained is being applied to the development of toughness standards for materials used in tanks for the transport of dangerous goods; this project is being carried out for the Ministry of Transport.

CANMET PORTABLE X-RAY STRESS DIFFRACTOMETER

A portable X-ray diffractometer that is inherently error compensating and can determine stresses in the surface of a specimen in situ, is being developed in CANMET. This unit will measure stresses on a spot of very narrow width in a single exposure of about 50 s. The CANMET portable X-ray stress diffractometer will accurately measure stresses across a steep stress gradient and display an immediate readout.

During the past year, an experimental model diffractometer head was made by a small company in Windsor. The head is currently being integrated with the other major sub-systems of the instrument, particularly the instrument control and data processing sub-systems. The performance characteristics of the instrument will be used as a critique during the design and construction of the first commercial prototype of the instrument by the same company in Windsor. Two thirds of the cost of this development work will be funded by the Program for Industry-Laboratory Projects (PILP) with the balance of the funding being supplied by the company.

In part, the accuracy of the CANMET portable X-ray stress diffractometer depends on the manner in which signals generated by diffracted X-rays impinging on the sensors in the portable head are collected and processed. This method of data acquisition and processing is unique and an application to patent has been filed with the US Patent Office.

X-Ray Stress Diffractometer
C.M. Mitchell of the Engineering and Metal Physics Section and D.W.G. White, Manager of the Metals Development laboratory, examining an X-ray line-profile from the prototype of a new X-ray stress diffractometer which will be used to measure residual stresses in structures in the field.

MICROSTRUCTURE AND PROPERTIES OF ALLOYS

This project explores the basic mechanisms of microstructure control operative during the processing of engineering alloys, and the relationships between microstructure and properties. Recent work has concentrated on controlled-rolled-microalloyed steels.

A review of microstructures of linepipe steels, including weld heat-affected zones, was prepared. It characterized all microstructural features observed, and summarized the current understanding of the origins of the various microstructures in terms of thermomechanical history and phase transformations.

A state-of-the-art quench-deformation dilatometer was commissioned and the transformation kinetics

of a series of niobium/vanadium microalloyed steels containing undeformed (recrystallized) austenite were determined. These experiments showed little effect of concentration of microalloy elements on the transformation behaviour.

The fracture toughness of simulated coarse-grained heat-affected zones (HAZ) with different prior austenite grain sizes and lath packet size was determined by Charpy and crack opening displacement tests. A technique was developed to simulate coarse-grained HAZ structures in tensile specimens, and hence to determine the tensile properties of HAZ.

Scanning transmission electron microscopy was used to characterize the microstructure of bonded, partially acicular ferrite steels and to correlate it with cleavage fracture behaviour. By comparing STEM (secondary electron) and back scattered electron images of the same areas, several ferritic and non-ferritic phases were clearly distinguished. Cleavage crack propagation was associated with carbide precipitation at interfaces.

DEVELOPMENT OF FREE MACHINING STEELS

Phase II of this project was completed. This phase determined the effect of replacing aluminium (Al) deoxidation by calcium (Ca) deoxidation on machinability. Burlington Steel supplied two 60-t test melts and it was established that the machinability of the Ca-modified melt doubled due to a reduction in abrasive alumina oxide inclusions. It is predicted that machinability may be further increased by reducing silica rich oxide inclusions.

Two steel companies have offered to supply steel for the purpose of testing Ca-modification in two commercial grades used in the oil and automotive industries.

Phase III work envisages a further improvement in the Burlington steel and Ca-modification of the Atlas steel by quantitative characterization of their inclusions and correlation with machinability and property data.

ZINC-BASE FOUNDRY ALLOYS

A project was initiated to study the foundry characteristics and microstructural modification of zinc-aluminum alloys and an industrial consulting committee selected from zinc producers and foundries has been formed to monitor the progress of this work.

Melting and casting practices for various aluminium (Al) alloys have been established using fluidity test patterns, simple plate castings and big blocks. Attention has been focused on the industrially important zinc-27 aluminium (Zn-27 Al) alloy to eliminate shrinkage defects on the drag surface. Variation in gating ratio and addition of titanium to the melt appear to improve the casting quality.

Microstructures of as-cast and heat-treated Zn-Al alloys have been characterized using optical and scanning electron microscopy. Titanium (Ti) has been added to modify the microstructures of the various Al alloys. Mechanical properties of the unmodified and Ti-modified alloys are being determined to study the effect of microstructure and chemistry on ductility. Similar studies will be done by adding other metallic elements.

DEVELOPMENT OF INSTRUMENTATION AND TECHNIQUES

Several pieces of equipment were installed this year: a Leybold-Heraeus automatic analyzer for hydrogen (H2A 2002) was commissioned for the analysis of hydrogen in metals on a routine basis.

Work on the anodic dissolution of steel and the reaction of the liberated hydrogen with a nitroxyl free radical is in progress. Studies involving thin layer chromatography, polarography and electron spin resonance spectroscopy of the free radical were used in establishing reaction patterns of hydrogen with the free radical.

The new Philips EM 400T transmission/scanning transmission electron microscope was commissioned and calibration is complete. As well as being capable of conventional transmission microscopy with an ultimate resolution of 0.2 nm, the new instrument makes possible chemical and crystallographic characterization on a scale of the order of 10 nm.

The new Cambridge 250 mkII scanning electron microscope is working to specifications with resolution of the order of 5 nm. The turbo-molecular pump can readily achieve chamber pressures of 533×10^{-7} Pa. The quality of the photomicrographs obtained is excellent and many projects are able to take advantage of this new facility.

COST RECOVERY IN MINERAL TECHNOLOGY DEVELOPMENT

Over twenty independent metallurgical investigations were carried out in the period under review for a variety of government agencies and for the private sector, employing PMRL's extensive mechanical testing facilities and electron-optical instrumentation. The Canadian Transport Commission placed heavy demands on PMRL metallurgical expertise in train derailment investigations.

TRANSFER OF MATERIALS DEVELOPMENT TECHNOLOGY TO INDUSTRY

The purpose of this project is to provide visibility for mature or developed technology in the Materials Development subactivity, however, there has been some delay in the implementation of this project.

The only project element in this category at present relates to attempts to develop improved abrasion resistant plate steels by controlled rolling and direct quenching. Abrasion tests indicated

that the relative abrasion resistance was governed by hardness only. Direct quenching conferred no advantage in abrasion resistance, and the experimental steels exhibited inferior transverse impact properties.

PERFORMANCE AND DURABILITY OF CONCRETE

CANMET researchers continued to develop data on mechanical and elastic properties and durability of portland cement, and portland cement concrete, manufactured from less energy intensive materials, for applications in Canadian marine environments and in the acidic waters of northern Canada; and to develop a database on portland cement type concretes for industrial applications involving exposure to sustained temperatures from 75-450°C for periods up to six months.

To conserve resources and energy it is imperative that less costly and less energy intensive materials with superior durability characteristics be used in the production of portland cement and portland cement concrete. The most promising of the less energy intensive materials for replacing cement in marine and general environment are granulated slag, fly ash and silica fume. The energy required to produce granulated slag is estimated at only 25% that for portland cement, and fly ash and silica fume are industrial byproducts. As slag and fly ash from different sources have unique properties depending upon the raw material used, it is essential that investigations be performed to obtain long-term performance data in concrete incorporating these materials under Canadian climatic conditions.

Research work done during the period under review concentrated on determining the performance and durability of large concrete prisms exposed to aggressive marine environment at Treat Island, Maine; determining strength development of concrete incorporating different combinations of fly ash and condensed silica fume; the partial replacement of fine aggregate in concrete by limestone dust; the behaviour of concrete at sustained elevated temperatures; and the evaluation of Melgran, a pelletized superplasticizer in concrete.

ALKALI-REACTIVE AGGREGATES

Reactions between certain constituents of portland cement produce deleterious effects that can lead to distress in major concrete structures. Present tests can only indicate potentially deleterious aggregates and therefore the prediction of performance of an aggregate in various environments over the long term is seldom possible. The problem of aggregate reactivity is further compounded by the increased alkali content of cement from modern plants, which are designed to reduce environmental pollution.

Engineers need methods for evaluating the potential alkali reactivity of aggregates quantitatively, to permit their selective use with or without beneficiation. CANMET researchers are attempting to develop test methods for identifying and quantifying reactive aggregates to establish criteria for the use of potentially reactive aggregates.

SPECIALIZED CONCRETES

CANMET continues to study a less energy-intensive method of producing lightweight aggregate than the rotary kiln method presently used in Canada.

Several shales from the coalfields of Alberta and British Columbia were evaluated by sintering in the laboratory. A sufficient quantity of lightweight aggregate will be produced by this method and evaluated on a commercial basis for use in lightweight concrete masonry units.

A PILP proposal is being prepared to develop a pilot-plant scale process using the technology generated in the laboratory for the production of lightweight aggregate and to determine the economic viability of the process.

A comprehensive state-of-the-art CANMET report on the production, properties and applications of vermiculite, perlite and pumice in insulating concretes was published.

CORROSION OF ASBESTOS/CEMENT (A/C) PIPE

Asbestos is currently ranked as a major public health problem and although there has been no direct correlation to indicate that ingested asbestos fibres causes cancer of the stomach and intestines, there is increasing resistance to using A/C pipe in water supply systems, and for sewage and industrial waste disposal.

The provision of clean water and safe sanitation is among the basic services required by any civilized nation. A/C pipe has for decades reliably provided these services, but with the recent emphasis on possible harmful effects of asbestos in drinking water, a re-evaluation of the corrosion of the A/C pipe was needed.

