CANMET REVIEW 1983-1984

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FOREWORD

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.

In simple terms, the three principal 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 — 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.

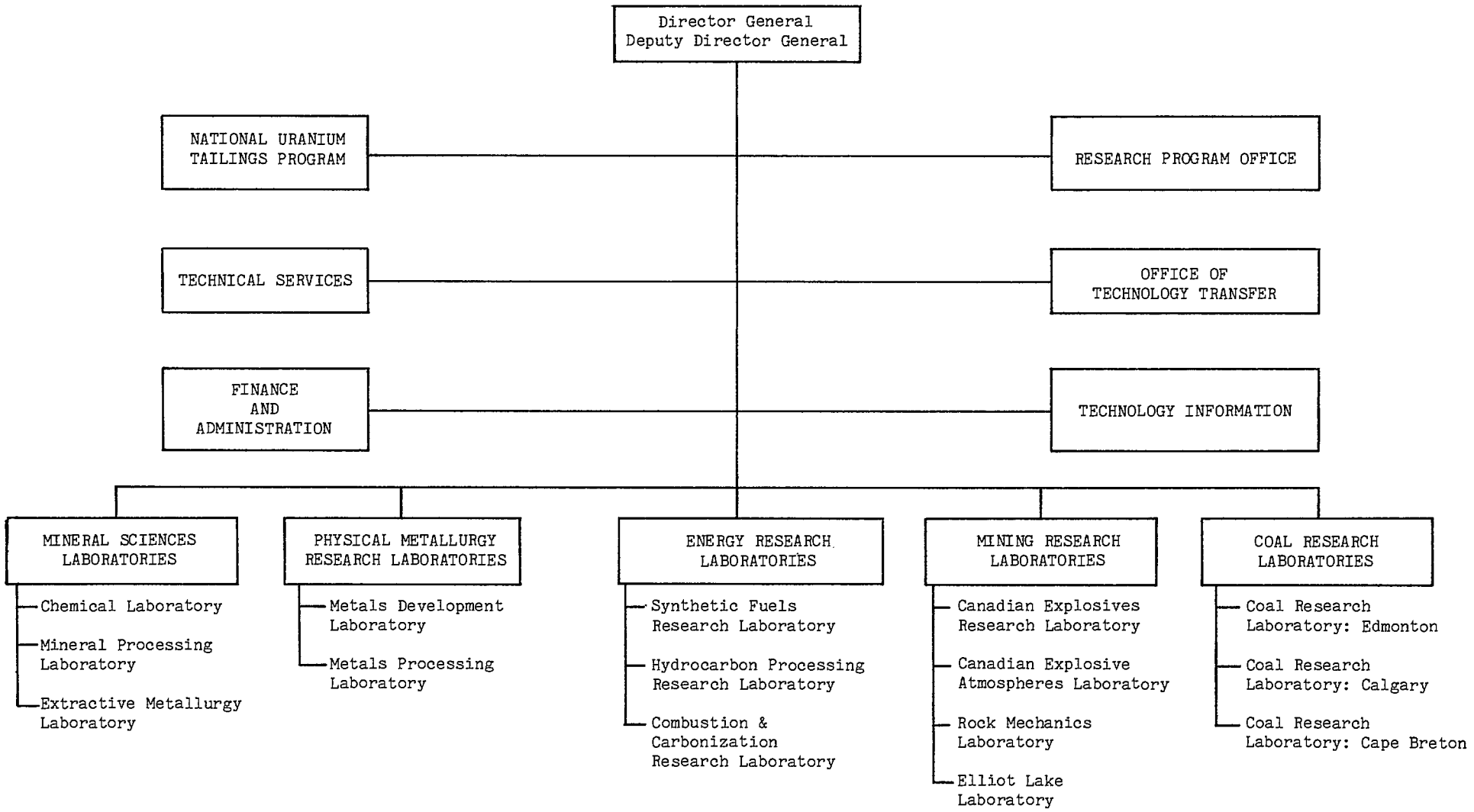
In addition, technology transfer is an integral part of all CANMET activities. A complete range of transfer techniques, from information dissemination to joint R & D projects, is used. Moreover, the longer-term R & D projects develop expertise which is also of use in shorter-term industrial R & D. This is carried out on industry request, commonly on a shared or cost-recovery basis, wherever the required R & D does not conflict with service-type investigations available from the private sector. Approximately one quarter to one third of the budget is assigned to the contracting out of R & D, thus supporting technology development across the country.

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 Assistance 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 diversion of research effort from the historic medium- and long-term research work in the branch. In addition to this increase in short-term research work, the START program also upgraded CANMET facilities and enhanced industry access to existing CANMET expertise and facilities. The transfer of know-how took many forms, from small workshops to on-site visits of the mobile foundry and the mobile coal preparation laboratories.

New research thrusts that may profoundly influence mining, metallurgical and energy research are the emerging 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

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY (CANMET)



CANMET MANAGEMENT 1983-1984

Director General - W.G. Jeffery

Deputy Director-General - J.T. Jubb

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

1983-1984

	PERSON YEARS	OPERATING FUNDS $ 000	CAPITAL FUNDS $ 000
ENERGY TECHNOLOGY			8 850
Conservation Technology	8	1 125	
Petroleum Supply Technology	92	7 534	
Coal Technology	147	11 811	
Nuclear Technology	28	1 107	
Renewable Energy Technology	14	863	
Research Program Office (incl. contracts)	9	1 014	
Office of Technology Transfer	1	109	
Information and Library Services	17	1 457	
Technical (Engineering) Services	31	1 849	
Management and other common services	56	5 355	
Grants and Contributions		150	
MINERAL TECHNOLOGY			2 124
Mining Technology	15	1 051	
Health and Safety in Mining	20	859	
Conservation and Resource Management	21	727	
Mineral Processing Technology	48	2 163	
Environmental Technology	30	1 796	
Materials Development Technology	38	1 945	
Metals Processing Technology	55	2 544	
Standards and Specifications	24	771	
Research Program Office (incl. contracts)	4	379	
Office of Technology Transfer	10	614	
Information and Library Services	19	1 385	
Technical (Engineering) Services	32	1 924	
Management and other common services	53	4 029	
Grants and Contributions		6	
ADMINISTRATION OF THE CANADA EXPLOSIVES ACT	14	504	44
TOTAL	786	53 071	11 018

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ENERGY TECHNOLOGY ACTIVITY

CANMET's energy research and development deal mainly with the processing and use of Canada's oil, gas, coal, and uranium reserves. As in past years the main objective of energy research is directed to fulfilling the goals of the National Energy Program. CANMET, because of the expertise which it has built up over the years, acts as Canada's foremost agent in the research and development of new energy technology.

This review summarizes the energy-related activities, and describes the progress and achievements during fiscal year 1983/84. 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. Other objectives are to assist in strengthening competitive capabilities of Canadian industry, and to provide leadership and liaison in dealing with groups at the international, provincial, or industry levels.

The fundamental principles, upon which the planning foundation and frame of reference are based, are 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 assumes the role of a public sector agency responsible for providing R & D under circumstances where the private sector cannot be expected to perform the services necessary for our society. Research planning at CANMET is based on this fundamental premise and comprises the frame of reference for the planning and programming task.

This review portrays the scope of the energy program in a variety of settings. Research projects are selected so they are most cost-effective in meeting a particular program objective, 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.

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 are also called upon to act as technical advisers on demonstration projects coordinated by other government agencies.

The importance of public and private sector cooperation through contracting, cost sharing, and joint projects is increasingly evident. 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 resources of coal, peat, uranium and low-grade petroleum materials, remains CANMET's main raison d'être. 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.

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, and 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 work on fossil fuels and placed greater emphasis in such areas as conservation, renewable energy sources, 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.

CANMET has main areas of interest in the area of energy conservation in the industrial minerals sector; these are: a) comminution, b) clay and brick kilns, c) use of supplementary cementitious materials in concrete. Most of the work is being undertaken under contract. However, in the area of supplementary cementitious materials involving the use of non-ferrous slags, CANMET has initiated some in-house research.

Residential and Industrial Energy Conservation

The ENERSOLVE program is concerned with increasing the efficiency of utilization and reduction of consumption of oil and gas in industrial processes. Much of the present industrial equipment, particularly if more than 10 years old, may not be operating or even operable at maximum attainable efficiency of fuel use. Scope exists to technically upgrade more installations to attain greater fuel economy. The program is intended to sup-

port 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 payback.

Five pre-engineering studies, including on-site testing, were carried out in 1983 for the following industrial processes: cement kiln; brick kiln; chemical processing boiler; uranium processing boiler; combined solid waste-gaseous-fuelled food processing plant.

Summary report on the results is being prepared, highlighting the performance results obtained and the recommendations for efficiency improvements, and including the cost-effectiveness of various options. It will also present a general methodology for testing and analytical procedures for the determination of the efficiency of industrial combustion systems.

CANMET is conducting a major research program in domestic gas furnaces 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 goal of the experimental program is to determine actual fuel savings with these new technologies. Field trials are also being carried out to measure, on an alternating basis, performance of conventional and advanced technology equipment in normal and in high energy efficiency housing.

Because of the large number of homes which have been recently equipped with the low efficiency conventional gas furnaces, CANMET is carrying out a major effort to develop equipment which could be used to upgrade these existing furnaces to the very high levels potentially available with the advanced new equipment. In fact, one major furnace manufacturer has produced a retrofit condensing flue system. Field trials on ten of the units are being carried out this heating season, with a view to bringing this product to market as soon as possible. A retrofit induced draft system will also be developed to offer major fuel savings and reduced air requirements at low cost.

Further work is being carried out to determine additional potential efficiency improvements in both new and existing systems. This work is concentrating on the elimination of the draft dilution device.

Work is now being carried out, in cooperation with the major oil companies, to determine the effects of lower fuel quality and high aromatic fuels on performance, in order to free up more middle distillate fuels for the diesel market.

Characteristics of smoke opacity, flue gas composition, temperature and ignition behaviour are studied to determine correlation with fuel properties. To date, 16 fuels have been investigated. The results suggest strong links with burner performance and physical as well as chemical properties of the fuels themselves. In general, high aromatic fuels generate higher levels of particulates and gaseous hydrocarbons. When the aromatic content is greater than 70%, ignition is poor, with rumbling and pulsation. High viscosity fuels show similar effects, especially those with higher aromatics. In fact, the burner fails to ignite when the fuel has a viscosity greater that 4 cSt at 40°C and a high aromatic content. Fuels with a high specific gravity tend to generate higher levels of NO_x. Work is now proceeding to isolate the effects of specific properties.

CANMET is carrying out a detailed R & D program on domestic wood-fired equipment. Field trials have shown that controlled combustion wood stoves, in particular, if of good design and properly located, can operate at efficiencies higher than conventional oil or gas furnaces, offering a renewable energy that can be set in place relatively quickly. Most present designs, however, have poor combustion, especially at low firing rates, giving rise to serious concerns about their pollutant potential. While they are normally among the simplest heating appliances in common use, solid fuel-fired appliances proved the most difficult when attempting to determine their efficiency or emissions performance.

Another study was performed for the Canadian Electrical Association to determine potential problems with the use of plenum heaters on oil furnaces. It was determined that chimney deterioration may increase with increased use of plenum heaters. If run with a lower outside temperature set-point, moist house air may flow up the chimney, condense and migrate into the mortar, causing deterioration. In the worst case, the interior of the chimney might collapse and cause flue blockage. This may occur in chimneys that are in good condition; defective chimneys, of which there are a large number, would be even more prone to this problem and should be repaired before a plenum heater is installed. A more severe problem may exist with a different type of control strategy — a two-stage thermostat operation throughout the winter. This may result in continuing condensing conditions when the oil furnace is firing on a reduced cycle length in cold ambient temperatures. Under such conditions, rapid chimney deterioration is possible. To minimize chimney problems, the oil furnace should be run for a fixed period every day, say between 1600 and 1900 h, each day of the heating season, to dry out the chimney regularly, while also operating with a low outside set-point the rest of the time. This might even have an electrical demand benefit for the local electric utilities.

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 this past year on the development and exploitation of sodium beta-alumina for use in energy

storage and conversion. During the past year, the electrical properties of single-phase, theoretically dense sodium beta-alumina, produced in the previous period by a spray-drying process, have been determined and the influence of progressively greater concentrations of potassium on the sintering, microstructure and electrical properties of this material has been studied and the initial data published.

The development of sodium/potassium sintered precursors has continued with emphasis on the development of commercially viable processes (unlike the freeze-drying route used initially). Unfortunately, it has proved difficult to produce the required material using commercially available raw materials and industrially acceptable processes. Work has continued under contract to McMaster University to produce these materials using a spray-drying process to sinter them to over 98% theoretical density and ion exchange the materials to proton-conducting solids.

During the period, the contractor succeeded in producing small, highly conducting discs of one of the materials in the hydrogen-conducting form and demonstrating its use in an electrolyser operating at ≅100°C. Patent application for the processing of the precursor and for its conversion to the hydrogen-conducting form has been filed.

CANMET continued conducting and sponsoring research on other electrolytes used in electrical storage and conversion devices. Contrary to data published by others, CANMET has shown that sintered zirpsios commonly contain a grain-boundary glass and are readily degraded by water (exposure to air is sufficient) and liquid sodium at 350°C — the latter precludes these materials displacing sodium beta-alumina in a conventional sodium-sulphur battery. The degradation is due to the preferential dissolution of the glass phase. The correlations between processing and subsequent degradation under service conditions were reported in papers presented to the Annual Meeting of the Canadian and American Ceramic Society and subsequently published.

Hydrogen by Photoelectrolysis

Basic and applied research continued during 1983, in coordination with outside contractors and with the International Energy Agency (IEA), on the production of hydrogen from water. The contract with McGill Industrial Research was completed by 1983, and preliminary tests appear very positive. Work to develop methods for preventing photocorrosion of semi-conductors by kinetic control of charge transfer by depositing catalysts on the surface has continued.

Participation in the IEA Task VI activities on hydrogen production by photocatalytic electrolysis of water using solar energy continues, as this program has been officially extended until the end of the 1984/85 fiscal year. CANMET work under this project has been submitted to the IEA Task VI, and a paper reviewing CANMET's total contribution so far, has been submitted for presentation at the 5th World Hydrogen Energy Conference and for publication in the Conference Proceedings.

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 greatly enhance Canada's huge reserves of heavy oils and tar sands in western Canada. The objectives remain 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

Only processes which involve mining have been successful so far in the production of synthetic crude oil from the Athabasca area where our largest resources of unconventional heavy oil are located. Expanded commercialization of these processes, which will provide a major stimulus to the whole Canadian economy, is highly dependent on development of a new generation of technology.

Demonstration is crucial for extraction processes which are the key to improving overall economics, environmental compliance and compatibility with hydrogen upgrading processes. In recognition of this priority, EMR provides 25% of the funding while participating in Phase IV of the AOSTRA/ Industry study of the feasibility of establishing an Oil Sands Demonstration Centre in Alberta. A decision on engineering, procurement and construction may be reached by the end of 1984.

The success of pilot and commercial in situ projects in western Canada, including the large Lloydminster, Cold Lake, Wabasca, and Peace River reservoirs is encouraging. In situ thermal processes now have realistic potential for completely offsetting the declining production of conventional oil in western Canada. AOSTRA and industry have the primary mandates for in situ oil recovery. However, EMR's presence provides an improved balance of R & D and development of Canadian expertise primarily via contracts and cooperative projects.

McCallum Stewart and Associates completed an overview assessment of deep heavy oil reservoirs in western Canada and conducted detailed studies of two reservoirs in Alberta and two in Saskatchewan which are candidates for demonstration of the use of a downhole steam generator.

Winestock Petroleum Consultants completed an authoritative study of problems, incentives, and priorities associated with enhanced heavy oil recovery. Specific recommendations concentrate on improvement of reservoir sweep efficiency. The study complements the screening of blocking and diverting agents conducted

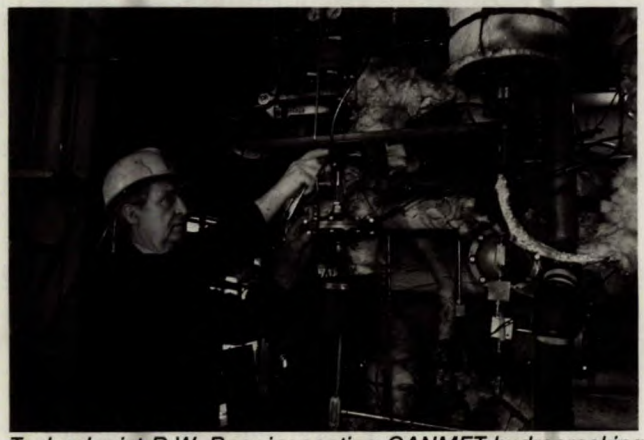
John Margeson adjusting a valve on an experimental unit to study the recovery of bitumen from oil sands

by the U.S. Department of Energy under a Canada/U.S. Memorandum of Understanding for bilateral research on bitumen and heavy oil. Follow-up research based on the Winestock recommendations is planned.

Contracts were initiated for studies of thermodynamics, kinetics and problems associated with the conceptual use of wet oxidation for steam generation using untreated water and low-cost ancillary fuels; low-pressure physical modelling of in situ steam processes in complex reservoirs; and development of innovative methodology for numerical modelling of in situ steam recovery of heavy oil.