Based on reviewing the recent world literature on this problem, two reports were written. The first provides background information on matters relevant to A/C pipe corrosion for the non-specialists. The second report critically reviews the corrosion environments of A/C pipe (waters, soils, gases) corrosion agents, various corrosion mechanisms (including the microbiological conversions of sulphur), the current theoretical explanations of A/C pipe corrosion, and various control and improvements of that corrosion.

THERMAL SHOCK RESISTANT CERAMICS

Work continued on research projects to gain a better understanding of the causes of thermal cracking of brittle materials as a contribution to the development of ceramics having improved thermal shock resistance.

Thermal shock resistance is currently measured by wholly empirical methods involving laborious simu-

lated testing to destruction. A theoretically based methodology has recently been developed, enabling one to quantify thermal shock resistance by a numerical scale derived mathematically from measurement of a multiplicity of basic parameters at low and high temperatures. This method is, however, time-consuming and requires complex equipment.

A simplified method based on the product of thermal diffusivity and thermal expansion has been shown to correlate well with thermal spalling of rocks and thermal shock resistance of clay flue liner bodies. Work is proceeding to further evaluate this CANMET method against a series of acidic and basic refractories, and of materials for thermal storage, where there are perceived problems of inadequate shock resistance.

During the period in review, the equipment for measuring thermal diffusivity was modified to provide for microcomputer controlled automation of the measurement process.

ELECTRODES AND REFRACTORIES FOR THE STEEL INDUSTRY

CANMET researchers are committed to determine the nature and mechanisms of failure of refractories in secondary steelmaking vessels, specifically ladles-employed processes for specialty steels. The results will be useful in selecting the most appropriate materials.

Work to date has delineated the mechanics of corrosive/erosive wear with respect to both the rebonded fused-grain chrome-magnesia brick used in lining the slag zone and the direct bonded chrome-magnesia brick used below the metal line and in the freeboard area.

Attempts by industry to establish correlation between measureable physical and electrical properties of graphite electrodes and refractories and their service life have been unsuccessful. Studies to date have examined conductivities, strength, densities and porosities and are currently directed to examination of impurities and microstructures of electrode materials, seeking some critical differences or combination of differences, following which appropriate test methods may be selected or devised.

ABRASION RESISTANT CERAMICS

Abrasive wear of chutes and bins is a significant element of cost in mining and related industries. Work continues to develop abrasion resistant materials for applications in linings for materials handling systems subject to abrasion and corrosion. Ceramic liner plates were successfully employed to reduce this expense. Alumina for this purpose is costly in terms of materials and energy for processing. A recent improvement was achieved using alumina toughened with a finely dispersed phase of zirconia, however this proved to be equally or more costly.

A project to use a relatively inexpensive high-alumina porcelain toughened with thermally polymorphic materials such as quartz and rutile as the dispersed phase for ceramic liner plates was initiated. The first porcelain body evaluated proved to be unacceptable for commercial production due to a too short firing range. An appropriate modified body is currently under investigation.

In Europe and the USSR wear resistant slag ceramic and fused basalt liners are widely employed. This approach has been pursued through a series of small contracts to develop wear resistant glass ceramics, culminating in the current contract to produce recrystallized ceramics based on waste iron and steel slags. Results are promising, but the technology is foreign to the Canadian industry.

A contract was let in 1982 to examine a third technique, the application of wear resistant coatings using spray pyrolysis. Early results show only partial success.

STANDARDS AND SPECIFICATIONS

REFERENCE MATERIALS

CANMET undertakes, on an ongoing basis, to prepare and certify samples of ores, concentrates, metals and related materials for use as compositional reference materials, by means of interlaboratory and in-house programs. The compilation of methodological information from these programs is an important ancillary benefit to CANMET and the analytical community. In 1982, the Canadian Certified Reference Materials Project (CCRMP) distributed approximately 1400 units of reference materials in Canada and abroad with a revenue of approximately $65 000.

The Chemical Laboratory of Mineral Sciences Laboratories is active in the analysis of reference materials and participates in the interlaboratory certification programs of other agencies such as the Standards Association of Australia.

In this review period, industrial, government and commercial laboratories continued to contribute analytical results for the interlaboratory certification programs. The analysis of the Chemical Laboratory provided results for the certification program and for the total chemical composition.

CCRMP prepared four samples of uranium tailings, one each from Bancroft and Elliot Lake, Ontario, and Beaverlodge and Rabbit Lake, Saskatchewan. These materials are for use as quality control samples for the National Measurement Program of the National Uranium Tailings Research Program.

ANALYTICAL METHODOLOGY

CANMET continued to develop and improve analytical methods, techniques, and laboratory facilities,

and to participate in working groups and/or serve on committees of national and international organizations which develop and disseminate information on standard analytical methods.

AGGREGATE/CONCRETE TESTING AND STANDARDS

At the request of the Committee on Hydraulic Cements of CSA and the Canadian cement industry, a joint project was initiated at the end of 1978 between Canadian cement testing laboratories and CANMET to assess existing cement specifications and testing methods in Canada. This assessment is to be carried out on a continuing basis over the next 10 years with the purpose of providing the committee with an essential tool in the updating of standards or development of new standards on cements in Canada. CANMET is coordinating the program and is in charge of the overall organization, including the preparation and distribution of test samples and the compilation, analysis and publication of test data. The cement test samples for the program are obtained from the current production of a cement plant selected at random from among the participating companies.

NONDESTRUCTIVE TESTING

The role of Certifying Agency has for many years been assumed by EMR on a cost recovery basis. An extensive network of regional test centres has been set up throughout Canada at various technological institutes, DND establishments and other institutions in order to ensure easy accessibility for the public. The examinations are both set and marked by the central authority, EMR, in order to maintain uniformity.

In the next fiscal year NDT personnel will be certified on a national level, the change from a two-level to a three-level system for certification will be continued and major certification tasks will be computerized.

Certification of NDT Personnel
E.R. White and M. Breton of the NDT Section preparing an examination paper on a word processor for the certification of personnel in nondestructive testing.

METALS PROCESSING TECHNOLOGY

HEAT TREATED RAIL

The principal aspect of the CANMET heat-treated rail project continues to be the development of hard, strong, wear-resistant rail; two approaches were investigated in the past year. The first continued experiments with fluidized-bed cooling to control transformation temperature and the second was concerned with the effects of varying aluminium, nitrogen and vanadium concentrations on the hardness and strength of chrome-vanadium premium rail steels.

Wear work continues with the collaboration of the NRC Tribology Laboratory in Vancouver and under contract with the Technical University of Nova Scotia. Wear tests, simulating heavy duty service on curved track, have been carried out on disks of varying microstructure and hardness. The data obtained are being assessed and will be correlated with optical and transmission electron microscopy observations and microhardness measurements of the worn specimens.

Techniques have been established to obtain the fatigue crack propagation rates and threshold stresses of rail steel compact tension specimens. The knowledge of rail steel fatigue characteristics is considered necessary because many common rail defects are caused by fatigue and can lead to rail failures and derailments unless they are detected in time. The extent to which cracks grow before catastrophic fracture depends on the particular critical stress intensity value of the steel. Preliminary experiments on a commercial rail have given results that appear to be valid.

MARINE MATERIALS

The main focus in this project continues to be the generation of data relevant to the specification and performance of steel ship plate for ice-breaking vessels.

The laboratory continued to provide technical support for the materials interests of the Canadian Coast Guard at a variety of levels. As an adjunct to in-house research on the toughness characterization of ship plate, samples of different grade steels from an ice-breaking freighter were subjected to failure analysis. It was noted that while both samples had undergone considerable plastic deformation at low temperature (-25°C), the plastic strain in the A grade material culminated in a brittle propagating crack. Arrangements were made to obtain a detailed inspection report on the vessel in question in order to obtain field data on fatigue-crack incidence and weld corrosion.

Laboratory work on weld corrosion has continued and corrosion tests of three ship steels welded with three electrodes were started. These tests are designed to demonstrate that it is possible to produce corrosion in the laboratory similar to that observed on icebreakers operating in Canadian waters.

A sample of hull plate containing a weld from an icebreaker operating in the Beaufort Sea was examined during the year. This sample showed corrosion similar to that seen on other icebreakers with the weld metal corroded preferentially with respect to the hull plate. However, the hull plate was also heavily corroded with the corrosion primarily taking a pitting type of attack. There was no accelerated attack of the HAZ.

Work on the general aspects of Arctic marine corrosion has been pursued using long term sea water exposure. Four racks of corrosion specimens each containing samples of 21 different alloys were placed in Barrow Strait south of Resolute, NWT, by the Department of Fisheries and Oceans in April of 1981. One rack was lost when a part of the mooring failed, and the other two racks were on a mooring that could not be located. (Unusual ice conditions are believed to have snagged the subsurface buoy and moved the moorings. The rack that was recovered was found some 75 km from where it was placed).

Analyses of the specimens recovered showed that corrosion rates in the Arctic were not significantly different from those in more southerly waters.

In the area of welding technology, new equipment for submerged-arc one-sided tandem welding has been commissioned and used to produce butt welds on 25 mm plate specimens. This research will determine if this high energy, high productivity process can be utilized without detriment to the fracture toughness of the HAZ or the weld metal.

NAVAL MATERIALS

The research work undertaken in this project is partially funded from the R & D budget of the Defence Research Establishment Atlantic (DREA) of the Department of National Defence (DND). However, the work is also of interest to the Canadian Coast Guard Service (CCGS), Canadian Stone Marine Ltd., and other Canadian brass and bronze foundries.

The aims of this project are to identify the mechanisms responsible for the low fracture toughness of sand-cast ice-breaker propellers and to recommend industrially-usable heat treatments to improve their impact toughness.

Also, in the case of high-noise damping propellers, the object is to minimize propeller vibration by using a propeller material of high damping capacity such as a Sonoston alloy.

The general objective is to encourage improved processing of metals in Canadian industry to yield increased productivity and decreased pollution and energy consumption. Research is focused on foundry technology, metal forming, milling and improved processing specifically directed to materials for land, rail and sea transportation.

EXPLORATORY FOUNDRY RESEARCH

This project investigates suspension casting techniques for the production of castings. The introduction of inert, wettable fine solid particles into a melt has certain potential advantages. The suspensoid does not undergo liquid to solid shrinkage and thus the overall shrinkage characteristics of the melt could be significantly modified. It is also possible that additional mechanical working can be used after solidification to produce some types of fibre reinforced composites. It may also be possible to introduce particles which will increase the strength without affecting other properties detrimentally. For example, improved abrasion resistance of electrical contacts might be achieved without decreasing their conductivity.

Preliminary investigations into this technique have demonstrated the importance of wettability of the particles without dissolution. Various coating techniques have been tried, but have not been fully successful due to rapid dissolution of the coating. Work will continue to find the appropriate combination of correct density, wettability and non-solubility.

INTERCRITICAL HEAT TREATMENT

Investigations have continued on heat treatment techniques to improve the low temperature properties of plain carbon and low alloy cast steels. Following cooling from the austenitizing temperature, the castings are reheated to a temperature within the critical range and either water quenched or air cooled. The castings are then given their normal tempering treatment.

The effect of intercritical heat treatment in improving toughness in cast steels has been evaluated and was found to be most effective for thick-section castings, the greatest improvement being registered by the low-alloy LCC grade. Manganese content seems to be critical, with good results only being achieved at levels above one per cent. The toughening mechanism involves a grain refinement produced by intercritical normalizing, and a layered ferrite/tempered martensite structure produced by intercritical quenching.

COMPUTER PROGRAMS FOR RISER CALCULATIONS

Following feedback from industry and an evaluation of the performance and costs of existing software, the contract was altered from evaluation of existing programs to the development of a new program. Close collaboration between the contractors and CANMET personnel resulted in the creation of a new risering program which compares favourably with existing programs and which has the potential for further improvement. It is anticipated the software will be made available to Canadian foundries at a nominal price.

MICROCOMPUTERS IN THE FOUNDRY INDUSTRY

Statistical process control software has been developed and demonstrated at a workshop at Mohawk College and at four large foundries in Ontario. The software is simple to use and yet is highly effective in the analysis of foundry production data for the quantification of statistical variations in specific process variables and the identification of the causes of such variations. The software facilitates the presentation of the results in the form of control charts or other graphical formats that are easy to interpret.

DEGRADABLE BINDERS

Studies on the properties of newly developed degradable sand and core binders were confined to methods to accelerate the curing of the binders, without adversely affecting the working life of the mixtures. A technique was devised to apply a moderately hard vacuum to the mixture so that full curing could be obtained in a period of about 15 min. In other tests, it was shown that the mere establishment of a continuous flow of air through the sand mass could accelerate the curing process. This flow could be accomplished either by pressurized air or by the application of a vacuum to a mould with an open surface, however in both these cases, only the areas where a substantial flow occurred cured rapidly and the dead spots that existed failed to cure. It would appear that the formation of CO_2 bubbles is a rate controlling step in the curing and any technique which removes the CO_2 assists in accelerating the curing process.

ELECTROSLAG CASTING

Techniques have been developed for the production of water-cooled moulds for use in the electroslag casting (ESC) process. These moulds are cast in pure aluminum complete with integrally cast water-cooling channels. It was calculated that this technique could reduce the mould costs by two-thirds. A number of circular castings (10 in. diam.) (250 mm diam.) have been produced, mostly to an AISI 4340 composition. In addition, castings simulating a valve-body casting and a roll-shape casting have been made. It was demonstrated that the properties of the ESC material were similar to those obtained in rolled material of the same composition, and that the technique could produce shapes having equivalent properties to those obtained by forging.

The design of equipment for thin-wall production has been completed and all parts required have been either ordered or made. Erection of the equipment is almost complete and preliminary studies will be starting in the next fiscal year.

GRAVITY PERMANENT MOULD CASTING

A series of castings have been produced in both grey and ductile iron compositions in a specially designed cast iron mould installed in the PMRL gravity permanent-mould casting machine. Various commercial inoculants were tested by casting rods of different diameter to produce standard tensile samples. It was found that chill-free hypoeutectic grey iron could be produced in the half-inch rods (equivalent to a quarter-inch plate). For ductile iron a fully carbide-free structure could be obtained only at high carbon equivalents. Silicon contents up to 4.0% were needed for the half-inch rods.

A contract has been awarded to the Department of Mechanical Engineering of the University of Ottawa to develop a mathematical model of the heat flow in permanent moulds. A computer program has been written for the modelling of temperature distribution in a permanent mould and the casting for a two-dimensional case. This program has been adapted for use with the EMR computer. A program for a three-dimensional system with cylindrical symmetry is in preparation. A test casting for the establishment of parameters such as mould/casting heat transfer coefficients has been designed.

Electroslag Casting
H.P. Guindon of the Foundry Section stripping a cast aluminum mould from an electroslag-cast steel shape.

CAST-TO-SHAPE DIES

Activity on this project element has been in two areas. Techniques employing the Shaw Process have been used to produce the cast iron dies, both for the low pressure work as well as the gravity permanent-mould casting studies. A variation in the standard practice for Shaw moulds has been devised, in which a male pattern and vacuum moulding techniques have been employed. The second area of activity has been in the preparation of a rig for testing candidate die materials for thermal fatigue. The test piece is heated by induction with the aim of producing a temperature profile at its surface similar to that produced at the surface of a metal mould when poured with liquid iron.

LOW PRESSURE DISPOSABLE MOULD CASTING

A new casting method was developed which incorporates the advantages of both low pressure permanent mould and conventional disposable mould casting processes. A simple prototype system was constructed and test castings were poured successfully in cast iron, aluminum and a copper-base alloy. Design and construction of a full-scale disposable mould casting system has recently been completed.

Extensive testing was conducted using existing dies and proprietary coatings to identify all production variables in the low pressure casting system that affect casting quality. These tests were then repeated using an existing die modified to produce a more difficult casting with a thin wall segment. A new die design has been devised, and the patterns required have been produced. The dies have been cast and will be available for use in the next fiscal year.

IMPROVED CUPOLA MELTING PRACTICE

Preliminary investigations revealed that the necessary relevant melting cost data were available. As a result, a melting cost survey was conducted involving the establishment of standard casting methods, collection of data and the creation of special microcomputer software to facilitate cost analysis. Melting costs have been determined for 21 foundries and compared to cupola design and operating practice. Optimum cost targets have been established for each foundry using standardized costs and total potential savings of approximately $2 million per annum have been identified.

Development work on the CANMET Cupola Software Package was continued both at CANMET and at three cooperating foundries. This work has confirmed the accuracy and value of the software and preparations are in progress to offer the software initially to the Canadian foundry industry through CPDL. The American Foundrymen's Society (AFS) has requested permission to act as a distributor in the United States and discussion between CPDL and the AFS are underway to establish a mutually satisfactory agreement providing appropriate remuneration to the Crown.

Contract research on effect of increased tuyere velocity on cupola performance was undertaken to establish a closely controlled and documented cupola operation at a commercial foundry in which the influence of tuyere velocity on melting efficiency could be isolated from other cupola operating variables. The work has been completed and the results indicate that tuyere velocity exerts a significant influence on combustion characteristics in the cupola. The participating foundry is now collaborating with CANMET with follow-up work to modify their cupola operating practice to take advantage of the new combustion conditions resulting from the use of high-velocity tuyeres.

ROLLING MILL PROCESSING TECHNOLOGY

Resources for this project have been applied in three directions: in-house research, development of facilities for future research and contract research.

To assess the validity of applying theoretical equations to predictions of load and power requirements in rolling, two avenues were explored. Firstly, predicted mill loads based on the theoretical analyses of Sims and Hockett and using cam plastometer flow-stress data were compared with mill data.

Secondly, an in-depth study was undertaken of the influence of inhomogeneities in through-thickness deformation on mill loads predicted using Sims' analyses and cam plastometer data. As a result of this study, future computation of yield stresses from mill data will incorporate corrections to account for the effects of geometry and through-thickness temperature gradients.

The cam plastometer is now fully operational and flow stress-strain rate correlations have been completed on several steels. The influence of friction on recorded die pressures and, consequently, of flow stresses was re-examined in the light of recently reported work. This study demonstrated that for the geometry of specimens used on the cam plastometer, corrections for friction could be ignored.

Plans to upgrade the cam plastometer to simulate the hot rolling of strip have been completed. The first step in the upgrading has been the acquisition of a micro-computer for experimental control, and data acquisition and processing.

Work has continued on the development of software for automatic control of mill operation for future research on rolling processes. Computer programs have been designed leading toward control of roll speed and direction and speed and direction of the roll-separation drive system. Roll separation was monitored by software control in tests designed to develop a slowing and stopping procedure at a prescribed mill gap.

The engineering design and acquisition of components for a new high-speed screwdown system have been completed. This system which will be installed in 1983 will allow significantly more con-

trol of interpass time and enable more precise simulation of industrial processes for modern high-strength steels. Preliminary work to interface the new unit with the PDP 11/23 microcomputer is in an advanced state.