Upgrading of Bitumen/Heavy Oil (Hydrocracking)

A total of eight pilot plant runs, each 30 days in duration, were carried out under this project in support of the demonstration unit now under construction in Montreal. Blend 24, a new potential demonstration plant feedstock, was utilized. In addition, a series of five runs with different additive concentrations and compositions was carried out with this new Venezuelan heavy oil feedstock and, although this feed proved to be one of the hardest to process to date, suitable conditions were identified for long-term trouble-free operation.



Technologist R.W. Beer inspecting CANMET hydrocracking pilot plant used for development of bitumen and heavy oil upgrading

To assess the impact of heavy gas oil recycle on process operability, a pilot plant experiment was performed using a mixture of Blend 24 and heavy gas oil. This technique appears promising, but final evaluation awaits analysis of a comparison run.

As a cost-cutting measure, Petro-Canada was contemplating eliminating the hydrogen recycle scrubbing system in the demonstration unit now under construction. To assess the impact of such a move on process operation, a pilot plant run was conducted at the lower recycle hydrogen concentration expected in the absence of a hydrogen purification unit in the demo plant. Based on the results of this run, it was recommended that a hydrogen scrubbing system be installed in the demonstration plant.

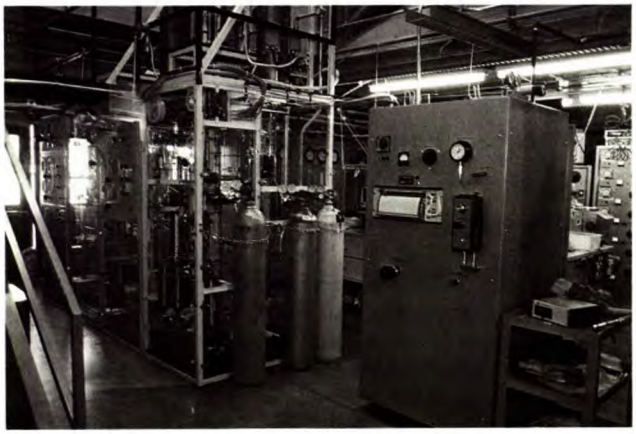
A series of continuous stirred tank reactor (CSTR) experiments were completed to assess the effect of space velocity on the thermal stability of the hydrocracking process. A residence time distribution study was also performed during these runs.

Technologist C.A.W. McNabb operating short path length distillation unit for separation of products from CANMET hydrocracking pilot plant

A series of additive optimization experiments in the autoclave were completed and experimental programs for assessment of new and modified additives and for feedstock processibility are underway. The additive assessment program has identified new techniques for additive improvement which will be actively pursued during 1984/85.

CANMET participated in a joint Petro-Canada/Lavalin/EMR process-modelling study for the CANMET hydrocracking reactor. An in-house computer simulation study of solids concentration profile in a varsol-air-glass beads system was also completed.

Work on spectroscopic and mechanistic studies of the hydrocracking process is underway, while detailed microscopic and spectroscopic characterization of additives and reactor solids was performed in conjunction with the pilot plant and autoclave program. The information from these studies is proving invaluable in the assessment of the factors influencing additive activity and the mechanisms of coke formation and inhibition.



This dual mode hydrocracker is used to test and develop catalysts for the hydroprocessing of synthetic crude distillates

As part of an assessment of the factors influencing coke formation, an in-house experimental program on the effect of coal oxidation on additive coke inhibition was initiated, and a preliminary correlation of asphaltene hydrogenation with coking was completed.

Work was carried out under a cooperative agreement with Petro-Canada in support of the commercialization of the CANMET hydrocracking process. Two feedstocks were assessed by establishing the 'system coking propensity' using a proprietary method developed by CANMET. The results are contained in a confidential report.

The Catalytic Hydroprocessing Section is responsible for the preparation of CANMET additives for evaluations and tests in the pilot plant. Twelve batches of additives were prepared during the year. Because of lengthy procedures involved, spanning several days, the additive preparations often required considerable planning and organization involving members from different sections of the division.

Work contracted out in support of CANMET hydrocracking included studies in the areas of cold modelling and three-phase flow, gamma densitometry, the kinetics of coke formation, and the influence of coal oxidation on additive activity.

Upgrading of Bitumen/Heavy Oil (Novel Concepts)

CANMET has continued its efforts to develop a catalyst for transforming the heavy feed from both conventional and unconventional sources to more acceptable refinery feedstocks. One product of this work would be lowering of the viscosity of the bitumen and heavy oil to levels compatible with conventional pipeline standards.

The work performed during the year resulted in the development and perfecting of a method to prepare catalyst supports having a wide range of pore structures and pore-size distributions. Several catalysts were prepared using these special supports. All of these catalysts had large pore diameters and hence were capable of providing access to large hydrocarbon molecules such as asphaltenes. Experimental data on the efficiency of these catalysts to convert the asphaltenes contained in Athabasca bitumen to lower molecular weight species were obtained and evaluated to determine an optimum pore structure for asphaltene conversion.

Dr. E.J. Anthony, Research Scientist, operating the computer-controlled data acquisition system and analyser bank for the pilot-scale fluid-bed combustor

In the future, hydrocracking processes are expected to be used to upgrade heavy oils and bitumens. These will yield from 5 to 10% unreacted pitch. To utilize this material, testwork has been underway to convert pitch into useful products through catalytic pyrolysis of pitch followed by catalytic gasification of the remaining char, both in fluidized-bed reactors. Results show that some 30% of low sulphur liquid products and 6% gases (mainly methane) can be produced from pitch. The major difficulties experienced are feeding molten pitch into the reactor and the agglomeration of bed material (catalyst) with sticky pitch. For the present, testwork is restricted to solid feeding of pitch which is diluted with catalyst at a rather low pitch-to-catalyst ratio.

Upgrading Synthetic Crudes To Transportation Fuels

Work was initiated to investigate the possibility of utilizing refractory processing residues (pitches) such as those from the CANMET hydrocracking process for the production of road asphalts. The utilization of these processing residues undoubtedly has a significant influence on the commercial viability of any non-coking synthetic crude production operation such as the CANMET hydrocracking process. The quality of asphalts containing various amounts of pitch from runs at different levels of conversion has been studied.

This work on the blending of pitches with base asphalt stock is accompanied by fundamental studies of the individual components of both pitches and asphalt blends and correlations of the contents of the various components with asphalt properties. This will enable the tailoring of pitch-asphalt stock blends to attain the derived asphalt properties. Arrangements have been

made to conduct additional studies on asphalts at the TOTAL Oil Company in France.

At CANMET the use of sorbents is being studied for the removal of catalyst deactivating nitrogenous and sulphurous components in synthetic crudes. The economic removal of these components would obviate or reduce the need for hydrotreating and allow the use of active hydrogenation catalysts at lower temperatures at which the hydrogenation is thermodynamically more favourable than at the high temperature required with conventional catalysts. Various sulphidic minerals, mining wastes, halogenated ilmenite and ziolites have been investigated for removal of nitrogenous components. The sulphidic minerals and mining wastes were found to possess insufficient capacity for further consideration; the halogenated ilmenite, however, possessed some interesting properties.

The approach taken for in-house research in the separation of saturated and aromatic hydrocarbons is to study the possibility of attaining the desired separations by reverse osmosis. This complex work is still in the early stages and during the year considerable efforts were needed to establish additions and improve the required facilities.

Hydroprocessing of Syncrude middle distillates from fluid-coked Athabasca bitumen was carried out over a sulphided nickel-tungsten on alumina catalyst using semi-pilot plant hydrotreaters. Production of specification diesel fuels was achieved by additional input of hydrogen to saturate excessive aromatic concentrations. Compositional analyses of feedstock and products were performed using low-resolution mass spectrometry and aromatic carbon content was determined by C-13 NMR. By this means the effects of hydroprocessing temperature and LHSV on aromatics conversion were monitored. Differences in reactivity, including the effects of thermodynamic equilibria and cracking, were observed for various aromatic species. Engine tests performed provided the relationship between the aromatic content and the cetane rating of the products obtained. Comparisons were made between these and previously published results for distillates from delayed coking.

Materials for Production and Processing

CANMET has continued its work on the prediction of the load and power requirements for roll forming of thick section plate. A contract has also been completed which defined the welding procedures to avoid weld metal cracking in heavy section Cr/Mo steel weldments.

Contract work continues on a basic study of the effect of weld process parameters on the microstructure and mechanical properties of welds using the metal-inert gas and flux-cored narrow-gap welding processes. The work on development of NDT methods for characterizing defects in heavy section welds has progressed to the stage where an ultrasonic wave system and an acoustic emission system have been assembled under contract and will be subject to shop trials in the coming fiscal year.

Studies were carried out, at the CANMET laboratories, which determine the effect of various environmental factors on the service performance of pressure vessel materials. Current work is directed to evaluating the degree of temper embrittlement in weld metal. A series of welds have been prepared by the submerged-arc narrow-gap process using a range of currently available welding wires and fluxes. Initial results indicate that the decrease in notch toughness attributed to temper embrittlement was of the order of a 20°C increase in the Charpy transition temperature. The phenomenon of hydrogen-induced disbonding in stainless steel weld overlay has been studied by simulating, in an autoclave, the pressure-vessel operating environment of high-pressure, high-temperature hydrogen. The crack morphology associated with disbonding has been studied metallographically and a simple computer model of the hydrogen profile during the autoclave treatment and subsequent cooling has been made. Some suggestions have been made associated with weld overlay fabrication and pressure vessel shutdown conditions to ameliorate the problem of disbonding. Future work will concentrate on improving the interface conditions through the weld overlay process.

With conventional oil reserves declining and prices escalating, heavy oil will undoubtedly play an important role in the future to help meet our growing energy needs. Therefore, a study of materials to support the processing of oil sands was undertaken.

Laboratory tests were conducted using mild steel and stainless steel type 304 to determine wear rates in simulated oil sand slurries at atmospheric pressure and temperatures ranging from 40°C to 90°C in aerated and deaerated conditions. The results were calculated in terms of compatibility with a mathematical model that allows separation of corrosion and erosion rates on the basis of the differences in their variation with test velocities. The welding of heavy-section steels for applications such as thick-walled reactor vessels, and offshore structures requires the development of narrow-gap welding processes to reduce the volume of weld metal and improve productivity.

Through external contracts, the development of narrow-gap welding is proceeding in two major industrial fabricating shops. Submerged-arc narrow-gap systems have been commissioned and weld procedures for joining Cr/Mo steels in thickness up to 200 mm are being developed. The final phase of this work will involve the joining of representative curved sections of heavy-walled pressure vessels. The narrow-gap welds must meet the stringent notch toughness properties required by the petrochemical industry.

In-house work on this project has involved the evaluation of the microstructures and related mechanical properties of Cr/Mo heavy section welds prepared by the narrow-gap submerged-arc welding process using a

square wave AC power source. Of the nine wire/flux consumable combinations that have been evaluated, approximately 50% resulted in welds which achieved a toughness requirement of 40 J at -40°C.

Materials for Oil and Gas Pipelines and Off-Shore Structures

The development of high-strength low alloy (HSLA) steels for linepipe application is an evolutionary process with a continual demand for leaner alloy chemistries, thicker gauges, high strengths and greater toughness.

Currently, Canadian linepipe producers cannot supply large-diameter pipe to grades higher than 483. One processing route which could potentially produce high strengths for a given steel chemistry is on-line accelerated cooling (OLAC). A commercial Mn-Nb-Ti-Mo steel has been controlled-rolled to six schedules using a range of finish-rolling temperatures, followed by either air cooling or quench cooling at rates simulating OLAC. The accelerated cooling was sufficiently rapid to produce a mixed fine-grained polygonal ferrite, acicular ferrite microstructure. These structures were more uniform and less bonded than the air-cooled structures. Dilatometry tests show that cooling rates in excess of the 4-6°C/s used were necessary to ensure a fully acicular ferrite microstructure. Electron metallography has shown that accelerated cooling increases substructural strengthening but reduces precipitation strengthening. Simulated OLAC resulted in significant strength increase with little change in tensile ductility. Although incomplete, impact tests have shown improved toughness with reduced fracture surface separations. An optimum combination of strength and toughness was found for a schedule having a finish rolling temperature just above A_{r3}. As a development to promote the laboratory's capability to evaluate the potential of OLAC, a small-scale facility has now been designed for the PMRL rolling mill.

The precipitation of Nb and/or V carbonitrides provides an important strengthening mechanism in microalloyed steels. In order to determine how various process parameters can affect precipitation and the resultant mechanical properties, a quench dilatometer has been used to perform simple simulations of rolling practice. Using hardness as a measure of the mechanical properties, it was found that cooling rate had the largest effect, while deformation temperature and cooling temperature were less important. The size and distribution of precipitates are now being characterized by transmission electron microscopy.

Earlier work with the CANMET rolling mill on the development of microstructure during roughing showed the importance of the accumulation of strain during several light passes. Although a mixed structure of recrystallized and unrecrystallized grains persisted during rolling, there was progressive austenite grain refinement. These results have been compared with the results of single-pass deformation schedules on a quench dilatometer. Data were developed on the time for static recrystallization and recrystallized grain size, as a function of initial grain size, strain and temperature. Similar final grain sizes were obtained after one pass of 50% deformation, to those obtained in rolling mill tests where multiple passes achieved 50% total deformation.

In contract research at McGill University, recrystallization kinetics during and after hot working have been determined in microalloyed steel containing 0.05% to 0.25% Ti. A computer program, using microalloy interaction coefficients, has been developed to predict the solubilities and order of precipitation of microalloy compounds for specific hot-working conditions. Recrystallization kinetics determined earlier in this contract research for steels with single, binary and tenary microalloyed additions of Nb, Mo, and V were correlated and interpreted in the practical terms of microalloy chemistry and the design of controlled-rolling processes.

In a three-year contract with McMaster University, the distribution and chemical composition of precipitates in linepipe containing Ti have been characterized by high-resolution STEM electron microscopy. Earlier work demonstrated the importance to the final precipitate characteristics of process parameters during casting, rolling and welding. A model of Nb and Ti partitioning which is dependent on the solidification path has recently been tested for examining continuously cast slab in various locations that had been cooled at known rates. The prediction by the model that there would be significant differences between precipitates in the extreme outer skin and those at the centre of the slab has been shown to be correct. Some progress has also been made in interpreting energy loss spectra to determine carbon and nitrogen contents of precipitates.

Mechanical damage in the form of dents and gouges can be produced in a pipeline during construction by rocks and debris in the trench or by contact with the construction equipment. The research investigates how damage affects failure behaviour and the degree to which it can be tolerated. Earlier work examined the offset of dents; current work focuses on gouges and gouge-dent combinations. Pipe specimens that have been gouged to simulate scrapes have been pressure tested; all failed by fractures that initiated at the gouge. The results were compared with existing failure models and a new model incorporating the concept of plastic collapse stresses was developed. This model may be used as a first approximation to determine the safe operating pressure of a pipe with a gouge. Pipe specimens with a gouge-in-a-dent are being prepared for testing.

Pipelines are subject to electrochemical attack from two sources during service that can lead to subsequent failure. Internal hydrogen attack can result from the transmission of sour (H_2S-containing) oil or gas. External attack can result from soil-borne corrodents through attack at pipeline coating defects.

As supplies of 'sweet' oil and gas diminish and more sour wells are exploited, H_2S-attack will become increasingly important. In recent years, costly failures

caused by H_2S have occurred in western Canada. Awareness of the problem resulted in a collective initiative with industry in share-funded research at PMRL, now in its third and final year. Two forms of H_2S-induced cracking, sulphide stress cracking (SSC) and stepwise cracking (SWC) are being studied. The susceptibility to SSC and SWC of nine gas transmission pipes, covering Grades 290-483, has been evaluated using standard NACE test methods. SWC data obtained on unstressed coupons cannot reliably predict the behaviour of a sour pipeline under stress, because some steels fail by intergranular or cleavage mechanisms independent of SWC. However, other steels, chiefly those with elongated inclusions, apparently fail under stress by an 'SWC mechanism'. The standard SSC test is in principle capable of predicting behaviour of a sour pipeline under stress, regardless of details of the failure mechanism. Extensive measurements to characterize inclusions in the steels have been made in two orientations and correlated with the crack-length measurements of the SWC tests.

Many Canadian pipelines are in the last stages of their projected life. As pipelines age, coatings deteriorate and cathodic protection can become less efficient. This process leads to possible failure by stress corrosion cracking (SCC). Comparisons of the SCC susceptibility of specimens from various locations in two grades of linepipe steels have just been completed. The comparisons were made by slow strain-rate tests in CO_3/HCO_3 environments. The following conclusions result: (i) Grade 483 steel is more susceptible to SCC than Grade 414 steel, with weld metal being more vulnerable than HAZ or parent metal; (ii) an anodic dissolution-hydrogen embrittlement mechanism operates in a CO_3/HCO_3 environment with maximum susceptibility at potentials near the primary passive potential; (iii) typical crack propagation rates are about 10^{-6}6mm/s.

As shallow and sweet oil and gas wells are depleted, higher quality steel tubular goods are needed for service in the harsher environments prevailing in new, deeper wells.

Work has been started to develop and evaluate materials and processing techniques for producing these oil-country tubular goods. Also, preliminary sulphide stress-cracking tests have begun on three Grade 621 steels.

Stresses in a pipeline can change because of shifts in the soil supporting the pipe or through changes in pipe-wall thickness, for example by generalized corrosion. Monitoring stress changes in a pipeline periodically offers the possibility of detecting stress concentrations before failure.

CANMET and NRC/IMRI are jointly sponsoring research at Queen's University to correlate magnetic measurements with stress level. A unified theory of ferromagnetic hysteresis has been developed. Magnetic measurement interpretation is made more complex because a mechanical stress cycle shifts magnetization towards anhysteretic magnetization (which is also slightly stress dependent). Current work is directed towards the refinement and application of this theory to incorporate time-pressure effects and to detecting stress changes resulting from simulated generalized corrosion.

Earlier work has identified the coarse-grained heat-affected zone (CG HAZ) of a linepipe seam weld as a region of low toughness. This problem is being addressed in two contracts.

In the first contract the fundamental factors controlling the toughness of the coarse bainitic microstuctures which characterize a CG HAZ have been studied with particular emphasis on the role of niobium.

In the second contract, only recently started, attempts will be made to reduce the overall heat input in making a seam weld by using a combination Gas-Metal-Arc Welding/Submerged-Arc Welding (GMAW/SAW) process.

Another aspect of this project has been the problem of reliably producing large-diameter linepipe fittings to the specifications of Grade 414 and above. Recently concluded work has shown that adequate strength and toughness in the weld metal cannot be obtained simultaneously if the normalized and stress-relieved process route is used. Weld consumables and process conditions appropriate for a quench-and-temper process route have been chosen in a cooperative project with a fittings producer in which, to date, preliminary welds have been made.

The effects of welding consumable formulation and joint type (constraint) on weld-metal toughness will be investigated for Shielded-Metal Arc Welding (SMAW), Flux-cored Arc Welding (FCAW) and Submerged-Arc Welding (SAW) processes. The experimental work has recently started to evaluate currently available consumables from several manufacturers for each process. Some of this work is being done under contract (SMAW & FCAW).

A set of special clip gauges to ensure fatigue-crack closure has been designed and made, as well as a set of specimen grips. A series of trial welds have been made to select the correct joint type and welding procedure. The specimen design has now been finalized and a series of drawings made. Further welding trials are necessary followed by strain gauge measurements of residual stresses before actual fatigue-test specimens can be produced.

The investigation of the effect of sea water temperature on corrosion fatigue-crack growth rate in steel was completed. Analysis of PMRL experimental results and all available results from other laboratories show that fatigue-crack growth rates in cold sea water (0°C) are, by almost a factor of two, lower than growth rates in sea water at room temperature. It means that fatigue damage in offshore structures will accumulate at a significantly slower rate in cold seas than in warm seas.

The three fatigue-testing systems (100, 250 and 500 kN capacity) for testing of welded T-joints in the new corro-

sion fatigue laboratory have been commissioned and the first six joints (23 mm thick) tested. The AC potential instrumentation for monitoring of the crack growth has been calibrated.

Stress concentration and stress intensity factors have been determined for cracks at the weld toe in a plate T-joint for various weld geometries and modes of loading, using finite element analysis. Ten 3-D cases for surface cracks with depth and aspect of ratios of interest, have been solved. The solutions will be used in analysis of PMRL experimental data, and finally in development of procedures for production of residual life of flawed structures using fracture mechanics.

Stress distribution and SCF in a T-tubular joint loaded axially and in-plane bending have been determined. Analysis of stress redistribution in the presence of cracking is underway.

Conversion of Natural Gas to Liquid Fuels

Canada has large amounts of natural gas that are surplus to domestic needs. Natural gas can be reformed to synthesis gas (also available by gasification of coal and biomass) with well-established technology and this gas can be converted to liquid fuels by means of the Fischer-Tropsch (FT) process. The conventional FT produces products having a wide range of boiling points. Generally, the objectives at CANMET are to develop FT catalysts with increased product selectivity for producing high quality diesel fuel from natural gas so as to decrease Canada's dependence on imported crude and establish a blending of stock for the hydrogen-deficient distillate liquids. The first stage of this project continued in 1983/84. The design of a fully automated high-pressure flow system with a microplant-scale fixed-bed reactor controlled by a unique six-zone computerized furnace and with on-line products-sampling capability has been completed. Also, all equipment and accessories required at this stage have been purchased.

In the area of direct conversion of methane or natural gas to gasoline or diesel range hydrocarbons, thermal pyrolysis studies have been carried out in a tubular flow reactor of high-purity alumina.

Some effort has been directed toward the conversion of methane to liquids via the acetylene intermediate route. Although acetylene has been produced commercially from natural gas pyrolysis, a techno-economic feasibility study of this conversion for a significantly larger scale is being carried out by SNC in a 50/50 contract. In-house work has also been initiated into the preparation and testing of catalysts for the conversion of acetylene to hydrocarbon liquids.

COAL TECHNOLOGY

Coal Reserves Assessment

Canada's coal reserves are substantial but, because they are such highly variable substances, extensive studies are required to determine the quality of individual deposits. Increasing competition for export markets, particularly in the Pacific Rim, adds urgency to the need to know more about these resources. Since the physical and chemical structure and geological origin of Canadian coals differ from European, American and Australian coals, it is particularly important to investigate local coal characteristics to ensure the marketability of Canadian coals.

Data gathered from all major operating coal-mining companies in Canada and from provincial government regulatory agencies have been incorporated in the report "Coal Mining in Canada". This report includes data on production and a description by coalfield of Canada's recoverable coal. Detailed productivity data, gathered from most operating coal mines, will form the basis of an initial assessment of Canadian productivity. Canadian productivity will then be compared with that of other major coal-producing countries.

Scientists also continued their active participation in efforts to assess reserves in cooperation with industry and other federal and provincial agencies. Continued cooperation between the Ottawa and Sydney, Nova Scotia, analytical laboratories and provincial resource departments under the federal-provincial development agreements added further material to the growing national database on coal quality. Coal-quality studies included work on new analytical techniques for minor and trace elements, and contributions to both national and international coal-quality standards deliberations. Under a program of commercial coal evaluation, scientists acquired and analyzed company samples and prepared an updated supplement to the "Analysis Directory of Canadian Commercial Coals".

Coal-Mining Methods

Coal-mining technology leadership lies primarily in Europe and the United States. The productivity of the domestic industry could be increased quickly and economically through the transfer of this highly developed technology to Canada. To be effective, this technology must be modified to suit local geological conditions and the operational context of the industry. Regulatory, economic and social factors must be considered. A jointly sponsored demonstration under full-scale operating conditions is one way to ensure effective transfer of this technology.

A location to demonstrate longwall mining in a western Canadian mountain coal seam was determined and the engineering study for the demonstration completed. As a market for the incremental coal production could not be found, the project will not go ahead. Under the START program, a two-day seminar was held at the University of Calgary to consider the feasibility of, and the general requirements for, establishing a longwall mining operation in western Canada. A handbook was produced as a result of this seminar.

Scientists at CANMET's Calgary laboratory are developing, with the aid of their major computer facility, a

model of a surface-mining operation. CANMET researchers, cooperating with the System Analysis group of the National Research Council, have made considerable progress in building an operational model and in specifying its application in decision making. Meanwhile, documentation of operations at a strip coal mine serving an Alberta electrical utility continues.

Under contract the geological and geotechnical conditions for longwall mining in the Lethbridge area were evaluated and a final contract report issued. Extraction of the Galt seam appears to be technically feasible using the longwall method.

The main roads driven in a north-south direction might require arch supports, but rock bolts would suffice for gateroads driven in an east-west direction. Dry mudstone in conjunction with coal in the floor provides sufficient strength for the shield supports used in longwall.

Strata Mechanics

In eastern Canada problems specifically related to deep mining are beginning to manifest themselves. As the Cape Breton Development Corporation (CBDC) extends both multi- and single-seam coal extraction beyond 700 m below seabed, the problems will become more pronounced. Strata mechanics research at the Cape Breton Coal Research Laboratory has been directed towards the evaluation of roadway support systems; assessment of existing mining practices related to gateroads and packing systems; mining subsidence; gas/rock outbursts; and field instrumentation to evaluate mine stability by gathering data on deformation and in situ stress.

Excessive gobside roadway closure results from the underdesign and failure of the gateside packs presently used.

Strata mechanics crew collecting data in a longwall gateroad

Gateside packs must be of adequate size and strength to provide resistance to the pressures caused by redistribution of stress as the coalface advances. Gateside pack performance affects the degree of deformation experienced in the gateroad. Deformation can lead to fracturing in the strata surrounding the roadway, allowing air to leak into the gob. CANMET scientists are developing a specific gateroad deformation model for the Sydney coalfield and establishing a gateroad deformation databank. Information derived from a detailed gateroad survey of 35 km of accessible roadway at Lingan and No. 26 Colliery forms an integral part of this work.

CANMET researchers continued efforts to understand the mechanics of the rock/gas outbursts which stopped development of the 'main deeps' at No. 26 Colliery. Scientists measured in situ strata gas pressure, made visual assessment of outburst cavities and measured strata properties in the laboratory.

An evaluation of existing undersea subsidence criteria and an assessment of its applicability to the Sydney Coalfield is being undertaken. The identification of potential instrumentation techniques for measuring seafloor subsidence is currently in progress.

At the Donkin-Morien mine a series of in situ stress determinations were made in the No. 3 tunnel. Extensive instrumentation has been installed in the No. 2 tunnel, driven by a 7.6 m tunnel-boring machine, to monitor strata movement support response.

The NOVACO Point Aconi pit site was used in a preliminary assessment of geostatistical techniques in the Sydney coalfield. Geostatistical techniques may also prove valuable for resolving strata mechanics problems.

CANMET, in cooperation with coal-mining companies in western Canada, studied the strata mechanics associated with hydraulic mining in thick and steep coal seams. The knowledge gained will be applied in other mining areas which have similar mining conditions.

Laser equipment for surface subsidence monitoring

Scientists developed a remote sensing system to measure subsidence-induced surface movements in the rugged terrain and adverse climate of the Rocky Mountains. The system uses tiltmeters to sense ground movement and radio telemetry to transmit data. Remote control and alarm features incorporated in the system extend coverage to inaccessible areas beyond the mountain ridge. In addition, CANMET scientists applied an electronic distance measuring (EDM) laser/infrared system and aerial photogrammetry techniques to assess subsidence. A western Canadian mining com-

pany was provided with the EDM system. The area and frequency of coverage was extended by the use of aerial photogrammetry.

Schmidt hammer for testing rebound hardness of rock

Under contract a classification system, based on foreign technology, for coal measure rocks was proposed. The method will be used to determine which mining methods should be applied to a specific mine deposit. The basic rock-testing facilities at the Calgary Coal Research Laboratories are being used to determine rock properties. Rock classification systems derived from these properties are used to plan pillar design, roadway, and face supports, as well as to predict caving and surface subsidence.

A contract on resin bolts continues. Suitable material has been selected, modes of failure and displacement of horizontally bedded roofs have been determined, and a study of individual bolts to assess modes of failure completed.

Coal Mine Health and Safety

Methane is adsorbed within the coal seam during coal formation. When the coal is mined, this methane is released. Together with the dust produced during mining and the inherent combustibility of the coal itself, methane creates an underground mining atmosphere where explosion and fire are serious hazards. Historically, CANMET research centered on the development and demonstration of carbon monoxide and methane monitoring systems using the tube bundle technique. Last year the emphasis shifted to the development of systems based on wire telemetry. An environmental monitoring system, developed under contract, was field tested at a western Canadian mine.

An accelerated oxidation test to categorize coals by their susceptibility to spontaneous combustion was standardized using three western coal samples of different rank. Researchers are now developing methods to analyze gases evolved during low-temperature oxidation of coal.

Understanding the phenomena associated with dust explosion generation and propagation is fundamental to coal mine safety. Researchers studied the inter-effect of stone dust and methane on coal dust explosibility using bench-scale apparatus. A larger scale dust explosion apparatus will be used to determine the effect of scale (size) on dust explosion phenomena.

Investigations have shown that methane accumulates at a faster rate within the coal pile of a clean coal silo than within the coal pile of a raw coal silo. Coal processed at one western Canadian mine plant has a negligible emission rate and, as may be expected, methane emission within its coal storage silos was negligible. Significant accumulations of methane were found at another mine plant within the coal pile in both raw coal and clean coal storage silos, and on the surface of the coal pile when the silos were discharging. The coal processed at this plant has a measurable methane emission rate.

Under contract, research on the reaction mechanism of spontaneous combustion will continue. A literature review determined that it is feasible to use biotechnology to control methane in coal mines, coal silos and in shipholds during transportation.

In Cape Breton, ventilation research was directed toward reducing the dangers from methane at the working face. An improved ventilation system for the cutterhead of a prototype tunnel-boring machine (TBM) was developed. The cooperatively designed ventilation system quickly and efficiently removes methane from the TBM's cutting head. Analytical support was provided by a provincial research organization. Under contract this organization developed a tracer gas technique to study ventilation flows in the cutting head area of the TBM. A similar technique will be used to monitor air leakages in coal-winning districts and development drivages.

Reduced faceline air velocities caused by air leakage through gateside packs and the unconsolidated gob is a serious problem in the Sydney coal-field. Under contract a report on the availability of sealants has been completed. A sealant technique proposed in the report is undergoing trials by CBDC. CBCRL will assist in monitoring its effectiveness. The modes of air leakage through the gob are being assessed to determine if a correlation between leakage and strata geology exists and to measure the degree of compaction occurring within the gob.

CANMET researchers recommended that an anemometer (used to measure airflow) be withdrawn from service. This was one of a series of instruments tested in CBCRL's wind tunnel.

Direct fire fighting in underground coal mines is both difficult and dangerous. CANMET contracted AMCL to review inerting systems recently developed and used in Europe with remarkable success and safety.

Underground coal workers risk contracting pneumoconiosis and pulmonary disorders. Monitoring and controlling respirable dust levels will reduce the risk. Data on respirable dust concentrations obtained from the Cape Breton Development Corporation was analyzed. Although coal production has increased, improved ventilation maintained dust exposure at relatively constant levels over the past decade.

CANMET researchers continue to explore means of reducing toxic gaseous diesel emissions in underground coal mines. Dynomometer tests on coal-mine related emissions reduction equipment showed that emulsification of 15% water into diesel oil reduced soot and NOx concentrations by approximately 40% when applied to the discontinued Deutz 714 series engines, but not with the new 413 series engines. Further, conventional baffle-type water-scrubbing technology was transferred to Hovey and Associates of Ottawa for use in all flameproof applications including, for example, oil rigs. An unsolicited proposal from Hovey resulted in the development of a radiator circuit heat exchanger. Progress was made also with respect to the reduction of water consumption associated with the use of the CANMET-developed venturi high capture efficiency scrubbing system. Finally, much progress has been made in the development of a total exhaust ceramic wall-flow filter (Corning) including health assessments, underground trials and development of on-board regeneration techniques. This filter has a future potential application to coal mine diesels for both environment improvement and for flame- and spark-arresting duties.

Coal Mine Safety Certification

In 1953 the federal government established a laboratory for certification, on a cost-recovery basis, of coal-mining electrical equipment for use in explosive underground environments. This original mandate has evolved slowly over the years, to include numerous fire-resistant materials and fluids, diesel machinery and explosive gas detection equipment in both underground and industrial hazard locations. Researchers continue to improve the quality of both the certification service and the standards on which the service is based.

The laboratory issued 83 certificates during the year. However, this does not include non-certification testing figures relating to work on behalf of other certification and governmental agencies and private industry applicants. These other projects totalled 66 this year. Two of the major items certified included a 25-foot tunnel-boring machine for the Cape Breton Development Corporation and a unique erector-transporter for underground assembly/disassembly of the tunnel-boring machine.

A Quality Assurance Program was established to retest previously certified products. A Memorandum of Understanding, signed with the CSA, allows their staff to make inspections for the Canadian Explosive Atmospheres Laboratory (CEAL). The oil and gas industry and inspection authorities continue to be interested in CEAL's program for approval of flameproof equipment.

CEAL's continued development of standards resulted in the approval of the CSA Standard for fire-resistant hydraulic fluids as a national standard.

Coal Preparation

Coal preparation refers to the upgrading of the mine product to meet the specifications of a particular end use. Impurities such as free mineral matter and sulphur are removed, and the moisture content is adjusted to produce a product that is consistent. In addition to reducing the technical problems encountered in end uses, preparation can reduce environmental emissions and transportation costs. In today's economic and environmental climate, these are important considerations for both coal producer and user. They will be especially important if Canada is to remain competitive in the export market.

Research in coal preparation is an interdisciplinary effort, as coal is both a mineral and an energy commodity. In addition to improving processing methods, CANMET scientists supported the coal industry through characterization of commercial coals.

Understanding the behaviour of oxidized coals during upgrading and dewatering processes enables researchers to develop techniques to improve recovery ratios. CANMET scientists characterized coal samples using Fourier transform infrared spectroscopy and surface techniques such as photo-acoustic and diffuse reflectance spectroscopies. Instrument modifications and the in-house development of computer-based deconvolution methods enhanced the resolution capabilities, making it possible to apply these techniques to coal. A gas desorption technique under development is designed to predict the extent of oxidation of both raw and washed coals. The amount of fines generated during crushing depends upon the friability of the coal and the type of crusher used. The amount of fines generated can be correlated with the so-called ΔP index.