Finally, the ingot reheating capability of the rolling mill facility has been significantly upgraded by the acquisition of a large capacity globar element furnace with programmable control for pilot-scale simulation of multi-stage reheating practice.

Investigation has continued into the causes of and development of processes to minimize the undesirable duplex grain structure which develops during controlled-rolling of microalloyed high-strength steels on a contract basis.

Rolling Mill Processing Technology
Staff of the Metal Forming Section conducting tests on the PMRL/CANMET experimental rolling mill to establish rolling schedules for a thick-gauge linepipe steel.

FORMABILITY AND PROCESSING OF SHEET STEELS

Research on the in-line galvanizing of continuously annealed Mo and V bearing dual-phase steels was extended to the influence of a simulated paint bake cycle on the strength of the base steel. The results indicated that metallurgical changes accompanying in-line galvanizing do not affect the response to paint-baking.

The computer program for data gathering and calculation of tensile parameters relevant to formability was modified and enlarged to select and output definitive data. This same program has been enlarged to calculate strain hardening parameters plotted using a cubic spline. These plots are then used to compare the influence of microstructural variations on ductile flow. A program was developed using a strain-rate change, to calculate strain rate sensitivity and the program is being further refined to resolve some output data inconsistencies arising from discontinuous metal flow and sensing of the load change after the increase in strain rate.

In contract research, fractographic studies have been undertaken to gain insight into the ductility-strength relationship in dual-phase steels produced by different processing routes. Results indicate that inferior ductility of batch-annealed compared to continuously-annealed steels has its origin in the ferritic rather than the transformed phase.

FLUIDIZED BED METAL PROCESSING

Earlier work has shown that uniform properties throughout a complex cross-sectional shape are attainable using proper consideration of product shape and the direction of air-flow. Rail, for example, is an important candidate product for fluidized-bed processing.

These techniques have been adapted extensively to other projects on rail-steel development and accelerated, controlled cooling of linepipe grade steels. The pilot-scale bed has been upgraded by the installation of new higher current elements to permit more rapid "heat up" and greater flexibility of operation.

NEAR NET SHAPE FORGING

Near-net-shape (NNS) forging is a specialized approach applied to forging and roll-forming technologies to produce complex shapes to almost final dimensional specifications.

The initial phase of this project has been completed with a review report on the modelling of metal deformation processes based on state-of-the-art finite element methods and related fields. Areas for research in the next phase of the project have been identified and recommendations made for the development of models of plastic flow behaviour.

In contract research, an investigation is underway into an assessment of the cold forgeability of various grades of steel. Strain paths and the influence of inclusions that lead to failure are being examined. The ultimate objective is to

upgrade the strength levels of steels that can be satisfactorily cold forged but which are warm forged at present.

WELD MECHANICS

The objective of this project is to develop the experimental and numerical methodology to determine and predict residual stresses and distortion resulting from the welding of steel structures.

In the current experimental program, the residual stresses that develop in welds are calculated using the finite element method, which is being performed under contract at the University of Waterloo. The data required for the finite element calculations have been obtained by monitoring the thermal/mechanical behaviour during the preparation of single-pass submerged-arc welds in stainless steel.

The residual stresses developed in the single-pass welds will be measured experimentally at PMRL using X-ray diffraction and hole drilling techniques. The experimentally determined values will be compared with those calculated by the numerical method.

THERMAL/MECHANICAL SIMULATION OF METALLURGICAL PROCESSING

The overall aim of the project is to develop an understanding of metallurgical processes through the use of the Gleeble simulator, leading ultimately to improved commercial process efficiencies.

A cooperative program on continuous casting has been established with the Canadian steel industry. A program simulating continuous-casting operations has been developed in the Gleeble 1500. This program involves the melting and solidification of a steel sample. Hot ductility tests are performed in situ at various temperatures following solidification.

In the coming fiscal year, the response of a range of steel compositions to this continuous-casting program will be studied.

In the simulation of welding processes, the effect of energy input on the microstructure and notch toughness of the heat-affected zone of vanadium-bearing microalloy steels has been determined. This work relates directly to the fabrication of large diameter pipelines and offshore structures.

WELD NOTCH TOUGHNESS

The objective of this project is to determine the effect of nitrogen on the notch toughness of welds prepared in steels for line-pipe and offshore structures.

A cooperative program has been established with the Canadian steel industry to study the effect of nitrogen on heat-affected-zone notch toughness of a range of nitrogen-bearing microalloy steels. A program for the simulation of the coarse-grain heat-affected-zone region has been developed for the Gleeble 1500 machine. The electroslag casting process has been used to make a series of steels with low sulphur (0.005%) and a nitrogen content ranging from 0.07% to 0.015%. The steels are control rolled to plate.

The future program will be to evaluate the microstructure and notch-toughness properties of the simulated heat-affected-zone specimens.

COST RECOVERY IN METALS PROCESSING

Government, industry and the universities made substantial use of PMRL's casting, heat treatment, metal forming and non-destructive testing facilities on over a dozen occassions in FY 1982/83. Work ranged from examination of defective steel castings for a private company to swaging of cylinders for a university.

TRANSFER OF METAL PROCESSING TECHNOLOGY TO INDUSTRY

The objective of this project is to maintain a continuing record of the transfer of technology from projects undertaken in the Metal Processing Technology sub-activity.

The Canadian foundry industry is kept informed of foundry-related research at the Physical Metallurgy Research Laboratories through periodic issues of the CANMET Foundry Newsletter. Two Newsletters were issued in 1982/83. Judging from the response of industry, the Newsletter continues to be a useful vehicle for the transfer of foundry technology.

CONSERVATION AND RESOURCE ASSESSMENT

MINERAL INSULATION

The mineral wool industry of Canada is composed of many small, independent producers that utilize the traditional blast furnace slag/cupola furnace method for mineral insulation production. Cupola furnace technology has a number of disadvantages composed with the more energy efficient and environmentally acceptable electro-melt technology and, because good quality mineral wool is produced in several European countries using this latter technology research work continued to concentrate on the development of this technology for the production of mineral wool. This work included the use of blast furnace slag, the traditional raw material, and non-traditional materials such as diopside, trap rock, basalt and asbestos tailings. Additional advantages of electro-melting are that homogeneity and composition of the melt are more easily controlled and the fine as well as coarse raw materials may be melted, thus recycling of waste shot is feasible.

COMMODITY BACKGROUND STUDIES

CANMET frequently advises EMR and other government departments and agencies on technology related to the exploitation of mineral commodities. CANMET also undertakes to fill gaps in technology related to the husbanding of domestic mineral resources and to keep abreast of developments associated with mineral commodities on which there is no current research. In pursuance of this policy, critical reviews of state-of-the-art technologies are undertaken and during the past year CANMET has been cooperating with the Mineral Policy Sector of EMR in a series of studies on certain imported strategic mineral commodities, namely alumina, chromium, manganese and zirconium.

In response to increased interest in industrial minerals by industry and provincial and federal governments, CANMET undertook a review of industrial minerals with regard to R & D needs and problems of the industry in order to recommend a course of action for CANMET in identifying problem areas and planning research toward solution of these problems and the further development of industrial minerals in Canada.

MINERALOGICAL STUDIES OF MARGINAL AND COMPLEX ORES

Studies were undertaken to determine the mineralogical character of the ore minerals of the New Brunswick sulphide ores and to provide technological data relating to the mining and processing of such deposits and to thus assist governments and the mining industry in assessing the economic exploitability of these resources.

Further reports in the series will be delayed because of the commencement of a two-year mineralogical study of the Buchans orebodies in central Newfoundland which has been undertaken as part of the Canada-Newfoundland Cooperative Mineral Program.

The detailed study of the movement of minerals and metals through the processing circuits in the mill of Brunswick Mining and Smelting was continued.

The study of complex sulphide deposits in other parts of Canada has begun with the investigation of a large stratabound Cu-Co deposit in northern British Columbia.

PRECIOUS METALS RECOVERY FROM ORES, TAILINGS AND RESIDUES

The project to develop new technology for the recovery of precious metals from Canadian ores, tailings and residues was continued, the aim being to assist governments and the mining industry to assess the economic exploitability of these resources. The improvement of the recovery of Platinum-group element (PGE) in processing plants depends on measurement of the properties of significant minerals combined with accurate analysis of their PGE content. Some of the common minerals contain very small amounts of PGE that must be measured precisely in order to carry out suitable calculations of metal balances and the same difficulty arises in research on the recovery of silver in the zinc industry.

In continuation of the work being undertaken on gold recovery from tailings, samples from two sites in Nova Scotia were examined mineralogically and procedures were developed that achieved recovery of about 90% of the contained gold. The best approach was found to utilize flotation followed by cyanidation of the concentrate. Results of the work are now being used in economic evaluation of proposals for gold recovery.

CANADIAN SILICA RESOURCES

Work continued on the important project to characterize and assess Canadian silica deposits that have potential for the economic recovery of silica sand for the glass, glass fibre, artificial abrasives, silicate chemical and foundry industries, and to determine, by laboratory investigation and evaluation of selected samples, the technical feasibility of producing quality sand from these resources.

Increasing concern by both industry and government regarding present and future sources of high-purity silica sand particularly for markets in southern Quebec and Ontario, points to a need for a detailed study and evaluation of the more promising silica deposits in those areas. Canadian requirements for silica sand are largely met by imports from producers in northeastern United States and it is important that Canada should become less dependent upon imported silicates and that every attempt should be made to increase the geographical spread of the Canadian producing areas which, at present, are localized in Ontario, Quebec and Manitoba. A request was made by the Departmental Committee on Ocean Mining for a limited study of four samples of sand taken from the Hibernia oil fields to determine the potential of this sand, primarily as construction sand but also as a source of high-purity silica sand.

NON-FERROUS PYROMETALLURGICAL SLAGS

CANMET researchers continued to develop methodology to reduce the loss of valuable metals such as nickel, copper, cobalt and precious metals, and to increase the rejection of undesirable elements such as arsenic, bismuth and antimony, from slags.

Most concentrates of copper, nickel and lead sulphide ores are treated by pyrometallurgical smelting however many concentrates contain minor amounts of valuable metals, such as cobalt, precious metals, molybdenum and zinc, some of which may be lost to the slag. Methods for either decreasing these losses or for recovering the metals from the slag would help conserve Canadian mineral resources. One possible route for rejection and discard of unwanted elements would be to collect them in the slag which, when cooled, would hold these elements in a relatively immobilized form.

A literature review on non-ferrous pyrometallurgical slags was conducted with special emphasis on the metal losses to the slag and their subsequent recovery. Metal losses occur by mechanical entrainment and by chemical dissolution and new smelting processes were developed and old ones modified to include separate slag cleaning operations to achieve higher efficiencies in metal recovery. Current industrial processes such as slag recycling, electric furnace treatment, top-blown rotary converter (TBRC), submerged combustion (Sirosmelt) and slag fuming were reviewed.

Samples of seven non-ferrous industrial slags were obtained and examined by chemical analysis and electron microprobe techniques. Most were quite low in valuable elements, although one lead smelter slag showed fairly high values for silver, lead and zinc. Preliminary slag cleaning experiments involving melting with added pyrite indicated that most of the Ag, Cu, Ni and Co could be extracted from the slags into a low-grade matte phase.

Laboratory investigations were undertaken on the distribution of silver between slags and the corresponding matte and metal phases. Several experimental variables such as temperature, time, slag to matte ratio and composition of the slag have been studied on a laboratory scale with respect to matte smelting, converting of copper matte and slag cleaning conditions. The silver was distributed preferentially in the matte or metal phases, as expected.

Some British Columbia copper concentrates report values of molybdenum in the vicinity of 0.1%. These are currently not recovered and they can represent a loss of about 10% of the molybdenum in the initial bulk (Cu + Mo) concentrate. Investigation of the distribution of molybdenum between slag, matte and copper metal phases was undertaken.

Characterization and measurement of phases in blast furnaces at Brunswick Mining & Smelting was undertaken using samples from various heights within the blast furnace. Microscopic examination, X-ray diffraction analysis, scanning electron microscopy and electron microprobe analysis established the identity of the phases present and this information was used as the basis for quantitative measurement of the phases by image analysis.

PRIMARY MINERAL WASTES

CANMET researchers continued to compile and publish data on the occurrence, physical and chemical characteristics, and potential use of Canada's resources of primary mineral or mineral based wastes. A contract to study the use of chemical gypsum for cement production will be extended into 1983/84.

SPECIALIZED MINERAL FIBRES

A large quantity of asbestos fibres are incorporated in asbestos cement product as reinforcement in terms of strength, durability and resistance to fire and weather. However, because of potential health risks, attempts are being made to replace asbestos by other material, notably glass fibre. Normal glass fibres made from soda-lime-silica or borosilicate compositions are not suitable for use in cement reinforcement because highly alkaline cement matrices will corrode the fibre and the desired mechanical properties will be lost. Alkaline-resistant glass fibres with high zirconia content were developed and are now commercially available. The alkaline durability of these products in the short term appears satisfactory but the long-term performance is unconfirmed and therefore research is required to develop alkaline-resistant fibre compositions from inexpensive and readily available raw materials.

A comparison of the compositions of asbestos and certain glasses indicates that the alkaline resistant properties of asbestos could be due to the presence of high concentration of magnesium oxide (MgO) and that the effect of the addition of MgO on glass durability should be investigated. Asbestos tailings contain more than 40% MgO and could be a potential raw material. Glass fibre can also be produced from different raw materials such as diopside and basalt. These fibres will be produced and evaluated for alkaline resistance and long term performance in cement matrices. A literature survey of alkaline-resistant fibres is in progress.

The large increase in fuel prices has made refractory insulating fibres the fastest developing area of mineral fibre production. The range of refractory fibre is not broad. The most common are the aluminosilicates with about 40-60% alumina content. Other common refractory fibres are made from silica, alumina, carbon and zirconia compositions. Most are expensive. This project will investigate the technical feasibility of producing refractory fibres with inexpensive indigeneous materials, including asbestos tailings.

MINERAL PROCESSING TECHNOLOGY

The objective of this subactivity is to develop and promote technology for improving recovery and grade of ores and concentrates from Canadian mineral resources.

SIMULATED PROCESSING OF ORES AND COALS (SPOC)

Significant advances were again made in this project, which will provide the mineral and coal industries with a computer methodology for circuit and equipment optimization and design. This technology is needed to allow the industry to fully use state-of-the-art methods of process optimization in times of increasing process costs and decreasing grades in orebodies.

During 1982-1983 progress has been achieved in the development of a sensitivity analysis program for material balance computations; development of a conversational linear and polynomial regression

program to be part of a general model calibration package; completion of a study on ball mill modelling using some laboratory measurements to determine the breakage functions; and full scale sampling to determine the selection function as well as the residence time distribution. Documented FORTRAN programs to process the experimental data have been merged to the existing software libraries and a feasibility study to determine the most suitable site for a two year off-line optimization study was completed. The Equity Silver Mines concentrator and the Devco coal plant at Victoria Junction were identified and work is in preparation for phase three studies in these two plants. The transfer of material balance software (MATBAL, BILMAT) continued as well as the distribution of the first edition of SPOC Manual.

HYDROMETALLURGICAL LEAD

This project is being carried out in cooperation with the Canadian lead smelting industry and the USBM. Conventional lead smelting processes may be unable to meet the proposed in-plant hygiene specifications for lead and cannot readily handle the lead residues produced by processes designed to treat complex sulphide bulk concentrates. Chloride processes for lead will give a lead chloride ($PbCl_2$) product from which it might be possible to recover the lead and regenerate the chlorine. Sulphate processes will result in a lead sulphate product which could readily be converted to $PbCl_2$ by brine leaching. Therefore, the incentive is to develop and evaluate leaching, purification and electrolysis techniques for recovering lead from $PbCl_2$. The principal stimulus is the hygiene problem, although the flexibility to treat lead residues from a variety of extraction processes is an obvious advantage.

Arsenide and silver minerals are encountered in many lead concentrates and a literature review on the leaching of silver from various residues and intermediate products has been carried out and the report is in the editorial stage.

IRON ORE

CANMET researchers continued to identify methods that can be used to improve grade and quality of iron ore concentrates, quality of pellets, lessen environmental impact and improve process control.

A study was done on the mineralogical and microstructural changes in thermal indurated green pellets based on concentrates from Sherman Mines, Ontario. Pellets indurated at 1300°C for 5 min showed a wide range of microstructural variation, however the bonding or iron oxide through the grain growth is considered the most contributory factor to pellet strength without much interfacial silicate phase being present. A final report has been written.

Another study was performed on Sept-Iles pellets to determine the influence of two important parameters which affect induration, viz. temperature and time. A report of this work is in the editing stage.

A report completed on water treatment for recycle and disposal under the co-authorship of Environment Protection Service, (E.P.S.) and CANMET, has been sent to the Iron Ore Technical Task Force. The colloidal particles were characterized mineralogically, size distributions of hematite and silica particles were established, and electrophoretic mobility and zeta potential determined for the various effluents studied. Tube test and jar test studies performed on various effluents indicated that there were six different possible treatments available to settle out colloids. There is a variation in settling rates and costs involved in these treatments but it has been left to the Task Force to decide which they would prefer on the basis of economics. Advantages and disadvantages of each treatment procedure are discussed in the report.

METAL EXTRACTION AND REFINING

New Brunswick has the largest reserves of zinc, lead and silver in Canada, however the economic exploitability of these resources has been severely hampered by the complexity of the orebodies. It has been demonstrated that high recoveries, which are essential for the economic viability of many of the deposits, can only be achieved through the production of bulk concentrates which, because of their complexity and relatively low grade, are not amenable to conventional extraction/refining processes. Development of a new extraction process is essential to economically recover the zinc, lead, copper, silver and other saleable byproducts from the bulk concentrates, while minimizing environmental problems associated with the removal and/or disposal of pyrite and sulphur dioxide.

Three processing options for producing high value refined products are being studied. The relative technical and economic merits of a chloride extraction process are being investigated at CANMET and two sulphate extraction processes are being investigated primarily at Sherrit Gordon Mines and the New Brunswick Research and Productivity Council (RPC) by means of shared-cost contracts with industry, CANMET, and the Department of Regional Economic Expansion (DREE), with CANMET as scientific authority.

Work on the sulphation roast leach (SRL) process has been completed at RPC under a DREE shared-cost contract with Anaconda on the application of the SRL process to Anaconda Caribou ore. A number of significant improvements in the SRL process were achieved, particularly with respect to gas cleaning and cooling using a spray reactor in place of an electrostatic precipitator. The technical feasibility of recovering gold and residual silver from SRL process leach residues by cyanide leaching was also confirmed.

Work on the modified pressure sulphuric acid (PSA) leach process to produce a high grade high-recovery lead/silver concentrate from Brunswick Mining & Smelting (BMS) bulk concentrate was completed in Sherrit Gordon under a CANMET/Sherritt shared-cost contract. A flowsheet incorporating a two

stage leach with an additional SO_2 reduction step to decompose lead jarosite was developed, and an up-dated engineering and economic assessment of the process was completed and a report issued.