The pilot plant has been and will continue to be an essential tool for coal preparation research. Having a sophisticated pilot-plant facility available enables engineers to study more fully the techniques best suited to their particular circumstances. CANMET'S pilot-plant facilities at Clover Bar (Edmonton) were dismantled and moved to a new building at Devon in January 1984. These facilities can generate the large samples of clean coal needed for utilization tests. Modifications provide

the pilot plant with up to 20 different flowsheet options. Researchers will assist industry in flowsheet optimization and help them with processing problems. The 10 t/h comprehensive pilot plant is being used to develop and test on-line instrumentation and to develop a distributed process control system. Froth flotation control systems are being reviewed under contract.

CRL pilot plant, Devon Coal Research Centre

A bulk coal sample (50 tonnes) from Obed-Marsh was washed to produce ~35 tonnes of clean coal needed for coal-methanol slurry research. This pilot-plant test also provided additional information on the performance of the Batac jig when cleaning plus 0.5 mm coal. Two flocculant manufacturers evaluated their product performance in the Envirotech thickener during this test.

Coal washeries are interested in finding the most cost-efficient methods to treat effluent. Engineers operating CANMET's mobile water treatment plant at two coal washeries found that the appropriate choice of flocculant and operating parameters substantially improved washery thickener/clarifier performance.

Before the mobile water treatment plant was operated at the washery, flocculation efficiency was evaluated by settling rate tests. Electrophoretic mobility studies are used routinely to monitor coal/clay interactions and provide a basis for interpreting settling rate test observations. Slurries containing 1% to 40% solids by weight were measured with excellent reproducibility using a new slurry density monitor.

The molecular weight and molecular size distributions of several flocculants were measured by low-angle laser light scattering and gel permeation chromatography. Under contract, polymers were characterized by quasi-elastic light scattering and residual polymers were determined in solution.

The large portion of fines present in western Canadian coals makes both dewatering of clean coal and fines and treatment of fines costly. A highlight of the year was the construction of the first mobile dewatering plant. The plant can be hooked up to a commercial plant to study the company's dewatering needs, or to identify and optimize dewatering practices without interrupting operations.

A consulting company will base its design for a mobile fine coal treatment plant on strategy formulated at CRL. Under contract it was found that froth flotation, spirals and water-only cyclones are suitable options for a mobile plant. The difficulty in incorporating a heavy-medium control and recovery system in a limited size mobile plant rules out the use of heavy-medium cyclones.

The ash and sulphur contents of an eastern Canadian coal can be lowered to less then 1.3% by direct flotation followed by a reverse float. Combining flotation with high-gradient magnetic separation (HGMS) will further

Mobile coal dewatering plant

reduce the sulphur and ash to about 0.8%. HGMS has been used to effectively treat coal fines. Dry jigging, high-tension and high-intensity magnetic separation have been used to successfully treat western Canadian thermal coals.

Light coal can be separated from the relatively heavier ash and pyrite more effectively under the quiescent condition of a flotation column than under the turbulent agitation found in conventional flotation cells. A flotation column was installed at the Cape Breton Development Corporation, Victoria Junction Coal Preparation Plant and will operate onstream. A Szego — 450 grinding mill, added to the column, will facilitate separation of pyritic sulphur from the coals.

A better understanding of fine coal recovery from high-sulphur coals is needed before this technology can be improved. CANMET scientific staff are analyzing the results of surface potential and contact angle measurements, as well as potentiometric titrations under different operating conditions. Under contract, coal depressants were investigated, the effect of humic acid on the flotability of coal and pyrite compared with that of dextrin and carboxymethyl cellulose. These results will be used to selectively separate ultra fine coal pyrite from high-sulphur coals.

Demulsifier chemicals to separate stable emulsions into aqueous and bitumen/oil phases were evaluated. Characterization of both the emulsion and the interactions which take place when a demulsifier is added will help scientists develop new treatment methodologies. The size of oil/bitumen droplets in w/o emulsions was measured using the electron scanning microscope.

A literature review suggests that electrophoresis is an appropriate technique for studying emulsion/demulsifier behaviour. Low-angle laser light scattering and thermal analysis techniques will be used to characterize emulsions/demulsifiers.

Carbonization

Canada exports about 16 million tonnes of coal annually, most of which is high-grade coking coals from Alberta, British Columbia or Nova Scotia. To provide technical support to Canada's metallurgical coal producers, the Energy Research Laboratories and Coal Research Laboratories continue to provide expertise, laboratory and pilot-plant facilities for comprehensive carbonization and cokemaking investigations. CANMET, as a member of the Canadian Carbonization Research Association, provides all experimental facilities and scientific and technical personnel for assisting in planning and carrying out research of immediate interest to both the coal and steel industries.

The CANMET technical-scale coke ovens are extensively used by the coal and steel industry to evaluate the coking properties of coking coals and blends having potential commercial applications. Results of these coke-oven trials are often supplemented by small-scale tests to measure dilatation and by laboratory analyses to determine the chemical, rheological and petrographic properties of both coal and coke.

In recent years, CANMET scientists, with the participation of the Canadian Carbonization Research Association (CCRA), have carefully sampled coal blends and coke samples from Canadian integrated steel plants. These coal blends were also coked in pilot-scale ovens under various conditions to reproduce the coke characteristics found in the much larger industrial ovens. It has been determined that the ERL ovens could be operated to produce coke having the same strength as industrial cokes. This allows steel companies to confidentially evaluate new coals and blends on a pilot-plant scale. For buyers of Canadian coal it demonstrates conclusively that results obtained by CANMET on behalf of our coal export producers can be directly applied to industrial ovens.

In 1983, work was extended to an international round-robin investigation in which coal and coke samples from a Canadian steel producer were exchanged with similar samples from a Japanese steel mill. Complete analytical and pilot-plant evaluations were done at ERL and the research centre of a Japanese steel mill. Results showed that CANMET pilot-ovens produced coke of strength similar to that produced industrially in Japan. Analytical results from coal and coke evaluations from ERL compared favourably with most parameters obtained in the Japanese laboratories. These findings demonstrate conclusively to both buyers and producers of Canadian coals that CANMET results are accurate and can be directly related to industrial ovens.

Another element of the CANMET research effort involved trials in Algoma's No. 6 coke oven battery. Seventeen different coal blends were coked in the battery and then in CANMET ovens to determine if higher strength coke could be produced (to improve blast furnace productivities) by modifying existing coal blend compositions without creating excessive coking pressures.

At CANMET the following laboratory and pilot-plant carbonization activities are under investigation:

1. Addition of commercially available pitch materials to high-grade metallurgical coal blends.
2. Addition of commercially available pitch materials to poor-coking western Canadian coals.
3. Addition of residues from the CANMET hydrocracking process to poor-coking western Canadian coals.

Pilot-scale tests with 5% pitch added to a typical Canadian steel company blend indicated there were no negative effects on coke strength by adding any of six different pitch materials. Three of the better commercial pitch materials were utilized for an investigation with three ranks of poor-coking coals from western Canada. All pitches proved to be excellent coking additives and coke strength improved markedly when 7% pitch was incorporated into any of the coking charges, in several blends producing coke of a quality acceptable to the Canadian steel industry.

Several pitch residuals from the CANMET hydrocracking process have also been investigated as additives to poor-coking western Canadian coals. Microscopic point-count investigations on laboratory cokes made from various pitch additives with coal indicated that many of the CANMET pitches were excellent at modifying mosaic texture of coke. Chemical investigations also showed these pitches to have relatively high H-donor ability, high asphaltenes and high coking values — properties considered desirable for coking additives. A pilot-scale coking test showed excellent coke could be made by blending 10% of one additive to a normally poor-coking coal from western Canada.

In North America, metallurgical coke for steelmaking is generally wet quenched by spraying water onto incandescent coke in a quench car. Inconsistent quenching practices can cause variations in moisture contents resulting in operational difficulties in the blast furnace because of variations in the carbon/iron ratio. Dry-quenching coke has not been adopted by North American steel companies even though it avoids problems associated with moisture variations and results in large energy recoveries. ERL scientists have investigated the effects of wet- and dry-quenching techniques on coke quality by carbonizing an industrial blend in a 460-mm wide pilot oven.

Contract work at the Waterloo Centre for Process Development has recently compared the thermal rheological (dilatation & FSI) and petrographic properties of two Appalachian and three high-inert western Canadian coals. Each coal was stage crushed and washed at several specific gravities to modify ash and maceral compositions.

This CANMET/CCRA investigation was undertaken to determine the effects of several test oven charging variables on charge oven bulk density, peak coking pressure and coke quality. Charging variables included coal moisture, diesel oil additive, charge drop height and charging rate. Results showed consistent blend preparation and charge practice are essential to achieve consistent coke quality and coking pressures. Regardless of the method of adjusting bulk density, a good relationship was found between charge oven bulk density and coke strength and coal moisture. An excellent relationship was also developed between maximum wall pressure and coal bulk density.

Gasification

CANMET continued its work in the determination of gasification reactivities of Canadian coals. Several coals have been identified as potential feedstocks. The potential coals have been evaluated in the newly constructed fluidized-bed system. In the area of hot gas clean-up, an experimental system to study the removal of corrosive components was constructed.

Gasification reactivities of oil sand coke from Suncor (delayed coking) and Syncrude (fluid coking) have been established in the continuous fluidized-bed reactor.

CANMET's contract work in the development of spouted-bed technology for gasification of coking coals continued. As well, contract work was done on the evaluation of New Brunswick oil shale.

Liquefaction

During 1983 the construction of a prototype slurry preparation and feed system was completed and tested. A new hydrogen supply system to be used on the coprocessing plant was installed and tested on an existing pilot plant.

Various locations for the coprocessing plant were considered. In the absence of building expansions, it was decided to install part of the unit in the existing pilot-plant facilities. Consideration is being given to installing the feed slurry preparation system in an existing separate feed preparation building. A scale model of the major pilot-plant components was constructed as an aid to plant layout.

Recognizing the long lead time required for implementation and the human expertise needed, CANMET has embarked on a project aimed at gaining influence over, and insight into, the research, development and eventual demonstration of the strategic technology. The federal government will therefore be in a position to ensure that the best and most energy-efficient processes are considered or developed for Canadian coals. This will help in adopting the proper policies to establish a new resource industry.

Short residence time experiments have been performed under low severity conditions in an attempt to liquefy low-rank coals in bitumen and heavy oil solvents. A novel autoclave system allowing rapid injection of coal was designed and commissioned. Optimum operating conditions for producing the highest coal conversions were determined. Future experimental work will centre on the development of novel catalysts to improve process performance. In addition, a study was carried out on the effects of basic nitrogen-containing additives on dissolution of coal in tetralin and anthracene oil. Results obtained under atmospheric pressure conditions were inconclusive, but reactions carried out in an autoclave gave results which may shed some light on the nature of the interaction between nitrogen compounds and coal molecules.

Combustion

Designers of full-scale FBC equipment have a continuing requirement for detailed information which can often be generated on pilot-scale equipment. To meet this end, a test program with Evans coal and Havelock limestone was carried out to evaluate the combustion performance of this coal and the effect of limestone size in support of the CFB Summerside FBC demonstration program which is described below.

Comprehensive tests employing fluidizing velocities from 2.1 m/s to 3 m/s, both with and without fly ash recycle and two limestone sizes, were carried out. To study bed defluidization due to the accumulation of oversize materials a number of 24-h tests were conducted. During these tests the fluidizing velocity was lowered to determine the minimum velocity which could maintain fluidization over an extended period. Tests were also carried out to study the effects of inorganic salts on the performance of Havelock limestone as a sulphur sorbent.

Combustion performance on Syncrude coke and Fort McMurray limestone in the Mark II bed indicated that Syncrude coke could be burned satisfactorily, provided the bed temperature was kept above 800°C and the fluidizing velocities were low (~0.7 m/s). With higher velocities it was essential to operate with fly ash recycle, and the degree of burning in the free board began to increase to unacceptable levels above 1 m/s. This suggests that, except possibly in the case of very deep bed, AFBC is not a suitable technology to burn this petroleum coke and it is necessary to use circulating fluidized-bed (CFB) technology. The effect of deep bed on the AFBC performance of Syncrude coke will be examined by Queen's University in 1984.

A process controller and desktop computer were purchased to allow on-line data acquisition and processing. The software was also developed to run the system, thus allowing the experimental data generated to be processed and interpreted during and immediately after an FBC trial. It is anticipated that this system will lead to significant savings in time and increase the productivity of the FBC unit.

The system and analyzers used for the FBC trials with petroleum coke are now located in a controlled environment computer room. In addition, a gas light-up burner has been installed and commissioned, thus allowing the bed to be brought up to operating temperature with a minimum of difficulty.

In view of the wide range of coals available in Canada for which little or no information is available with regard to performance in FBC systems, a means of rapid ranking in terms of their relative reactivity is highly desirable. To this end, CANMET has undertaken a project to develop a bench-scale FBC 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 higher cost.

To expedite the application of FBC technology, a detailed study of the performance of Canadian limestone as sulphur sorbents using a 50-mm diam bench-scale FBC at MSL is underway. This unit has been improved by the installation of an electronic mass flow controller and mass flow metre, a gas sample cleaning system and a proportional controller for the electrical heating system. As a result, the accuracy of the data was improved and 31 limestones and dolomite samples from the Maritimes and Alberta were retested. Ten Swedish carbonate rocks were also evaluated; the ranking obtained for the rocks was the same as that found by a Swedish thermogravimetric analysis method. A computer program was compiled based on the Argonne National Laboratory model for predictive sorbent performance in the Summerside unit and any future FBC installations.

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 objectives. Contracts range from short-term work with narrow, specific objectives to long-term studies extending over several years, with the broad objectives of adding to the database on FBC performance of Canadian fuels and sulphur sorbents.

Circulating fluidized-bed combustion is a second-generation FBC technology with applications including the combustion of unreactive and high-sulphur fuels, washery rejects and solid fuels with a high percentage of fines. After reviewing the potential for this technology CANMET decided to complement its present R & D FBC facilities and a contract was awarded to Montreal Engineering Co. Ltd. for the conceptual design which was completed in September 1982.

As a result of increasing interest in burning coal-water slurries in FBCs, a contract was let to Babcock and Wilcox to burn three coal-water slurries in their '1-foot square' rig at Alliance, Ohio. The experimental work was substantially completed in 1983 and it is expected that the final work and report will be available by March 1984.

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, P.E.I. The design fuels are high sulphur (~5%) Cape Breton coal and wood chips. The wood chips are a supplementary fuel that can be co-fired with coal on a demonstration basis at a fuel rate of up to 30% of the total heat input.

The project was launched in 1977 and has progressed through three stages of competitive, conceptual and detailed designs carried out by means of parallel contracts to two teams of designers. The third-stage detailed design and a firm price proposal were completed on January 5, 1981, when Foster Wheeler Ltd. and Dominion Bridge Sultzer Ltd. each submitted a tender for construction of a turnkey plant addition, complete with two FBC boilers rated at 18 000 kg/h of steam each, fuel storage and handling equipment and all other auxiliaries.

The boilers were fired in late 1982. However, a series of problems with the boilers, spreader stokes and coal silo, difficulties with the fluidization of 6-mm × 0 Havelock limestone, and wear of the in-bed and waterwall tubes interrupted the smooth operation of the boilers. These problems are being addressed and it is hoped that the boilers will be accepted from the contractor in 1984. In the meantime, stack emission tests at 65% and 100% load were carried out in May by the Centre for Energy Studies (CES) of the Technical University of Nova Scotia. Due to field problems this test was subsequently repeated in November by Environment Canada. Negotiations were also completed with Treasury Board to allow the three-year demonstration program to be extended by one year to 1985/86 to allow for the delays introduced into the program because of the various design problems discussed above.

CANMET is still involved in a project in conjunction with Environment Canada (EC) to monitor leachate from the FBC waste disposal ditches created under advice from EC. This work has been postponed until 1984 because of problems in obtaining liquid samples and groundwater monitoring. In particular, trials with co-firing of high-sulphur coal and wood chips should be underway before the end of the 1983/84 heating season.

Pressurized fluidized-bed combustion (PFBC) is a potentially attractive method for producing electricity using combined power generation cycles. As part of this interest, an unsolicited proposal to review the major PFBC programs and to make recommendations about future Canadian work on PFBC was let to the University of British Columbia (UBC). This report was completed and accepted in March 1984. Subsequent work did not

commence as UBC was unable to find matching provincial government support in B.C. Work on PFBC is now in abeyance.

During 1983, ICP replaced its pilot-scale pulverized coal-fired utility boiler (in operation since the early sixties). The new unit is designed to accommodate low-grade coals and is based on the experience gained over 20 years on the old unit. The new unit has provisions for extended residence times for combustion under adiabatic conditions. This improves the assessment capabilities for coals which can be found in the Rocky Mountains, as well as other low-grade coals. Improved means of assessing deposition phenomena are incorporated as well as means of determining emissions and emission control design parameters.

In collaboration with various contractors CANMET carried out tests to determine the combustion performance of various coal feedstocks. These tests are ongoing and costs are shared with industry participants.

To understand better the mechanisms involved in the ignition, devolatilization and char burnout regimes of turbulent coal diffusion flames, CANMET has designed and built a controlled-mixing history reactor (CMHR) which is presently being commissioned. This unit is capable of producing a simplified combusting environment typical of that which coal particles encounter as they pass through a flame, but without the added complication of aerodynamic flow patterns found in flames and combustors. Because of the variability of the burning characteristics of different locations, a rapid yet simple method of evaluating coal reactivity is needed and it is anticipated the CMHR will fill this need.

The reactor has been installed and a microprocessor-based temperature controller has been incorporated in the control circuitry. This was done to gradually raise the device to temperatures to alleviate thermal shock problems. A computer model of the heat and mass transfer inside the ceramic tube has been developed.

To facilitate the use of coal in place of oil in industrial combustion systems, data must be obtained which compare the combustion and heat transfer characteristics of coal with those of fuel oil under similar aerodynamic conditions. The CANMET tunnel furnace has a refractory-lined precombustion chamber. It is designed to fire pulverized coal, light and heavy fuel at natural gas and coal-liquid mixtures. It has a thermal input of about 2 GJ/h and has a continuous access slot along its length for the insertion of flame probes.

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

Six thermal coals, five western and one Cape Breton, have been evaluated in the tunnel furnace. These range from high-volatile to low-volatile bituminous and in one case the coal was unreactive. The data evaluation and reporting of these combustion tests are nearing completion.

In April 1982, Energy, Mines and Resources Canada (EMR), the New Brunswick Electric Power Commission (NBEPC) and the Cape Breton Development Corporation (CBDC) entered into a collaborative agreement to demonstrate the preparation of coal-water mixture (CWM) and its utilization in utility boilers.

This agreement provided for the construction of a 4 t/h CWM pilot plant based on the Swedish Carbogel process and located in Sydney, N.S. It also specified that burners should be developed and tested in the 12.5 MW(e) unit No. 1 front-wall fired boiler and the 22 MW(e) tangentially fired unit located at the Chatham, N.B. generating station. The project is administered by a management committee comprised of representatives of EMR Canada, NBEPC, CBDC, the Nova Scotia Power Corporation (NSPC) and AB Carbogel. Technical input to the project is through a technical committee, which in addition to management committee members, includes representatives of the National Research Council (NRC), Ontario Hydro, New Brunswick Research and Productivity Council and the Centre for Energy Studies of the Technical University of Nova Scotia. Burners have been developed for each of the two Chatham units and the test program on Unit 1 was half completed by the end of 1983. Preliminary tests have been conducted on Unit 2 and completion of both test programs is expected in mid-1984 with a project report to be issued in the fall.

CANMET has undertaken an R & D program in support of the ongoing demonstration program in CLM technology. The combustion heat transfer and emissions characteristics of potentially commercial coal-liquid mixtures is being established in a program undertaken in the CCRL tunnel furnace. The coal-water mixture being used at Chatham has been studied and compared to the parent coal feedstock as pulverized coal, and with No. 6 fuel oil. As part of CANMET involvement in burner development, a burner was developed which incorporates some novel atomization and wear resistance features. This will be studied using CLM fuels and No. 6 fuel oil using a commercial atomizer for reference purposes.

As part of an ongoing effort to expand the use of high-sulphur Maritime coal for heat and electricity with minimal environmental impact, CANMET has initiated a project to demonstrate limestone injection multi-stage burner technology (LIMB) for substantially reducing acid rain emissions from pulverized-coal-fired boilers. The project, which is being carried out with the active participation of the Department of National Defence and the analytical support of Environment Canada, involves the retrofitting of an existing 20-MW hot water boiler at Canadian Forces Base Gagetown with 'staged-mixing' burners. Commissioning is scheduled for the end of 1984.

CANMET, on behalf of Canada, participates in a major project sponsored by the International Energy Agency (IEA). The project, co-funded by Canada, Denmark and Sweden, with U.S. guidance and support, involves the validation and optimization of advanced burner concepts under a three-stage agreement.

Stage 1, completed in March 1982, consisted of bench-scale furnace trails on 45 coals including nine from Canada. Its purpose was to elucidate the mechanisms of NOx formation from fuel nitrogen under pre-mixed and staged combustion conditions. Stage 2, now in progress, consists of combustion trials in three progressively larger furnaces to generate data for extrapolating to full-scale burner designs. Four coals, two from Canada, are being evaluated for NO_x production and two of the four coals, including one from Canada, will be evaluated for simultaneous reductions of SO_x and NO_x using limestone sorbents. Stage 3, if implemented, will be a utility boiler trial using the limestone injection multi-stage burner (LIMB) concept in one of the participating countries.

CANMET has been a member of the International Flame Research Foundation (IFRF) IJmuiden, The Netherlands since 1966 and has benefited through participation in combustion trials and technical committees. Much of the work done on coal flames at IFRF complements that at CANMET and the interaction is mutually advantageous. In addition, CANMET has been a participant in the development of an International Energy Agency (IEA) Agreement on Basic Coal Science. It is expected that Canada will participate in this program in the near future.

Canada is a leading participant in the development of CLM technology, having pioneered some R & D on CLM in 1970 and a subsequent demonstration project at Chatham from 1977-80. Collaboration with the U.S. and Japan in discussions has led to the IEA/CLM implementing agreement of which seven countries are now participants. Annex I, an assessment of CLM potential in the participating countries, is now concluded and Annex II, base technology, is continuing. Much of the foregoing contract and in-house R & D constitutes Canada's contribution to Annex II. A new annex is to be formed concerning the assessment of relevant coals for CLM manufacture and Canada will participate in this activity.

In addition, CANMET has been an invited participant in the extensive program of CWM technology being administered and funded by the Electric Power Research Institute (EPRI) in the U.S.

Coprocessing of Coal with Bitumen, Heavy Oils and Residuals

A report was completed on the coprocessing of an Alberta subbituminous C coal and a distillate fraction of Cold Lake heavy oil. Data from eleven experimental runs were reported. A comparison between the performance of vacuum bottoms and the distillate fraction as coprocessing media was presented.

Blends, of fractions from Cold Lake heavy oils were tested as coprocessing media. Significant information on the optimum coprocessing medium was obtained. A report including the data from five experimental runs is under review. A study comparing coprocessing and coal liquefaction is completed and a report comparing the upgrading alternatives is in preparation.

The commissioning of a short contract time batch coprocessing unit was completed. This unit was used to establish the hydrogen donor abilities of bitumens/heavy oils and CANMET hydrocracked pitch. This batch facility is currently being used for coprocessing a variety of bitumens and heavy oils with Alberta subbituminous coal to establish the relationship between hydrogen donor ability and coal solubilization.

Hydrocracked type analyses of coprocessing liquid products were carried out using a combination of preparation liquid chromatography and a TLC pyrolysis technique. The objective was to develop a fast and reliable method for quantitative analysis of saturates, aromatics and polar components present in the distillate products.

The results of this work allowed the comparison of coprocessing liquid products obtained using pure H_2 with synthesis gas. More detailed analyses of distillate products are underway to distinguish any change in the product quality when H_2 is replaced by CO/H_2 mixtures. During 1983 the construction of a prototype slurry preparation and feed system was completed and tested. A new hydrogen supply system to be used on the coprocessing plant was installed and tested on an existing pilot plant.

Various locations for the coprocessing plant were considered. In the absence of building expansions, it was decided to install part of the unit in the existing pilot-plant facilities. Consideration is being given to installing the feed slurry preparation system in an existing separate feed preparation building. A scale model of the major pilot-plant components was constructed as an aid to plant layout.

Materials for Coal Handling and Utilization

During 1983/84, much of the work under this project was devoted to materials studies in the EMR-NSPC (Nova Scotia Power Corporation) fluidized-bed coal combustion pilot plant at Point Tupper, N.S.

During the commission period, difficulties were experienced with the control of the planned temperature gradient. Various efforts, including modification of the tube core, showed some improvement but the temperature is still unacceptably high for some materials, such as carbon steel in the low-temperature cooled tubes. In the first 1000-h run, only two test probes, one high temperature and one low temperature, were used. In the

second 1000-h run only high-temperature probes were included. Based on the preliminary assessment of materials after exposure, low-temperature cooled tubes were modified and carbon steel specimens were removed from further long-term testing. The third 1000-h run was started before the end of the fiscal year.

Development of an erosivity test for the characterization of coal-liquid fuel was undertaken in an R & D contract. The erosion recycle test loop developed was a partial simulation of the environment existing in a burner nozzle for coal-liquid fuel. The erosiveness of the coal-water fuel was found not to be a monotonic function of recycling but was observed to rise to a peak and drop off. The viscosity of the slurry and the coal grain size were dependent on the number of cycles. Erosion testing using recycled coal-water fuel was found to be technically feasible.

Materials for Tar Sand Processing

In this project, a study of materials to support the processing of oil sands is being undertaken.

In-laboratory tests were conducted using mild steel and stainless steel type 304 to determine wear rates in simulated oil sand slurries at atmospheric pressure and temperatures ranging from 40°C to 90°C in aerated and deaerated conditions. The results were calculated in terms of compatibility with a mathematical model that allows separation of corrosion and erosion rates on the basis of the differences in their variation with test velocities.

Laboratory testing was extended to temperature ranges of 125°C — 250°C and a relevant pressure of 30 to 600 psi using a specially adapted autoclave. Corrosion and erosion rates were determined in aerated and deaerated slurries at different test velocities. Corrosion rates were determined under stationary conditions in corrosive and neutral solutions. The effect of erosion on the total wear at high temperatures in corrosive slurries was determined.

Materials for High-Temperature Energy Conversion Processes

Materials degradation is still a serious restraint in the development of high-temperature energy conversion systems. In this project, four R & D contracts were undertaken during 1983/84 to address the problem. In addition, experimental work was carried out at IMRI/NRC by a scientist seconded to that laboratory.

In many cases, alloy degradation in combustive atmospheres stems from the reaction of the active solute with dissolved oxygen or sulphur to form internal precipitates. The consequent denudation limits the alloy's ability to form a continuous protective film. By understanding the mechanism of internal attack, substantial progress can be made in the field of alloy protection. Experimental alloys (dilute FeCr, FeAl and FeSi) as well as SA210, T11 and T22 were selected for this study. The alloys are reacted in Rhine's packs consisting of Fe/FeO and Fe/FeS powder mixtures in the temperature range 700-1200°C. These parameters are useful in predicting alloy susceptibility to the internal degradation mode. The possible contribution of alloy grain boundaries and the interfaces between the alloy and the precipitates to solute (OIS) transport at low temperature will be assessed quantitatively.

NUCLEAR TECHNOLOGY

Work undertaken by the Mining Research Laboratories 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

In 1974, the need for an expanding role for nuclear power in Canada was recognized. Accordingly, policy was initiated to encourage exploration for uranium in Canada. In addition, URAG was established to ensure that there would be continuing reliable assessments of Canadian uranium reserves, resources and productive capacity, as a basis for certain aspects of energy policy. To implement this, three URAG departmental subcommittees were created: Subcommitte on Reasonably Assured Resources (Measured and Indicated); Subcommitte on Estimated Additional Resources (Inferred, Prognosticated and Speculative); and Subcommittee on Economics of Supply and Demand. The Mine Evaluation Group (MEG) is responsible for the leadership of the Subcommittee on Reasonably Assured Resources, as well as having membership in the other two.

Since its inception in 1974, MEG, on behalf of URAG, has assembled primary drill data on relevant uranium deposits on a continuing basis. At the same time, it has developed required procedures for computer storage of data, as well as a variety of assessment methodologies for determination of reasonably assured and inferred resources. A major internal confidential report containing details of such uranium reserves and resources is produced annually. This report also contains descriptions of the status of all relevant deposits, as well as their estimated productive capacities and projected production capabilities.

Underground Nuclear Waste Repository

The principal effort during this period was centered on automation and computerization of the thermal diffusivity and guarded hot-plate thermal conductivity apparatus. The project suffered a major setback caused by extensive damage to both items of equipment during transport from the contractor by commercial carrier.

Experimental trials revealed that the principle of operation was sound; however, some deficiencies in the hardware and software have become apparent. Trials are currently underway to establish the limitations of the system and the extent of modification that will be required.

Thermal conductivity and thermal expansion measurements of all underground Research Laboratory rock specimens were completed. Thermal diffusivity measurements will be completed when the equipment has been made fully operational.

Uranium Extraction — Conventional Technology

Ongoing research aimed at maximizing the recovery of uranium from conventional, low-grade and complex ores continued during this fiscal year. As well, recovery methods used to recover byproducts such as thorium and rate earths were investigated. CANMET continued to provide process technology which offers minimum environmental impact during the past year, the major concern being the isolation of radionuclides to permit safe disposal of tailings.

Specific projects undertaken in the review period were rejuvenation of a silica 'poisoned' anion exchange: mixing characteristics and mass transfer optimization in solvent extraction; the influence of the physical parameters as well as the effect of humic acid on crude insolvent extraction circuits; optimization of precipitation of uranium from purified solutions; development of a novel precipitation process for the hydrolysis of a high-purity uranium product from acidic strip to eluate solutions; counter-current sulphuric acid leaching of low-grade ores from Elliot Lake; infrared studies on precipitation and extraction products; and application of high-performance liquid chromatography to the separation and determination of thorium and the 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 so 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.

Specific projects undertaken in the review period were hydrochloric acid leaching of the preconcentrates and small pilot-scale leaching of Elliot Lake uranium ore; hydrochloric acid leaching on high-grade complex uranium ore from Key Lake; high-temperature caustic treatment of complex ores; and mineralogical examinations of leach residue of uranium ore.

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 promote the development of technology in the diamond-drilling sector of the Canadian mining industry.

Research and development contracts have been let by CANMET during the past ten years, during which time the major research needs of the industry were identified in cooperation with the Canadian Diamond Drilling Association (CDDA).

During 1983/84 research work concentrated on the problems of waterline heater safety and costs, commencing with a nation-wide survey establishing the range, technical features and cost-effectiveness of commercially available waterline heaters. The survey indicated that there has been a trend towards the use of propane-fired units. However, it also indicated that there is a great deal of scope for the improvement of certain aspects of all heaters (including their safety features), flexibility of burner requirements and their dependability, etc. It was in these areas that R & D work was concentrated, and a list of recommendations developed.

Field-testing standard and experimental oil-fired water line heaters

Interaction of Equipment and Mine Design

The wider and improved selection of specialized machinery, equipment and instrumentation for use in the mining industry has had considerable impact on Canadian mining in the past ten years.

It was recognized by CANMET in the late 1970's that it was important to define the compatibility of mine design and the many different types of equipment, together with the emerging technologies of robotics and computerisation, in order to promote and maintain the high efficiency of the Canadian mining industry in the coming years.

This work started in 1981 with a thorough literature search on equipment development, followed by a review which identified areas requiring immediate development. A comprehensive plan of action was evolved, commencing in 1983 with field visits and direct R & D assistance and encouragement in identified areas. The principal R & D projects initiated under this program were the development of specialized, remote-controlled mobile mining equipment; computer programs to assist in mining operations, especially in the areas of design, geostatistics, rock mechanics and monitoring of the mine environment; and the development of planned maintenance programs for plant and equipment.

Mining Technology Coordination

Mining companies, consultants, universities, manufacturers and suppliers of equipment, governments, and private R & D groups are constantly improving the technology and equipment used in the Canadian mining industry. CANMET recognised the need to act as an intermediary between these different groups in order to promote the documentation, exchange and transfer of research and development technology in the Canadian mining industry. In the 1983/84 period, CANMET established an information bank on current and developing mining technology, and the information and data collected will be available to governments and industry.

Potash Mining

The potash mining industry in Canada is a significant contributor to export earnings; however, the technology associated with potash mining is wanting, and this prevents the industry from attaining its true potential. CANMET is spearheading a series of massive research and development programs, in cooperation with industry, aimed at improving the extraction ratio of crude potash in the mining phases and improving the recovery of potash in the processing phases. These programs will continue in the future.

Model Development

CANMET continued to develop and upgrade the numerical procedures used for the analyses of stress and stability of geological structures. The numerical models developed from this work form the basis of modern rock mechanics and have important applications in deep-mining situations today. The prediction and evaluation of ground behaviour in response to mining has become an important part of mine design and planning, as it provides an opportunity to quantify stresses and displacements induced in the rock mass as a result of mining, and therefore makes it possible to predict and interpret ground behaviour on a rational basis.

The installation of a VAX-11/750 minicomputer allowed a major effort to be directed towards the conversion of computer software programs related to numerical modelling. This will facilitate technology transfer to the mining-engineering community. An interactive statistical/graphical package (DATAPLOT) has also been implemented on the minicomputer which has been widely used in CANMET research projects.

VAX-11/750 system

Rock Properties and Support Systems

An increasing proportion of Canadian underground mining in the future will take place under high stress. Under such conditions, the post-failure strength and deformational properties of the rock materials must be taken into consideration for design. The requirements for ground support under these deep-mining conditions entail research, and to this end the effectiveness and limitations of present underground support systems need to be established; new methods of support must be developed; the increased accuracy and sophistication of analyses, related to mine design, require that more exact constitutive equations concerning rock strength and deformation properties be developed; and new test methods and procedures must be developed to permit laboratory determinations of the required properties.

The development of a testing procedure for determining the residual strength and deformation properties of rocks has been completed. The new procedure is being used to determine rock properties in conjunction with ongoing rock mechanics investigations at the Copper Cliff South, Prince, Springhill and Donkin-Morien mines.