The recovery of silver in the modified PSA process still poses a serious problem, with silver losses to tailings in the range 25 to 30% and therefore a second shared-cost contract was initiated to establish material and energy balances and engineering design criteria, and to generate sufficient quantities of leach residues for studies at CANMET on the form and distribution of silver in the residues and on possible methods for improving recovery. Research projects undertaken during the year in connection with the development of the ferric chloride leach (FCL) process were; leaching studies for the control of sulphate build-up in leach liquors to prevent lead/silver precipitation as jarosites or sulphates, and investigations on factors affecting the formation of sulphates during the oxidation of sulphides in chloride media; the kinetics of oxidation of aqueous solutions of ferrous chloride by molecular oxygen at atmospheric pressure; and the study of electrowinning of metals from aqueous chloride electrolytes.

The history and present state-of-the-art for electrowinning copper, nickel, cobalt, zinc and lead from aqueous chloride electrolytes has been reviewed, and studies are being conducted to determine the conditions required for electrowinning smooth, compact, dendrite-free Cu deposits from aqueous chloride electrolyte.

DRY-WAY CHLORINATION-OXIDATION OF COMPLEX ORES

Differential thermal analysis (DTA) studies of reactions between sulphur monochloride (S_2Cl_2) and iron powder were initiated and indicated that the process might be used for the decomposition of S_2Cl_2 to produce sulphur.

Sulphur chlorides can be a significant and undesirable byproduct of chlorination reactions. They are not necessarily recyclable as a chlorination agent due to reactor heat balance restrictions or due to contaminants and therefore dechlorination methods are required for application to sulphur chlorides.

Iron powder, suitably diluted with sized, pure silica grains, was reacted in a rotary kiln with S_2Cl_2 vapour. The reaction was efficient and very selective toward the formation of ferrous chloride and readily condensable sulphur vapour and the product was smoothly transported as a threefold silica to iron dilution ratio. It is anticipated that this study will indicate a procedure for chlorinating some concentrates at moderate temperatures, and will also present a potential pyrometallurgical route for the purification of chlorinator off-gas sulphur.

Technical feasibility was shown and some operating parameters optimized for a pyrometallurgical chlorination process applicable to the treatment of sulphide concentrates. The chlorination steps are part of an overall flowsheet designed to recover zinc, lead, copper, silver and sulphur from complex New Brunswick ores. The conclusions derived from bench-scale experiments and from theoretical calculations indicate that Brunswick bulk sulphide concentrates can be efficiently chlorinated to yield a mobile metal chloride product with a recovery of the metals in the melts as high as 95%. Good quality sulphur can be produced, the reactions are highly exothermic and the process can be autogenous, the production of sulphur chlorides can be minimized and fuming of metal chlorides can be controlled.

COMMINUTION/BENEFICIATION OF COMPLEX SULPHIDE ORES

Research continued on the project to increase metal recoveries from the New Brunswick massive sulphide ores.

Flotation of all the valuable minerals into a single bulk concentrate followed by metal extraction using hydrometallurgical techniques was chosen as the most promising method for achieving this end. This scheme had been successfully employed for the Brunswick Mining & Smelting Corporation Limited (BMS) and Heath-Steele ores, and was then applied to the ore from the Caribou deposit which has proven to be the most difficult of the three New Brunswick ores to concentrate by selective flotation.

Bulk flotation of Caribou ore was carried out at CANMET in the CPDU using the same techniques developed for BMS ore. A total of 17 test runs were carried out, however, satisfactory recoveries were not achieved despite the very fine grind employed.

Several flotation separation techniques were tried in eight tests on fresh samples of Anaconda-Caribou CPDU bulk concentrate. These were based on use of different depressants, however none of the techniques was selective enough to be of practical value.

HYDROMETALLURGICAL PROCESS FOR NICKEL AND COPPER

Research work continued on the project to develop and demonstrate a laboratory scale, hydrometallurgical technology for treating nickel/copper sulphide ores to recover 95% of the non-ferrous metal values as well as the precious metals and to yield elemental sulphur and a saleable or discardable iron product.

This project was initiated in response to concern over "acid rain" which is expected to result in the enforcement of more stringent environmental regulations on SO_2 emissions. Although reductions in SO_2 emission can be achieved by conversion to sulphuric acid, marketing and storage constraints make alternative long-term solutions for SO_2 control desirable. Long-term strategies call for the development of processing concepts which produce elemental sulphur rather than SO_2 from base metal sulphide ores and particularly for nickel and copper where the sulphur to metal ratio is high.

A "Hydrometallurgical Copper Process" has been developed through the combined efforts of Great Central Mines (GCM), and Bacon, Donaldson and Associates Ltd. Based on the conclusions and recommendations of a CANMET evaluation of this process, further developmental work was carried out. The resulting modified GCM process is now considered to be an attractive alternative for copper production from copper concentrates. The modified GCM process has also been evaluated by CANMET in terms of significant improvement over the original process, comparison with other hydrometallurgical alternatives and with conventional pyrometallurgical copper processes and a report has been written; recommendations for future work have been made. The process is presently being considered by six British Columbia copper producers.

VANADIUM EXTRACTION FROM OIL SANDS BITUMEN

This project was initiated to assess the economic and technological feasibility of extracting vanadium from Athabasca oil sand bitumen before the bitumen is thermally treated, and to establish and optimize a technology compatible with the processes used for the separation of the bitumen.

Although of low concentration, an average 0.0025% V, the total vanadium reserve is substantial because of the huge tonnages of bitumen. Vanadium is used chiefly by the steel industry as an alloying element in the production of high strength low alloy steels. All the vanadium used in Canada is imported with the major world suppliers being the USSR and South Africa. Development of domestic production would ensure Canada with sources of this metal in all political climates, domestic jobs would be created and the vanadium would be a valuable byproduct from the tar sands operations. Additionally, corrosion problems would be reduced since vanadium appears to accelerate corrosion. Vanadium removal before the coking stage in the bitumen upgrading plants would result in a more acceptable byproduct coke.

SILVER RECOVERY IN THE ZINC INDUSTRY

Canada is the world's largest supplier of zinc concentrates and a major producer of zinc metal. Canadian zinc concentrates contain potentially recoverable quantities of silver, however, recoveries in Canadian plants range from 0% to >90%. Much work has already been done on silver recovery, and many investigations are in progress, but with limited success to date. Thus, a thorough and critical examination of the whole problem of silver deportment and recovery in the zinc industry appears to be appropriate - commencing with the ore and proceeding through the various processing steps to the final products and/or residues.

The whole project has been divided into several research study activities: silver mineralogy; silver balances in commercial processing plants; a review of silver leaching technology; a review of silver precipitation technology; and analytical development for chemical process control procedures.

The reaction of dissolved silver with sulphide minerals is being studied. Preliminary experiments are underway to evaluate factors affecting the removal of Ag from sulphate leach.

POTASH RECOVERY

Canada contains 37% of the 135 billion tons of the world reserves of potash which is used mainly in the production of fertilizer. There are still numerous problems associated with the flotation of potash ore and it is felt that surface chemistry studies such as contact angle measurements, zeta potential analysis, absorption of collectors, micro-flotation, etc., could provide data for establishing the potash flotation mechanisms and ultimately improving the recovery and economic efficiency of the process. A literature survey of technology and a review of problems being experienced by industry were undertaken, both are still ongoing.

BACTERIAL LEACHING

Research activities continued in the development of the technologies to utilize microorganisms in extraction and beneficiation processes to exploit mineral deposits which cannot be treated economically by normal processing.

Important advances are being made in the technology to harness bacterial leaching to provide an economically viable biohydrometallurgical process to extract and recover secondary metal values from sulphide ores, specifically those portions of mineral deposits which are left underground for mine support or which are below cut-off grade for conventional mining. Typically 30% of mineral deposits are left untouched in most mining operations. Treatment of such residual resources by bacterial leaching would enable more complete utilization of ore reserves.

The program to study the removal of silica from alumina ores (bauxite, clays, etc.) by biohydrometallurgical methods has two aims. In the short term, the aim is to upgrade bauxites by reducing the level of the silica which interferes with the production of aluminum by the Bayer process. The long term objective is the utilization of Canadian alumina resources as feed for the aluminum processors.

In current work, microorganisms from bauxite samples are being isolated and identified prior to determining their silicate-dissolving capabilities. If successful results are obtained, future work would entail evolving a continuous process.

DESIGN, DEVELOPMENT AND EVALUATION OF MINERAL PROCESSING EQUIPMENT

CANMET researchers continued to design, fabricate and test the Continuous Process Development Unit

(CPDU) equipment, which is not available commercially, to test and evaluate performance of equipment for mineral processing, and to compare the performance of alternative equipment designs.

A prototype 1-L CPDU tapered-tank flotation machine was subjected to rigorous testing as both rougher and cleaner using Anaconda-Caribou CPDU heads and bulk concentrate as feed. Generally, this machine was more efficient than the 2.5-L cell to which it was compared and the difference in performance is attributed to the more favourable froth surface area to volume ratio of the 1-L cell. It was concluded that to further improve cleaning efficiency to the same level as that obtained by batch cleaning it would be necessary to carry out the flotation operation in a number of cells connected in series.