A novel testing method was also developed for establishing the variation of the coefficient of friction along joints, as a function of joint surface roughness. The initial test results proved that the method enables an investigator to separate the influences of the various surface roughness features on the coefficient of friction.

Researchers studying rock-permeability test specimens

The relationships between interacting rock mass properties, the geometries of underground openings, and field stresses, with respect to the stabilities of both unsupported and bolted underground openings, have been defined by parametric analysis. The completed study resulted in a new method of analysis, which can be used to analyse rock mass stability and, consequently, to establish support requirements.

A preliminary investigation of frozen tailings materials, undertaken on contract by Nantar Engineering Ltd., resulted in a better understanding of concepts related to mining activities in sub-zero frozen ground materials.

Mine and Regional Stability

CANMET continued to investigate underground stability, particularly rockbursts, where high stresses are the major cause of rock failure. Using instrumentation, empirical and computer models are being used to study alternative mining layouts and sequences of extraction to alleviate these failures. Rock stress problems are most often associated with deep mining or operations with high extraction rates, and the end result of these high stresses can be pillar or wall failures, either gradually, or violently as rockbursts. In the past two years, ten hard rock mines in Northern Ontario have experienced rockbursts; however, rock mechanics tools to investigate and develop an understanding of rockburst phenomena preparatory to the development of control strategies are available, and the industry is resorting more and more to this technology.

The programs for monitoring rock stress in the Elliot Lake uranium mines were expanded with the installation of additional instrumentation and equipment. Substantial advances were made in understanding the stress

problems in these mines, although it was necessary to convert some of the testing equipment at the Elliot Lake laboratory in order to continue the investigations. Following rockburst activity at the Quirke Mine in Elliot Lake, it was observed that many of the mechanical rock bolts had failed, whereas friction-type supports were relatively undamaged.

A high-frequency acoustic emission/seismic events detector was tested in three underground hardrock mines in Northern Ontario. The results indicated that the range of the equipment was very limited and its operation was adversely affected by some normal mine conditions.

Rock-Mass Characterization

CANMET recognised that the evaluation of stability and support requirements in underground mines would be enhanced by the availability of a comprehensive rock-mass characterization strategy. This would serve, among other things, to reconcile the somewhat disparate roles of the mine geologist and ground-control engineer which commonly exist in many Canadian mines. Technically, it would hopefully improve understanding of how the rock mass interacts with support systems, such as backfill.

It is recognized that some specific operations in mining have special stability/support requirements, and in these cases, such as surface crown pillars, specialized rock-mass characterization systems are required.

During the review period considerable effort was made to determine the laboratory and in situ support characteristics of various types of cemented sand and rock backfill materials. The effects of size distribution, cement content, slag replacement and temperature were investigated. It was found that cemented backfill poured in mines in northern regions of Canada takes much longer to cure than in mines in warmer temperatures. In situ tests at one mine, where the rock temperature was 6°C, indicated that optimum strength was achieved after one year, compared to 28 days in laboratory tests at room temperature.

Aggregate grading and choice of absolute particle size were found to be crucial to the strength and stiffness of backfill. In many cases a better aggregate grading could result in reductions of the amounts of cement added. Tests are continuing to monitor the change in backfill modulus over time and as adjacent mining takes place.

A detailed structural geological survey was done around the surface crown pillar at Selbaie Mine, Quebec. This information will be used in future block models to try to predict the movement and stability of jointed rock and support requirements. Field-stress measurements were also taken at the Selbaie Mine, at shallow depth.

Hardware was developed for making roughness profiles on block specimens. A review of empirical models for stiffness prediction indicates that profilometric models now being developed will provide more consistent input data to a rigid block model. Progress has been made in identifying 'key-blocks' and the offset of in situ stress fields and joint stiffness on rock wedge stability.

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 environmental, 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.

Mine Health and Related R & D

The determination and adoption of the most appropriate technologies for improving the quality of both the underground environment and the participation activities to optimise working conditions has become a major aspect of the work being undertaken in the Mining Research Laboratories of CANMET.

The work incorporates four main elements: ventilation science; environmental monitoring; health-impact studies; and diesel emission control and certification of diesel equipment in respect to underground ventilation.

Ventilation science projects are related to coal mines as well as metalliferous and non-metal mines; therefore, the computerised ventilation network model is applicable to, and is being utilized by, various types of under-

Diesel control room at CEAL

ground mines. The R & D work is continuing to facilitate the improvement of these models, specifically in the technologies dealing with high ambient temperatures, high humidity and refrigeration.

Environmental monitoring work concentrated on the evaluation of toxic constituents in underground mine environments using laboratory equipment adapted for field (in mine) use, and the development and assessment of sensor equipment to continuously monitor the quality of the underground environment in an industrial situation.

CANMET continued to pursue Health Impact Studies related to the underground environment, which has involved the establishment of an Air Quality Index (AQI), currently being updated. The major polluting agency in underground mines is the diesel engine and the majority of the in-house and contracted-out R & D projects specifically deal with this subject.

In the field of Diesel Emission Control equipment CANMET has been intimately connected with the development of baffle-type water scrubbers, venturi scrubbers, ceramic total exhaust scrubbers, and water/oil emulsion fuel systems; all to reduce toxic emissions from diesel engines. During the period under review, work continued on the refinement of these devices, particularly on the aspects of regenerating filters without the need to remove them from the operating machines. There were some important and encouraging results and work will continue in 1984/85.

Underground Environment — Radiation

CANMET research and development work continued to concentrate on the development of radiation monitoring instrumentation; the quantification of radiation hazards in the mine environment and the full assessment of personal exposures; and the establishment of a national testing and calibration centre for radiation monitoring equipment.

Instrument development work continued under contract to EG & G Canada, who are developing a passive radiation data acquisition system (RDAS) for alpha, beta and gamma radiation monitoring in underground situations and mine tailings areas, and Alpha-NUCLEAR, who have developed a passive personal alpha radiation dosimeter to the point where laboratory and on-site testing is currently being planned. Alpha-NUCLEAR is also introducing, under contract, modifications to a computer-based radon daughter/thoron daughter continuous monitoring system for underground use.

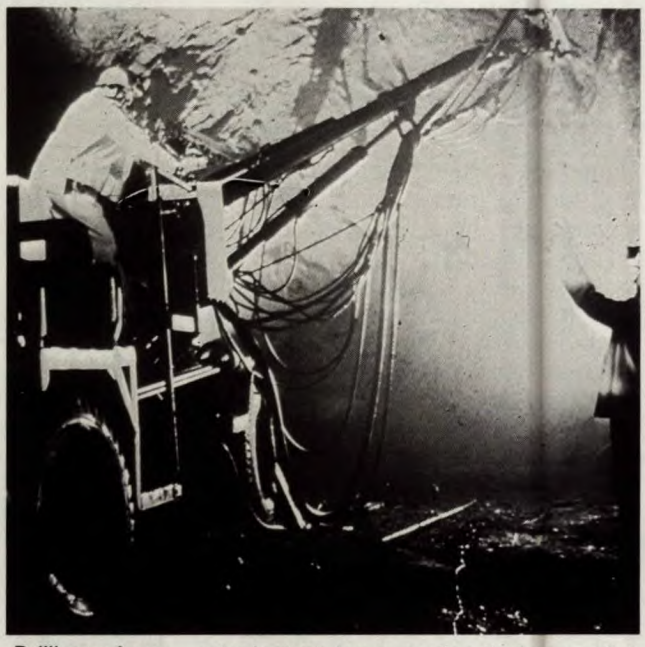
A program to identify and quantify, e.g., concentration and size distribution, long-lived radioactive dust (LLRD) in underground environments is in progress.

A program was initiated to assess the environmental radiation levels by monitoring the emanation of radon gas and decay products, as well as meteorological variables together with an investigation of the effects of backfilling operations on underground radiation levels and radiation level variance associated with other specific underground mining operations. These projects were being conducted at the properties of Dension Mines Ltd.

Background work has been completed and a final design has been prepared for the construction of the national Radon/Thoron Test Facility (RTTF).

Underground Environment — 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.



Drilling a face — a typical mining operation that can pollute the underground environment with dust, noise and vibration

There is a need to develop measurement techniques and programs to predict personal exposure, recognizing that there are large statistical fluctuations in space and time. The origins, character, composition, size distribution and other factors must be known in order to determine effective control measures and to guide and interpret epidemiological studies. This work requires the development of an extensive database, through sampling in mines, in cooperation with radiation and diesel emission scientists.

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

The difficulties involved in weighing small amounts of quartz on filters for use as standards in the infrared method have led to an ongoing investigation of other methods for checking these weights.

Computer programs were written to generate log-normal distributions of quartz dust data using parameters taken from the CAMPEDS sampling program of 1978 for the statistical evaluation of mine dust data. These distributions were then transformed by adding a constant to each value and the results were analysed graphically to simulate a comparison between two different sampling procedures.

A program was written to re-format the raw data from the CAMPEDS sampling program at the request of AECB.

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

The results from the combined working place, ambient exposures and medical study at the Labrador West Iron Ore Mines are being analyzed and further scientific reports prepared for publication.

A prototype optical asbestos sensor is being tested in the laboratory.

An optical sensor capable of assessing both diesel exhaust and mineral dust separately, in a combined dust cloud, is being developed. This is intended to be compatible with the Conspec system for telemetering to, and computer processing on, surface.

There is a great surge of interest in Ontario in gravimetric and X-ray diffraction assessments of airborne dust in mines. The laboratory is assisting many mines in setting up these programs. Publications are being prepared on the system developed at Elliot Lake Laboratory and its justification. This has involved further experimental work to refine some aspects. A contract has been proposed for development of a CAMPEDS dust sampler to match the improved miners cap lamp and battery under development.

Sulphide ores are difficult to wet for dust control programs and a laboratory study examining the use of surfactants and their influence on subsequent flotation is in progress.

Underground Environment — Noise and Vibration

Noise — Over ten years ago intensive work in Canadian mines began on personal hearing protection and audiometric testing. Today, noise measurements have become commonplace procedures in some sections of the industry. CANMET has contributed to the transfer of available noise control technology to the mining industry through cooperative field measurement programs and has been active in the development of measurement equipment suitable for use in mines.

The main effort is now being made in personal noise dosimetry, as it is thought that this trend in technology will prove to be the most compatible with the future Noise Exposure Index (NEI) measurements in mines. The new generation of dosimeters automatically provides all essential statistical data for the worker, management, union and environmental office to implement the NEI. The system exemplifies the important role of the computer program and the computer could even write the report.

Noise measurement studies at four Falconbridge mines (Falconbridge, Strathcona, Fraser and Lockerby) were carried out to investigate personal protection using practical and theoretical evaluation of all aspects of noise. These studies also measured the NEI according to the International Standards Organization regulation in order to obtain a large number of frequency analyses and statistical analyses to evaluate the efficiency of ear muffs and control noise exposure levels for all occupations. The efficiency of ear muffs under working conditions had been established previously at these four mines, at which time the effectiveness of enclosures to attenuate noise sources had also been investigated.

In the major underground mines in Canada the most common types of diesel equipment are Load-Haul-Dump (LHD) machines and ore trucks, the former being the noisiest machine in terms of operator noise exposure. Studies were carried out at Falconbridge's Strathcona Mine to determine what noise levels a scooptram produces at the exhaust outlet and the levels of operator's exposure to this noise under four conditions: without muffler, with small filter, with large filter, and with large filter, muffler and fume diluter; and to recommend improvements or means for their control.

Measurements of impulse noise of vehicles at the Stanleigh uranium mines, Rio Algom were performed and tests on the ventilation system at Rio Algom are already complete. All other tests on mining machinery have also been completed in the mines, mills and smelter at Falconbridge.

An environmental noise survey at Indusmin Ltd., Midland, Ontario has demonstrated that the noise level around the plant can be decreased. The key to a solution lies in a close rapport and cooperation between the company and the local municipality.

Vibration — Occupational exposure to vibration can reach intensities which may disturb comfort, efficiency and safety or health of workers. There is a distinction between the effects of vibration transmitted simultaneously to the whole body or a substantial part of it;

vibration transmitted to the body as a whole through the supporting surface, such as the feet or the buttocks; and vibration applied to particular parts of the body.

From a practical point of view it is convenient to treat whole-body vibration and hand-transmitted vibration as separate problems. The effects of vibration on workers in Canadian mines and mills have not yet been accurately defined. Vibration, and particularly localized vibration of the hand due to powerful pneumatic rock drills, has been cited as a potential hazard.

Experimental work conducted at the University of British Columbia under a CANMET contract was concerned with rock drills and provided the most comprehensive set of field data yet gathered in North America. The data provided representative details of the dynamic characteristics of drills commonly in use, and is important in assessing the effect of vibration upon people and in considering what design changes will facilitate decreased vibration levels. Test results showed that significant reductions in vibration levels can be obtained using vibration isolation systems.

ENVIRONMENTAL TECHNOLOGY

Mining, mineral processing, smelting and refining operations produce vast amounts of solid, liquid and gaseous waste products, much of which is toxic to animal and human life forms and their environment.

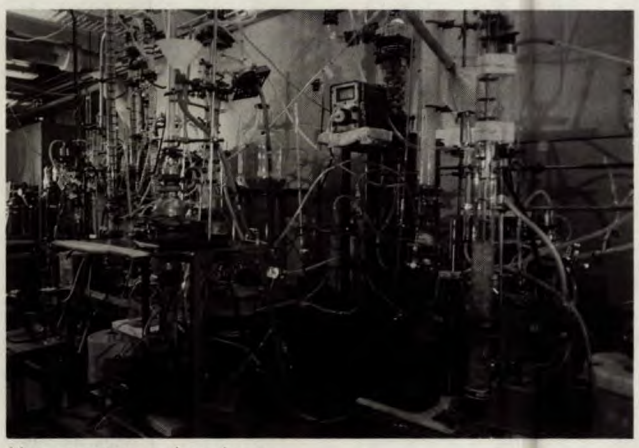
CANMET research objectives are to develop effective technologies to counteract or negate the toxic effects of these waste products.

Effluent Treatment of Toxic Wastes

Mining and metallurgical operations throughout Canada discharge tailings waste liquid and solid effluents which contain gangue materials and metals such as arsenic, antimony, zinc and lead. These metals are present in small quantities and are not usually economic to recover; however, they constitute an environmental problem, particularly with a change in pH from the alkaline neutralized effluent to the acid range. The acidity, which can result from acid rain or by oxidation of sulphides in the tailings to form sulphuric acid, causes leaching of the trace metals in the tailings and 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 tailing ponds and streams. During the period under review work was carried out on the removal of arsenic from mill effluents and the quality and treatment of thiosalt effluents.

Control of 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 to private industry. Of particular concern are non-ferrous roasting and smelting operations which result in sulphur dioxide (SO_2) emissions as well as the emission of arsenic and mercury and, in many cases, small quantities of other toxic elements such as cadmium, selenium, tellurium and lead. There is a need for more definitive data on the disposition of these trace elements in the concentrates and process circuits and on the form in which they are transported. Also required are data for modifying flowsheets for developing pollution abatement equipment for the economic removal and disposal or recovery of these elements. This is particularly applicable to those elements associated with dusts from smelters which, due to economic or location factors, do not have an acid plant and thus constitute particular problems, as do the roasting operations associated with the recovery of gold, silver, nickel and cobalt from arsenical ores.



Vap-aerators, absorbers

Research undertaken in this context included determination of the thermal properties of arsenides and arsenates, the reaction of SO_2 on pyrrhotite ores and SO_2 capture by solid materials associated with metallurgical processing operations.

Disposal of Uranium Tailings

With uranium mining operations, a large amount of low-level radioactive mine/mill waste is being produced which is conventionally discharged in tailings embankments on land. Weathering causes the oxidation of metal sulphides producing highly acidic tailings pore water which further leaches tailing material. With precipitation and recharge cycles, this acidic pore water, acting as a transportation medium for various metals and radionuclides, migrates to the surrounding environment as surface or subsurface seepage thereby severely affecting its natural quality. CANMET's research objectives have been the development of methods of tailings treatment, disposal and surface stabilization of inactive tailings piles; the reduction of the detrimental effects of contaminant transport via surface runoff; the study of groundwater infiltration as a subsurface seepage; and the study of surface erosion by wind and water.

Much of this work has been conducted at the Nordic Mine site at Elliot Lake where encouraging results are being obtained in area hydrology, chemical and radioisotope distribution profiles in tailings solids and in pore water, and migration of contaminants in the surrounding aquifer (contaminant plume). The groundwater flow regime in the tailings area has been established, and hydrogeochemical investigations are continuing to monitor migration of contaminants from tailings.

Work has been completed on flood-leaching characteristics of various mixtures of crushed rock from heap-leached uranium waste piles and iron hydroxide gypsum sludge.

Work has also been completed on phase one of the measurement of transport flux and transfer coefficients for various contaminants from underwater, buried, pyritic, uranium tailings in laboratory-scale lysimeter tests. The tailings under water were found to be in a reduction environment and it is believed that under such conditions secondary mineralization may be taking place within tailings. Further work is in progress for various other tailings and conditions.

Radon concentrations along tailings depth, diffusional parameters, and surface radon flux have been measured, along with various meteorological parameters using continuous in situ monitors and activated charcoal canisters. The results showed dependence of radon exhalation rates on temperature, pressure, tailings moisture content and porosity. No difference between vegetated and unvegetated area radon exhalation rates was observed.

Control of Uranium Tailings

Research continued to produce new operative techniques 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.

CANMET continued the series of lysimeter studies of tailings to identify whether relationships exist between laboratory and on-site test results and whether predictions about the chemical and physical changes in tailings can be accurately predicted. In simulated weathering-time cycles, correlations were made with measurements on actual tailings.

Also being studied are the relationships between compost or fertilizer cover with vegetation on the seepage effects with and without the presence of bacteria; comparisons of different tailings disposal techniques (layered, thickened discharge, etc.) with the normal random disposition using lysimeters; and freeze-thaw cycle investigations.

Laboratory experiments simulating the use of wood-waste for abating acid mine-water pollution were completed at Elliot Lake. Although preliminary estimates about the water capacity that can be treated were favourable, a larger-scale field experiment is required to establish the practicality of the process before lengthy work on optimization can be started.

It is well known that microbial mass has been shown to retain heavy metal ions from aqueous solutions. In recent laboratory work, various fungi growing on both hard woods and soft woods were identified and were subsequently placed in contact with mill tailings containing radium. The results indicated that the different wood-shavings had no effect on the adsorption of radium by the different organisms. Later data showed that desorption of radium was taking place quite rapidly with time and that it was not sufficiently long-lasting for radium recovery to be possible for practical use.

The development of alternative HCl technology to the conventional H_2SO_4 leaching of uranium ores has resulted in the solubilization of the radionuclides in the chloride solution. Tests have been carried out on various ion exchange resins. The resin with the best capacity to date is a Dow resin; however, the work is continuing on this resin, as well as on the sorption properties of other materials.

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. One method presently being considered for reducing the impact of tailings weathering on the environment is the establishment of a vegetative cover on the tailings.

CANMET's role consists of the demonstration and evaluation of methods for developing and maintaining a vegetative cover on the tailings, notably uranium tailings, and monitoring the effect the covers have on the quality of runoff and seepage water and on radioactive emanation rates.

Vegetation uptake of contaminants has been measured in various grasses, legumes, shrubs and trees growing on revegetated uranium tailings and its surroundings. Measurable amounts of radioactive substances have been observed in all plants; however, there were no significant variations observed in the various plant parts. Blueberries, tomatoes and apples growing on and around uranium tailings areas, and the skeletal bones of meadow voles established on revegetated tailings, were found to have some accumulations of radionuclides.

MATERIALS DEVELOPMENT TECHNOLOGY

The general objective of this subactivity is to improve the properties of materials derived from minerals and to expand their applications. 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 produc-

tion 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 and the residual stress levels in structures, and elucidate relationships between microstructure and physical properties in engineering alloys. Research is also 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 used in the steel industry.

Corrosion Mechanisms

Work during the past year was primarily concerned with studies of the mechanism of inhibition in coal-water slurries by some oxy-anion inhibitors. These inhibitors included chromate, molybdate, tungstate, phosphate and oxalate, and their effects were studied by weight-loss measurements and electrochemical techniques. Agreement between the rates determined by the two techniques was good.

The inhibitive films formed on steel in chromate, molybdate and tungstate were analysed using X-ray photoelectron spectroscopy, electron-probe microanalysis and Auger spectroscopy. The chromate-formed film appeared to contain chromium species in a film several monolayers thick, while the molybdate- and tungstate-formed films were of the order of a monolayer.

Other work focused on a preliminary investigation of the sulphide stress cracking (SSC) resistance of seamless tubing used for 'oil country tubular goods'.

Corrosion of Municipal Water Piping

A survey commissioned by CANMET reported that many Canadian cities are experiencing an excessive number of failures of underground water piping. However, the literature available in the public sector is scant and does not specify the failure mechanisms responsible, nor point to a viable solution of the problem.

To characterize the nature and extent of the problem a study was carried out in the city of Calgary, where most of the municipal water piping is cast or ductile iron. It was found that failures occurred through mechanical factors, which peaked in the winter, and to corrosion — which occurred at about the same rate throughout the year. Many failures resulted from a combination of mechanical factors and corrosion. In particular, a number of ductile iron water pipes were noted to have failed by corrosion through the wall after only 5-10 years of service in a corrosive soil.

A report on the observations at Calgary has been prepared and distributed to a number of municipalities in Canada. The findings have also been presented by the contractor at conferences in St. John's, Edmonton, and Toronto.

Plastic Flow, Fracture and Stress Analysis

During 1983/84, work continued on establishing and upgrading in-house fracture mechanics test facilities. Tests known as J-integral, KIC and CTOD can now be performed on single-bend specimens at any temperature in the range from $-150°C$ to $+150°C$. Associated test procedures and data analysis are completely computerized.

Investigations have been carried out on some specific aspects of fracture mechanics such as 'pop-in' behaviour arising from short arrested cracks in brittle material as well as the use of small specimens to obtain fracture toughness properties. Work on evaluating the hole-drilling method as a means of determining residual stresses has continued.

CANMET Portable X-ray Stress Diffractometer

The development of light-weight detectors, responsive to X-rays, and capable of accurately identifying the position of an incident X-ray photon, has made it possible in recent years to contemplate measuring surface stresses in structures of all kinds in the field with an X-ray diffractometer that is truly portable.

Several X-ray stress diffractometers are now commercially available which are, to varying degrees, portable or transportable. Notwithstanding this competition, development of the CANMET Portable X-ray Stress Diffractometer continues in the confidence that its design embodies several desirable features and that the opportunity exists to engineer the first commercial prototype in a way that avoids some of the shortcomings of the competitive instruments.

The CANMET diffractometer will be designed to operate in either the multiple- or single-exposure modes, i.e., with one or two detectors respectively.

Both modes of operation have certain operational advantages all of which will be available with the CANMET machine. In addition, the CANMET diffractometer can collect and process data in a manner that greatly improves the accuracy of stress determinations in structures that have large and/or distorted grains or gradients in crystographic texture. Patents for this technology have been applied for in Canada, the U.S., Japan and seven European countries.

In the past year, the performance of the instrument has been evaluated in CANMET through shakedown trials with the experimental or engineering model.

Microstructure and Properties of Engineering Alloys

Work on microalloyed steel included studies of recrystallization behaviour, the continuous cooling transformation (CCT) kinetics of plate and heat-affected zone

(HAZ), weldments and micromechanisms of cleavage fracture in plate and HAZ. The quench-deformation dilatometer was used to determine the CCT characteristics of microalloyed steels as a function of deformation temperature, deformation strain and cooling rate. Scanning transmission electron microscopy (STEM) and automatic image analysis (AIA) were used to characterize the microstructures of banded, partially acicular ferrite steels, and to correlate the microstructures with cleavage fracture behaviour.

A new scanning electron microscope (SEM) with energy-dispersive X-ray microanalysis capability was interfaced with the image-analysing computer. Techniques are being developed for quantitative analysis of SEM images of nonmetallic inclusions and for characterizing non-uniform size distributions of inclusions by the method of Dirichlet cells.

The worn surfaces of several experimental plate steels were characterized by SEM and optical metallography and correlated with the results of laboratory abrasive-wear tests. Models for high- and low-stress abrasion mechanisms were proposed. Finally, the microstructure and mechanical properties of cast copper-nickel-tin spinodal alloys were determined. The grain-refining effect of a number of trace element additions was studied, and both isothermal and isochronal age-hardening curves produced.

Zinc-Based Alloys

In view of the industrial significance of the new family of zinc-aluminum foundry alloys, this project was undertaken to establish their foundry characteristics and improve their ductility by microstructural modification. This work is of interest to zinc producers and foundries and to this end, discussions were held with Noranda Research Centre, Cominco, Kidd Creek mines, and other industrial groups.

A meeting of the industrial consulting committee formed to advise on industry's interests in developing these commercially important alloys was convened during the year. The committee's views are taken into account when planning research and it exists to help transfer technology that may be developed as a result of CANMET research.

A contract was awarded to Queen's University, Kingston to study the structure and mechanical properties of directionally solidified zinc-aluminum alloys containing 8, 11 and 27% aluminum. Various casting parameters such as gating ratio, riser volume, use of insulating sleeves, and pouring temperature were found to influence the occurrence of underside shrinkage. Research has indicated the means of materially suppressing this defect and it has become the subject of a patent application. Microstructures of the alloys have been modified by small additions of a number of elements and the mechanical properties of some of the modified alloys determined.

Development of Non-Leaded, Free-Machining Steels

Contract work continued on this project throughout 1983/84. Led by Professor D.A.R. Kay of McMaster University, research focused on replacing aluminum in heats of free-machining steels by additions of calcium and niobium — the calcium for deoxidation and the niobium for grain-size control. With elimination of the abrasive particles that originate from deoxidizing with aluminum, machinability tests at McMaster have demonstrated reduced tool wear.

Research continues to determine what calcium additions are required to ensure a minimum volume of the preferred anorthite deoxidation product.

Research is performed on steel from industrial heats supplied by Canadian steel companies participating in the program. Originally supported by one steel company only, seven currently contribute to the work. In addition to providing the funding for the program, CANMET lends support by characterizing inclusions using quantitative metallography.

Rapid Solidification Technology

This project was initiated to foster the development of rapid solidification technology (RST) in Canada. As a preamble to beginning a research project a review of the state-of-the-art and the industrial potential of RST has been completed. While the large number of potential applications has generated a world-wide research effort, in Canada there is little awareness of this technology.

A metal spinning apparatus is being developed which will facilitate the initiation of a research project in RST. Further discussions with industry will determine the major thrusts of this project.

Development of Instrumentation and Techniques

Development of new analytical methods on the scanning electron microscope (SEM) and Microprobe will give crystallographic information to supplement the elemental identification obtained from the energy dispersive X-ray spectrometer. The SEM has been adapted so that backscattered electron diffraction patterns may be observed.

Microbeam analyses were carried out for a large number of CANMET projects, often furnishing data vital to the successful completion of the project. In addition, CANMET carried out microbeam analyses on specimens varying from gold coins to defective bolts, which were submitted under the START and other cost-recovery programs.

The commissioning and calibration of the Philips EM400T transmission/scanning transmission electron microscope (TEM/STEM) has been completed. The

equipment is now in use full time for characterizing the microstructure of a variety of materials, including pipeline steels, naval bronzes, semiconductor and superconductor materials. Techniques developed in-house to extract precipitates from steels and bronzes for the purpose of microanalysis are well established. An ion-thinning unit for preparing and cleaning thin film specimens has been installed and is operating satisfactorily. Development of techniques for preparing specimens of semiconductor materials (in collaboration with Bell Northern Research Laboratories) is proceeding well and has led to detailed studies of defects in Si- and GaAs-based devices.

Determination of Hydrogen in Steels

Routine analysis of 100 samples submitted by PMRL scientists was carried out.

Analysis of over 400 carbon steel samples before and after treatment with a complex acid solution (NAP) gave values for surface bound hydrogen and residual (internally bound) hydrogen. The results showed that NAP treatment minimizes hydrogen embrittlement.

Studies aimed at minimizing the diffusion of hydrogen from steels during storage have the form of immersing samples in ethylene diamine tetra acetic acid (EDTA), imidazole and a mixture of imidazole and alkylated pyridines. These experiments have demonstrated that storage at 0°C in the media mentioned, limits hydrogen loss by diffusion over a period of one week to about ten per cent of the original concentration.

Performance and Durability of Concrete

CANMET continued to develop data on mechanical and elastic properties and durability of portland cement, and portland cement concrete incorporating less energy-intensive materials for applications in Canadian marine environments and the acidic waters of northern Canada. The most promising of the less energy-intensive materials for replacing cement are granulated slag, fly ash and silica fume. The energy required to produce granulated slag is estimated at only 25% of 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 materials used, it is essential that investigations be undertaken to obtain long-term performance data on their use in concrete, with and without high-range water reducers, under Canadian climatic conditions.

A series of investigations were initiated to develop data on the mechanical and elastic properties of concrete incorporating these materials. Data were also generated on the combined use of fly ash and silica fume in concrete and the performance of silica fume concrete under repeated cycles of freezing and thawing. The inspection of test prisms installed at Treat Island, Main was performed; visual checks were made, photographs taken and pulse velocities determined.

A report on limestone dust as a partial replacement for fine aggregate in concrete was completed. The study indicated that up to 10% limestone dust can be satisfactorily substituted for fine aggregate in lean concrete mixes. Studies on the durability of air-entrained concrete and non-air-entrained concrete produced some disappointing results. The investigation dealing with the combined use of fly ash and silica fume to increase the early-stage strength development of concrete gave encouraging results.

Corrosion of Asbestos Cement 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 or intestines, asbestos-cement (A/C) pipe is meeting increasing resistance to its use in water supply sewage and industrial waste disposal systems. 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 reevaluation of the corrosion of the A/C pipe was needed.

No laboratory work was performed but 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 non-specialists. The second, which will be available in 1984, critically reviews the corrosion environments of the A/C pipe corrosion agents; (waters, soils, gases); various corrosion mechanisms (including the microbiological conversions of sulphur); the current theoretical explanations of A/C pipe corrosion; and the various corrosion control measures available.

Thermal Shock-Resistant Ceramics

Ceramics are inherently brittle materials because, by virtue of their lack of ductility, they are susceptible to failure under tensile stresses induced by temperature gradients established during heating and cooling. In evaluating existing ceramic materials or new materials under development, it would be useful to have a method for at least ranking comparable materials for resistance to thermal shock. Current methods are lengthy, laborious and frequently expose the operative to unpleasant working conditions. An existing theoretical method requires the determination of a number of physical and thermophysical parameters between room and high temperatures, utilizing a variety of complex equipment found only in the most sophisticated laboratories. Its use is largely restricted to materials for engineering applications in advanced technologies, such as the space vehicle. A simplified treatment developed in CANMET is based on the product of thermal expansion and thermal diffusivity, each relatively simple measurements employing a minimum of relatively inexpensive equipment. To date, good correlation has been obtained between

the predicted thermal shock resistance of a suite of experimental clay flue-lining materials and those obtained by empirical test methods.

No productive results were obtained in the period under review as damage to the equipment necessitated extensive repairs and re-commissioning.

Electrodes and Refractories for the Steel Industry

CANMET is committed to determine the nature and mechanisms of failure of slag-zone and metal-zone refractories for Vacuum Oxygen Decarburization (VOD) and Vacuum Argon Degassing (VAD) ladles, and to report on specifications of modified or alternative materials.

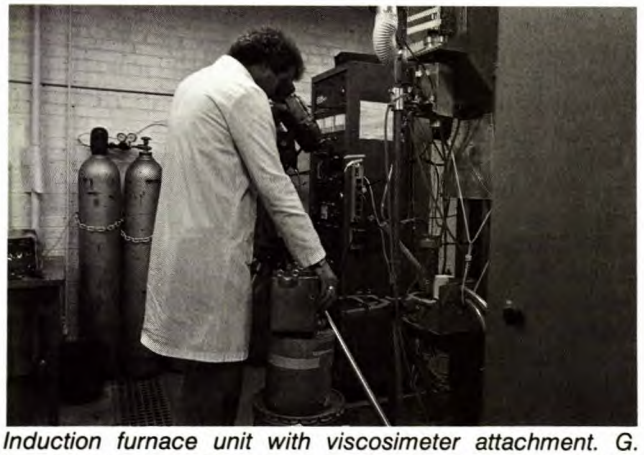
The electrode work aims to establish practical methods for evaluating measurable properties of carbon electrodes and refractories that could be related to their performance in operation and applied as acceptance standards for the materials. This project also satisfies an expressed desire on the part of the steelmakers for an 'independent' source of information beyond that of their suppliers, without necessarily implying lack of confidence in the suppliers, who are a continuing source of advice.

The steel industry is adopting electric arc-furnace technology. The high-powered units employed are efficient melters, but are underemployed if used for secondary steel-making operations, which are increasingly being performed in ladles and associated transport vessels in a variety of processes. These intermittently operated vessels are subject to thermal shock, to increased temperatures, more aggressive slags, vacuum pressures, oxygen blowing and gas stirring; all leading to a shorter lifetime of the refractory linings owing to corrosion, erosion and spalling. Work to-date has involved determining the mechanisms of attack relative to furnace practice, and has revealed the previously unreported adverse effect of vacuum at high temperatures.

Equipment for the automated testing of electrical conductivity of ceramics. G. McDonald, Operator

Ladle-lining lifetimes of only one third of those previously reported have been experienced following the introduction of the production of heat-resistant, titanium-bearing steels. Work is underway to comprehensively study and identify those elements of the process contributing to increased degradation and to show where changes in furnace practice could be advantageous.

The cost of graphite electrodes is a major element of the overall cost of electric-arc furnace technology. There is currently no test method for predicting the service performance of electrode materials. The aim of this project element is to examine the physical, chemical and electrical properties of electrodes, seeking correlation with known performance behaviour and, ultimately, to select or develop test methods that might be utilized for acceptance testing of electrode shipments. Initial work was conducted on a suite of small electrodes; however, all properties examined vary too widely to be appropriate bases for discriminating among them. Ultrasonic pulse velocity and eddy current measurements, perhaps in combination, appear to hold some promise, and investigations are continuing. Current work is directed towards examining samples obtained from a Japanese steel producer.