The recirculating system was for a 50 mm cyclone tested on Heath-Steele ore and also in the first two CPDU runs on bulk flotation of Caribou ore. It was found that a 50 mm cyclone could be utilized for classification in the CPDU by recirculating slurry at a rate required to give the required cyclone inlet pressure. However, the system was judged to be unsatisfactory for CPDU operation because pulp densities and system equilibrium were not flexible to pulp feed changes.

An initial test of the Alpine 100 MZR air classifier as a fine size fractionating device was carried out on a sample of Anaconda-Caribou CPDU tailings. Performance was up to expectations although very fine dust was lost to the bag filter from which it cannot readily be recovered and problems were caused by caking of the very pure material in the collection cyclone and on the internal surfaces of the rotor housing.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

CERTIFICATION AND TECHNICAL ADVICE

This subactivity of the Canadian Explosives Research Laboratory (CERL) has been developed to fulfill the requirement of section 14 of the Canada Explosives Act. During the 60 odd years which the Act has been in force, the laboratory functions of certificating explosives, advising on technical problems of explosives handling and investigating accidents involving explosives have been gradually developed. The expertise in Explosives Safety Engineering is developed in-house through contact with manufacturers' research laboratories, contracted research projects, in-house development projects and international contacts. Because of the proprietary nature of the commercial formulations, results of individual examinations for authorization are, and remain, confidential.

Responsibilities under the project continue to increase because of technical advances in formulation, and added international responsibilities as a major explosives producing country and also because of increasingly critical reactions from the Canadian public to accidental explosions.

Research Activities and Results

During the year, 159 new explosives were examined for authorization. These involved some 1838 sample units of work. Corresponding figures for year 1981/82 were 233 and 2059 respectively and for 1980/81 were 302 and 2756.

The economic downturn which Canada is experiencing has had a significant effect in reducing the total number of samples submitted for authorization. Although the number of high explosives (Classes 1, 2 and 3) and ammunition (Class 6) submitted in 1981 and 1982 were essentially the same, there has been a significant reduction in the number of fireworks (Classes 7.2.1 to 7.2.5) submitted. These are items normally purchased by individuals or communities for fireworks displays.

There was no major accident requiring the laboratory's involvement in manufacturing during the past year. CERL completed its contribution to studies on regional stability in underground mines by fabricating and installing explosive cutters on some 500 roof bolts. The laboratory is currently developing an explosive cable cutter for removing reinforcing cables used for underground roof stabilization.

At the request of the RCMP, the laboratory evaluated a number of containers for carrying limited quantities of detonators and explosives aboard aircraft. The final design is a standard fire-resistant house safe which has been modified to prevent communication between the detonators and the explosives. A report on this study has been published.

The laboratory has continued to improve several of its test methods and has documented many others. A new toy rocket motor test stand with associated electronics has been developed to eliminate the tedious calculations involved in obtaining certain performance characteristics. The ballistic mortar and the sand test have both been reappraised and reports published. The chemistry laboratory is putting the finishing touches on an analytical methods manual documenting all procedures and most of the laboratory's test procedures have also been documented. The laboratory has designed a new test facility for determining the fumes produced by explosives and some of the equipment has been ordered.

During the year CERL continued to provide technical advice to industry, government agencies and the general public including the identification for the RCMP of an explosive used in an attempted bombing in Halifax.

EXPLOSIVES RESEARCH AND DEVELOPMENT

The increasing costs of evaluating explosives has resulted in an attempt to develop a mathematical model which will predict the response of an explo-

sive to a certain stimulus. Although this model will not cover all stimuli, it should facilitate the evaluation of explosives. New test methods and equipment are continually being developed to assess hazards of explosives and as these new test methods come online, they are incorporated into standard test procedures. CERL conducts ongoing studies of existing and new products to accurately determine their properties, for example the evaluation of ammonium nitrate is almost completed, and characterization of emulsion explosives, the newest development in the explosives field, will be completed by 1984.

By 1985, the Canada Explosives Act will be converted from a chemical classification system to a hazard classification system. CERL will be evaluating a proposed test series (the United Nations Classification Series) to ensure that the conversion does not result in classification problems.

Developments in the explosives industry have resulted in the use of a greater variety of more finely divided materials (powders) as well as increased uses of plastics and other synthetic materials in the manufacture of explosives and pyrotechnics. As a result of these developments, this industry is encountering increasing hazards from dust explosions and electrostatic ignitions. Electrostatic hazards and/or dust explosions have been identified as the causes of two recent explosives manufacturing accidents which resulted in four fatalities and significant financial loss.

During 1982/83, CERL continued to study the thermal stability of explosives using its Accelerating Rate Calorimeter (ARC) and several different types of ammonium nitrate (AN) and mixtures of AN with fuels such as fuel oil and dodecane were evaluated. AN is a major component of most commercial explosives and its response to thermal stimuli may be a major contributor to the overall thermal stability of the explosive. A number of modifications were made to the ARC instrument to facilitate the loading of samples into sample bombs, pressure recording, and ground fault detection in the heating system. Currently the laboratory is evaluating a number of pure explosives such as PETN, RDX, and tetryl to fulfill some UN and NATO commitments before continuing the complex study of slurry and emulsion explosives.

CERL participated in the UN Group of Experts on Explosives meeting in August, 1982. It will also be attending an Informal Meeting in Pittsburgh during April, 1983.

During the past 12 months, CERL completed the installation of new test tanks to enable the laboratory to develop/evaluate certain tests. The major thrust was to evaluate a deflagration to detonation transition (DDT) test and develop an expendable pressure gauge for use in this test. The laboratory is currently testing a number of Canadian manufactured and imported explosives to determine how they react in this test.

The laboratory's Type 12 Impact Tool and U.S. Bureau of Explosive machine have been redesigned to permit the use of force rings. A number of reference standards including two UN explosives and one NATO explosive are currently being evaluated to confirm that the modifications did not affect the impact results (Test Series 3).

A series of commercial detonators has also been evaluated to determine if one or more of them are suitable as a reference standard for shock sensitive testing (Test Series 5).

The laboratory continued its study on factors affecting spark ignition of dusts, which required a significant upgrading of the laboratory's high-voltage equipment and measuring instrumentation.

The third phase of the Modelling of Slurry Explosives R & D contract was completed during which the Forest Fire Model and the critical energy criterion were further examined. The Fortran computer program of the Forest Fire Model for calculating the rate of decomposition of explosives was modified and adopted.

The study on the formation and distribution of hot spots in slurry explosives under projectile impact was further extended and a total of fifty-eight cases were studied for various combinations of variables, to complete the work and finalize the report.

The research contract with Queen's University on the fire and explosion hazards of ammonium nitrate was completed and was the subject of a seminar in November 1982, which was attended by government and industry representatives from Canada, USA and Europe.

MINERAL AND ENERGY TECHNOLOGY INFORMATION

The Technology Information Division combines into one functional unit all CANMET information-handling units: the Library Services Section, the Publications Section, and the Technical Inquiries and Documentation Section. Activities of the Division are described under three major headings: Information Resources Development, Information Processing and Information Dissemination.

INFORMATION RESOURCES DEVELOPMENT

The development of information resources encompasses the selection, analysis, evaluation and acquisition of published technical information related to CANMET's areas of expertise. These resources are required in order to facilitate and support in-house research as well as fulfill CANMET's strong commitment to "backing up" the national science-technology information network.

A total of 6377 new items were added to the Library collections, for total holdings of 205 877 volume equivalents at March 31, 1983. The Library currently receives 2386 periodical titles covering mining, mineral processing, energy and metallurgical technology.

INFORMATION PROCESSING

Information processing involves all those activities required to ensure that information can be effectively accessed by, and conveyed to, CANMET's many audiences and users, both actual and potential. It involves the organization through cataloguing and classification of information resources added to the Library collections, the development of a variety of indexes, catalogues and data bases, and the editing and physical preparation of reports by CANMET staff.

The Library staff, with increasing reliance on the computer-based UTLAS catalogue support system, was able to process 95 per cent of the new acquisitions.

MINTEC, the computerized data base on mining technology, increased by 1829 new records for a total count of 24 735 documents at year end. The mineral processing data base, MINPROC, stood at 6746 documents on March 31, 1983, an increase of 1678 records over the previous year.

Publication of the literary output of CANMET scientists and contractors resulting from in-house and sponsored research is one of the major activities of the Division. During 1982/83, 626 reports and papers were processed and published by the Publications Section. The table below summarizes the production by report category and source. The French version of "A Canadian Research Heritage" was completed and printed in November 1982. Editing, text processing and page makeup of Monograph 884, "Some instrumental methods for the determination of minor and trace elements in iron, steel and non-ferrous metals and alloys" was completed. The French edition of this work is in preparation and will appear in 1983-84.

INFORMATION DISSEMINATION

The goal of all activities involved in information resources development and processing is dissemination. The major clientele that TID serves is CANMET professional staff, to whom these resources are made available to support their research endeavours. However, CANMET's mandate includes the provision of technology-based advice to the government and technical information to the Canadian public. Consequently, the Technology Information Division provides services to other government agencies, as well as the Canadian public, especially the scientific and engineering communities,

CANMET PUBLICATIONS BY CATEGORY AND SOURCE
1982-1983

Category	MSL	ERL	MRL	PMRL	CRL	RPO	ERP	ADM	TID	TOTAL
CANMET REPORTS	9	2							1	12
Journal submissions	50	6	12	17	2					87
Oral presentations + Conference papers	27	22	24	16	10					99
Divisional reports	149	21	51	26	7		1			255
Internal reports	12	10	1							23
Confidential reports	2	39	5	9	1					56
Contract reports						94				94
TOTALS	237	90	104	78	21	94	1		1	626

by making known and available to them the unique and valuable information resources amassed by CANMET and organized and managed by TID as a public trust.

In the fiscal year 1982/83, the Library made 4056 loans over-the-counter to CANMET staff and filled 15 947 requests for photocopies for a total of 20 003 items, an increase of 5 per cent over last year. The circulation of current issues of journals to CANMET staff also showed an increase of 7.4 per cent over the previous year and amounted to 50 873.

As part of CANMET's commitment to the concept of a national science technology information network, a national service of document delivery, together with alternate location service is provided by the Interlibrary Loan Unit to Canadian industries, universities and government departments and agencies.

In fiscal year 1982/83, 5473 external requests for loans and photocopies were filled from the CANMET Library collections. The largest sector for borrowing continued to be the federal and provincial governments, closely followed by industry and universities.

Conversely, the CANMET Library borrowed 3356 items from other libraries to satisfy the literature requirements of CANMET research staff, compared with 2818 items the previous year. As expected, CANMET's Library continued to be a net lender, by a margin of almost 2 to 1, in its own areas of collection strength.

An ever-increasing usage of *MINTEC, the Mining Technology Data Base*, publicly available through Q.L. Systems since 1979, indicates its acknowledged value as a source of mining information for researchers in Canada and abroad. During 1982/83, 2511 searches were done on the file, an increase of about 10 per cent from last year.

MINPROC, the Mineral Processing Data Base, became publicly accessible through Q.L. Systems on January 1, 1983. Early results of use indicate that it, too, will be well received by the Canadian public.

The *Coal Data Base* is produced by cooperating IEA member countries. The Technology Information Division supplies Canadian input and is responsible for on-line access to the data base in Canada. This data base is made available through NRC/CISTI's CAN/OLE system. A total of 6095 searches were done on this data base during the year. Government agencies were the heaviest users followed by industry and universities respectively. The majority of searches originated in Ontario, followed by Alberta and Nova Scotia.

Inquiry Response Service

The Technical Inquiries and Documentation Section received 2572 major requests for information. Of these 2196 were handled by the Division's information officers, about 10 per cent less than the previous year. A decline in the number of inquiries directed to TID was anticipated as a result of the escalation of direct access to the MINTEC, MINPROC and COAL data bases. A breakdown by subjects and origin of inquiries is shown in the Table below. The remaining 376 inquiries were referred to CANMET scientists with specialist knowledge of the subjects involved or to other government and private agencies in cases where the requests appeared to have been outside CANMET's expertise or jurisdiction. Undocumented, "on the spot" inquiries involving names of various experts, mining company and industry association officials, addresses, readily ascertainable mineral production figures, and the like numbered just over 2000, while the Library reference staff responded to 765 general inquiries, answerable from the Library's own resources.

Various current awareness services are produced by the Technical Inquiries and Documentation Section. They include the following:

- Current Awareness Lists: computerized monthly printouts of new literature in diverse fields produced in cooperation with NRC/CISTI, using interest profiles constructed to match individual information needs. There have been 93 users of this service during 1982/83.

- MINTEC Fortnightly: a printed version of recent additions to CANMET's mining technology data base. It is now produced in a new format under a new title, "MINTEC/Mining Technology Abstracts". The first issue in the new format was published in February 1983. Currently it is being distributed to 81 recipients, primarily researchers in industry, government and universities. There were 24 issues in 1982/83.

- Bibliography of Canadian Contributions in the Field of Rock Mechanics: compiled annually by TID staff from a review of periodicals, proceedings of symposia and conferences, and lists of theses submitted to Canadian universities. The compilation is published in the Canadian Mining and Metallurgical (CIM) Bulletin.

- Current Contents - East European Mining and Mineral Technology: a compilation of translated tables of contents of East European periodical publications dealing with the mining, mineral processing and energy industries. It continues to be distributed to 26 clients interested in East European developments in mineral technology. There were five issues in 1982/83.

- Open File Reports: a bi-monthly bulletin of information on newly released CANMET publications and reports on research by external contractors sponsored by CANMET. Six issues were distributed in 1982/83 to over 800 recipients throughout Canada.

- The Catalogue of CANMET Publications: an annual cumulation of the bi-monthly Open File Reports Bulletin; supplemented by abstracts in English and French of all reports in the CANMET Reports series, and all papers submitted for

publication in external journals. It is distributed to over 1000 libraries, agencies and individuals at home and abroad, who expressed interest in the work of CANMET.

- Recent Acquisitions: a classified listing of new additions to the CANMET Library. Five issues were distributed to 130 clients during the year.

MAJOR INQUIRIES PROCESSED BY TID STAFF
BY SUBJECT AND ORIGIN, 1982-83

	Within Canada						Outside Canada				Total	
	CANMET	Other EMR	Other Government	Educational Institution	Industry	Other	Government	Educational Institution	Industry	Other	No.	%
Mining	41	7	27	25	108	30	2	14	48	6	308	14.0
Min. Proc.	78	5	6	8	46	14	6	3	7	2	178	8.1
Metallurgy	206	8	17	11	108	14	1	2	6	0	371	16.9
Energy	104	23	51	26	83	82	3	3	24	19	417	19.0
Gen'l Technical Inquiries	151	8	100	261	282	38	10	21	48	3	922	42.0
Totals: No.	580	51	201	331	627	178	22	43	133	30	2196	100.00
%	26.4	2.3	9.1	15.1	28.5	8.1	1.0	2.0	6.0	1.4		
	Total within Canada			Number	196.8		Total outside Canada			Number	228	
				Percentage	89.6					Percentage	10.4	

TECHNOLOGY TRANSFER

Created in December 1981, the Office of Technology Transfer (OTT) is a new component of CANMET. Reporting to the Office of the Director-General, OTT has a number of functions, including policy support, technology evaluation, project review and technology transfer. Perhaps the most visible contribution of OTT in 1982-83 was the coordination and writing of a submission to Cabinet on the Mineral R & D Program of CANMET. This submission on minerals technology, which included a new mission statement, received ministerial approval and was announced in the House of Commons by the Honourable Judy Erola in May 1983, together with a special two-year program, START (Short Term Assistance in Research and Technology), to help industry.

OTT's Technology Evaluation Group assessed a number of technologies, proposed or in the development stage, including processes for metal extraction of complex sulphide ores, coal liquefaction, and technologies for non-ferrous smelters. Under project review, OTT reviewed 35 R & D projects completed recently, and commissioned an indepth cost-benefit analysis of the Pit Slope Project, conducted at CANMET from 1972 to 1977.

Technology transfer activities focused on intellectual property and assistance to line divisions in relation to patent applications, assistance in market studies, and participation in planning via project authorization sheets. The technology transfer activity received a strong boost through the START program, under which $1.2 million will be made available for workshops, seminars, patent and licensing applications, special information packages, market surveys, and industry assessments.

NATIONAL URANIUM TAILINGS PROGRAM

As a result of a year-long study by a group of outside experts in uranium mining, processing and related fields, a National Uranium Tailings Research Program was begun in November of 1982. The 5-year, $10 million program will focus on the needs of uranium tailings management that are concerned with the safe control and disposal of uranium mine and mill tailings.

The overall objective of the program is to provide a scientifically creditable information base from which decisions can be made in establishing reasonable criteria for the protection of the environment, and which can also be used to propose practical guidelines for uranium tailings management in closing out tailing sites.

The program has been sub-divided into three major components: modelling, measurement and disposal technology. Modelling will focus on pathways analyses of radionuclides and other contaminants through the tailings into the biosphere; the measurement component will generate data to assist in defining the nature and extent of the dispersion and concentration of contaminants in the biosphere; and the disposal technology activity will examine various disposal options in relation to radiation exposure and costs, the results of which will serve as a basis for developing guidelines in closing out tailings.

The framework for the program structure and schedule covering the five-year period was completed at the end of 1982-83. The modelling activity is central to the program, but depends on the measurement input on the one hand to calibrate and validate the models, and the study of management technology options on the other hand to evaluate the future consequences of different disposal technologies and relate their performance to cost. Other elements of work considered basic to the program needs include the production of reference material standards for quality control of chemical analyses. Bulk samples were obtained for this purpose from four different uranium tailings sites in Canada. The elements for which analyses have been completed include: ^{230}Th, ^{226}Ra, ^{210}Pb, ^{210}Po, ^{232}Th, ^{228}Ra, ^{228}Th, and ^{238}U. Other elements determined were: Ti, Al, Ca, Ba, S and sulphate.

A system of computer data files has been developed to store and retrieve data on uranium tailings. A large amount of such data is currently on hand and considerably more will be generated as a result of the program. For the purpose of standardizing sampling procedures and obtaining representative samples from large tailing sites that would be comparable, a sampling manual was commissioned under contract. The manual describes the various factors that must be considered in defining a sampling program as well as for current sampling technology used to collect the necessary aqueous and solid samples. This manual is intended for use primarily by the program management, but will also be put in a form suitable for general public distribution in the near future. A review of the state-of-the-art of dynamic modelling of uranium tailings was also completed. The completed report evaluates and documents relevant models for pathway analyses of uranium tailings contaminants.

Other contracts completed during the year were: a report on the economic feasibility of removing pyrite from tailings in the Elliot Lake district which would reduce the contaminating character of the tailings and provide a source of sulphuric acid; the modelling of the behaviour of lysimeters, containing uranium tailings, located at the Waste Water Technology Centre at Burlington, Ontario; and a survey with descriptions of all uranium tailing sites in Canada.

APPENDIX A

CANMET PROFESSIONAL STAFF

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PUBLICATIONS

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J.L. Harcourt; Ed. Asst. (English)
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