Induction furnace unit with viscosimeter attachment. G. Lemieux, Ceramic Technician, measuring viscosities of high-temperature silicate melts

Abrasion-Resistant Ceramics

CANMET continued to develop relatively inexpensive abrasion-resistant materials for applications such as linings for materials-handling systems subject to corrosive and erosive wear. The literature related to Canada's mining industry regularly reports on the problems and costs of high wear rates experienced in mining equipment and related chutes and bins. Although ceramic tiles have been used efficaciously, no Canadian supplier has been regularly available. Imported materials are available, based on aluminous porcelains, alumina and zirconia-reinforced alumina and mullite.

In-house work has centred on the development of porcelain-type materials reinforced with cristobalite, the well-known high-strength composition of Japanese electrical porcelain.

Under a series of small contracts, the Ontario Research Foundation (ORF) has developed compositions suitable for production of tiles of glass ceramics and slag ceramics. These compositions have not yet elicited much interest; however, the technology, although common in Scandinavian and Warsaw Pact countries, is essentially foreign to North America.

The spray-pyrolysis technique has been examined as a means of applying abrasion-resistant coatings to ceramic and metal substrates; however, the technique has been shown incapable of producing coatings of sufficient thickness for use on components of 'ceramic' internal combustion engines under development (e.g., hot diesels).

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 1983, the Canadian Certified Reference Materials Project (CCRMP) distributed approximately 1550 units of reference materials to users in Canada and abroad.

J.H.G. Laflamme, with furnaces used to synthesize compounds used as reference standards in electron beam analyses

CCRMP was organized by CANMET to fulfill the demand for geological reference materials of Canadian origin from Canadian industrial, commercial and research laboratories. CANMET involvement is essential because continuity and impartiality are essential for long-term credibility and public acceptance of reference materials. This is consistent with other industrialized nations which also have assigned the production of reference materials to government institutions.

The Chemical Laboratory is active in the analysis of reference materials for the certification program and for the total chemical composition, and also participates in the interlaboratory certifications 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.

Analytical Methodology

CANMET continued to develop and improve analytical methods, techniques, and laboratory facilities, mainly in support of CANMET programs, 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

This project continues to provide technological expertise and information for Canadian and international standards-writing organizations concerned with aggregates and concrete by: performing development work on in situ tests, non-destructive testing (NDT) methods and other tests; coordinating the Canadian Standards Association (CSA) round-robin cement-testing program; organizing conferences on the use of NDT and new concrete materials; and representation on national and international committees.

Aggregate and concrete testing and standards contribute much to ensuring that concrete will perform as specified in construction projects, thus protecting the interests and the safety of the public.

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. CANMET continues to coordinate 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 current production of a cement plant selected at random from among the participating companies.

Hay Chevrier, Technician, operating a machine for the compression testing of concrete

A comparative study on the use of in situ tests for strength prediction of concrete at early ages was carried out to determine the within-test variability of various in situ tests currently being used in the field, and to determine their ability to predict early-age strength development of concrete for formwork removal purposes. The methods investigated included penetration resistance, pulse velocity, rebound number and two types of pullout tests.

CANMET, in association with the American Concrete Institute and the Corps of Engineers, U.S.A., sponsored the First International Conference on the Use of Fly Ash, Silica Fume, Slag and Other Mineral Byproducts in Concrete, at Montebello, Quebec, August 1-5, 1983. More than 325 people from 15 countries attended this conference at which 100 technical papers were presented. The proceedings have been published.

The CANMET film on NDT of concrete was revised and also translated into French, and should be available for release in 1984.

The Zeiss semi-automatic video plan system has been tested for pore analysis of concrete and compared with the results obtained on the Quantimet system. The former will be used for future analyses of pore and particle-size distribution.

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 and centres, 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. NDT personnel are being 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 continue to be computerized.

METALS PROCESSING TECHNOLOGY

Exploratory Foundry Research

Experiments have been conducted to find compatible suspensoid-metal combinations, where the suspensoid is readily wettable by the metal, but does not dissolve easily, and the density difference between the two components is small. For example, silicon carbide and aluminum is not a successful combination because finely ground particles of carbide cannot be dispersed homogeneously in the melt, and the addition of fluxes merely produces dross around the particles. Further investigations have been undertaken in which molybdenum powder is mixed with molten copper; however, density differences appear to be a potential problem.

Degradable Sand and Core Binders

During investigations on accelerators for degradable sand and core binders, difficulties were encountered with the slow curing rates of the newly developed sand binder when added to a large sand mass.

Numerous experiments were undertaken to speed up the reaction between the acid syrup and the limestone precipitant. Increases in curing rates have been realized by pre-warming the sand, increasing the quantity of limestone, or decreasing its particle size, but only at the cost of a shorter working life.

The incorporation of gamma butyrolactone did not result in the benefits hoped for. Although initial hydrolysis is comparatively rapid, the rate of reaction diminishes rapidly with the rise in pH of the system. A similar compound, but with more predictable hydrolysis, is thought likely to accelerate the hardening sufficiently to satisfy anticipated commercial needs.

Halides of cations, which are more noble than calcium, increase the speed of hardening when added in moderate quantities to a dry mix. However, working life suffers, there is a noticeable loss in final properties and the packing density is also reduced because the moulder mix is stiff.

Electroslag Casting

Operating parameters including withdrawal forces, wire feed rates, power inputs and oscillation speeds have been assessed and control limits established to optimize the production of thin-wall hollow cylinders using the electroslag casting process. Problems have been encountered with a poor outer surface finish which has been related to excessively rapid rate of heat extraction by the water cooling. Measurements have been made to control water flow rates so that heat extraction can be controlled. The water-cooled mandrel has been redesigned to reduce the rate of heat extraction and at the same time has been modified together with the outer mould to enable cast electrodes of chosen composition to be melted in addition to wire. With this arrangement the composition of the hollow cylinders produced by the process will no longer be limited to the compositions of commercially available feeder wires.

Dynamic Properties of Casting

A contract has been issued to Alloy Casting Industries Ltd., New Hamburg, Ontario to determine the fracture toughness characteristics of two low-alloy steel widely used for producing steel castings for low-temperature applications. To date, the test castings have been produced but the low temperature properties and the static and dynamic fracture toughness characteristics have yet to be determined.

Gravity Permanent Mould Casting

In connection with the research work on inoculation of grey and ductile iron cast in metal moulds, plate castings have been poured in grey iron moulds incorporating reaction chambers containing MgFeSi, to produce inmold ductile iron. The resulting castings had excellent nodularity but always contained regions with irregular

graphite, probably associated with oxide carried over from the reaction chamber. The effect of filtering and/or re-design of the reaction chamber and runner system is now being investigated.

A grey iron mould for a more complex, wheel-shaped casting with a central sand core has been designed and manufactured. The mould developed cracks after approximately 30 castings had been poured. Faults in the castings attributable to stresses set up in the mould during cooling have been noted. The effect of variables such as mould temperature, break-out time, and alloy composition on this defect are under investigation.

Work continued on the study of the influence of gating design on the quality of permanent mould cast irons. A series of plate castings have been poured both in grey and ductile cast iron, side-gated either at the bottom or the top. No consistent effect of gate position on surface quality or on internal structure was noted. A ceramic filter was used in pouring one ductile iron casting but again, there was no noticeable improvement in casting quality.

Work on thermal profiles in permanent moulds was continued under contract by the University of Ottawa where researchers have written finite difference programs to model heat flow in permanent moulds. The current versions treat two-dimensional flow for Cartesian or cylindrical co-ordinates, and three-dimensional flow for castings and moulds with cylindrical symmetry. Programs for a more general three-dimensional case, and modifications to allow for variables such as a finite pour time and solidification shrinkage, will now be developed.

Electric Furnace Melting

An electric furnace survey modelled after the CANMET cupola survey has been started as CANMET's contribution to a joint CANMET-Ontario Hydro study of the melting efficiencies, operating practices and melting costs of electric induction furnaces in Ontario iron foundries. CANMET activities in this project have included: technical definition, project logistics and responsibility for the metallurgical aspects of tests at eight foundries in Ontario. Hydro carried out the evaluations of the electrical performance of the furnaces. A joint report will be issued in mid-1984.

Mobile Foundry Laboratory

As part of the federal government's START (Short-Term Aid in Research and Technology) program, a mobile foundry laboratory facility has been designed and outfitted for transportation to any Canadian foundry location. The main objectives of the program are to utilize state-of-the-art technology to evaluate production methods in Canadian foundries and to demonstrate the benefits of improved process control. Not only will the information derived from these visits be used to assist the foundries to assess and improve their production methods, it will be used also by CANMET in guiding future foundry research.

Equipment has been purchased and installed which will permit the following four activities to be addressed: evaluation of moulding methods and materials, spectrographic determination of metal composition, microstructural analysis and the use of microcomputers in foundry process control.

Four teams, made up of personnel from the Foundry Section, have taken special training in the operational use of the laboratory. To date, nine foundries have been visited, and the reception and enthusiasm of the foundries has been uniformly high. A total of about 50 foundries are scheduled for visits in nine of the ten Canadian provinces. Following each visit, a confidential report is made which lists the data acquired, conclusions drawn and any recommendations for improving a foundry's operations.

Foundry laboratory software-Microcomputer software for designing the risers of steel castings has been written under contract by Queen's University. The model has been evaluated against experimental castings weighing up to 250 kg, and demonstrated to two commercial foundries. Final refinements are now underway to make the software commercially viable.

Low-Pressure Disposable Mould Casting

Development of a new low-pressure disposable mould casting process continued with production trials using commercial automotive casting patterns. Experiments were conducted using different pattern washes, metallic and non-metallic moulding media, and different casting and gating configurations. Results have been encouraging with casting yields substantially higher than that obtained with the present commercial casting process. Trials are continuing with a view to improving metal quality and reducing casting defects.

Processing of Ultra Clean Steels

Experimentation has established the benefits of low residual elements in steels to improve the fracture toughness and stress corrosion cracking in plate, and to improve the ductility in plate, strip and sheet. The benefits of low carbon and low residuals on formability are also well known. In this new project, ultra clean steels and ultra low carbon steels will be produced and co-operative ventures will be sought with the steel industry aimed at quantifying the improvements in properties accompanying the reduction in carbon and impurities and comparing these improvements with the cast.

Equipment for the induction-melting and teeming of 225-kg heats of steel under vacuum has been purchased and is now being installed. Meanwhile, studies in the foundry on the deoxidation of induction-melted steel have resulted in changes to melting and teeming practices aimed at eliminating the harmful aggregation of inclusions. A database has been compiled on the concentration of inclusions in some commercial steels and on the impurity levels obtained with the current melting equipment in the PMRL foundry.

Included in this project has been the development of an on-line accelerated cooling (OLAC) system in tandem with PMRL's 457-mm diam two-high, experimental rolling mill for processing ultra low carbon and ultra clean steels. A system has been designed under contract and is currently being fabricated.

Rolling Mill Technology

In the production of modern high-strength steels foreign competition, especially from the Japanese, has a distinct technological advantage because of the more powerful mills, superior process-control systems and on-line accelerated cooling systems. Undoubtedly, the Canadian steel industry will move to higher levels of technology, as capital funds permit, in order to optimize current as well as future facilities, basic data and understanding of the deformation process as well as the effects of accelerated cooling. CANMET has continued with the difficult experimental work to obtain accurate, detailed information about the mechanisms that describe the deformation of a metal and of the metallurgical changes that accompany the deformation. From such information, new rolling schedules can be developed and evaluated on the PMRL rolling mill.

The cam plastometer and the mill were applied interactively to develop controlled-rolling schedules and to predict the forces generated in rolling microalloyed steels to thick gauge plate. The predictive model, developed from this work, has shown that increased reduction per pass reduces redundant work in the hot rolling of large-thickness slab and plate. With reduced redundant work, the efficiency of mill loading and power consumption is improved, and because of the enhanced homogeneity of deformation, grain structure and mechanical properties are also improved.

In a related aspect of this project, a numerical model of temperature and stress-strain profiles was developed with the finite element method "MARC" loaned by Atomic Energy of Canada. This work demonstrated that problems of inhomogeneous deformation, local stresses and strains, and the effect on deformation of temperature gradients can all be successfully treated by the finite element method; homogeneous flow theories do not lead to accurate predictions.

Significant equipment upgrading has also been undertaken. A new electromechanical screwdown drive and regulation system has been installed on the experimental mill. This system rapidly closes the roll gap between passes and provides the options of semi-automatic, or computer (automatic) controls, as well as manual operation of the rolls. Interpass times are reduced by a factor of two and roll-gap setting is more precise. The overall operational capability and flexibility of the mill, therefore, has been significantly improved for developing new rolling schedules.

The software for automatic control of the mill has been successfully tested for operation of the screwdown system. Software has been developed for automatically controlling mill direction.

Major improvements continue to be made to the cam plastometer that has now been linked to a microprocessor. Programs to control tests, capture and process data and to produce numerical or graphical outputs have been successfully tested. Under contract, a system has been designed to adjust loads rapidly and automatically between hits. Finally, a fully programmable in situ induction heating unit has been selected and acquired. These improvements will greatly increase the scope of the plastometer for both applied and fundamental research on the metallurgy and mechanics of deformation processing. Of special importance will be the investigation of the strip rolling of microalloyed steels.

In studies carried out under contract, controlled rolling of a molybdenum-niobium-vanadium (Mo-Nb-V) microalloyed steel has been simulated by hot torsion experiments. The influence of roughing deformation, finishing-schedule deformation, and post-deformation cooling on the refinement and homogeneity of grain structure has been investigated.

Formability and Processing of Sheet Steels

The sheet metal industry is experiencing an era of new challenge and competitiveness in an essentially mature market. The major user of sheet steel, the automotive industry, is demanding ever more stringent quality assurance from its suppliers of fabricated components and raw steel.

To meet the required dimensional and shape tolerances on stamped and drawn parts, fabricators must operate with a better understanding of the forming characteristics of these steels. The steel industry, for its part, must upgrade its processing capabilities to supply steels of consistent quality and properties. The objective of this project is to assist both industries by contributing to the basic understanding of processing and metallurgical variables on press shop formability.

A new computer data acquisition and processing system has been developed to analyze tensile and rigid punch tests. New criteria and test parameters, within statistical uncertainties, have been derived to improve the understanding of the correlations among formability factors. An extensive capability for representing these correlations graphically has been established with the departmental computer hardware — CDC CYBER.

The comparative formability of dual-phase and commercial steels was studied and related to chemistries, microstructure and textures. Fracture processes and fracture surfaces were studied in detail and, finally, the steels were heat treated to investigate the hardening that occurs during a paint-baking cycle and the relative sensitivity of the steels to yield point return.

Fluidized-Bed Metal Processing

On-line heat treatment in fluidized sand beds to control cooling rates and hence, phase transformations in rails

and other shapes, has been shown to yield significant property improvements. This technique has also been effectively utilized to simulate a range of cooling rates in hot sheet during runout from a rolling mill to a coiler.

The suitability of fluidized-bed technology to controlled cooling and tempering of steel tubular products for oil and gas recovery in deep wells will be evaluated. However, as a preamble to this work, the hydrogen sulfide stress corrosion cracking resistance of a series of Grade 90 tubular casing steels was assessed by standard National Association of Corrosion Engineers (NACE) tests. In other studies the usefulness of the short-rod test in assessing fracture toughness is being evaluated on some Grade 95 and 140 casing steels.

Near Net Shape Forging

Near net shape (NNS) forging to near final dimensions saves material by reducing flash, saves energy by reducing processing steps and offers direct economic advantages by substantially reducing finish machining. Although this technology was developed for specialized, expensive alloys, it is also applied to mass produced forgings in modern steels. However, the technical issues are complex because material flow is inherently non-uniform and this restricts the development of uniform microstructure and properties. Approaches to resolving these difficulties combine forgeability, studies of grain movement during hot deformation and mathematical modelling of the deformation process.

Techniques and procedures have been developed and experiments performed to study the effects of deformation on the grain structure of a simple metal (pure iron) in hot forming and a cooperative program to determine the forgeability of stainless and valve steels was started with Queen's University. A fully coupled thermal elasto-plastic finite element code is under development to model thermomechanical behaviour in deformation processes.

In contract research, an investigation to assess the microstructural features which limit formability in mass-produced cold forgings was completed. Four commercial steels were studied and the effects of the size and shape of test specimens on the manner in which the specimens failed and the effects of microstructural features, principally inclusions, as initiators of failure, were studied in detail.

Weld Mechanics

Residual stresses in single pass welds were measured experimentally and compared with the residual stresses computed by the finite element technique. The experimental work was carried out at PMRL by the cut and section technique. In this technique, strain gauges were mounted on a weldment and the strain release measured when coupons carrying the strain gauges were cut from the weld. Residual stresses were calculated and the results showed that the magnitude of the stress found in an experimental weld exceeded the yield stress of the weld metal, and approached the ultimate tensile strength.

Thermal/Mechanical Simulation of Metallurgical Processes

The computer-controlled Gleeble 1500 thermal/mechanical simulator was used to study continuous casting in cooperation with two major Canadian steel producers. In this program, the effect of changes in casting speed and cooling rate on the structure and properties of a range of steel compositions was studied. The objective of the work was to understand the mechanisms by which cracks form during continuous casting.

Several studies of factors affecting heat-affected-zone structure and mechanical properties in welding operations are underway: the role of niobium on heat-affected-zone toughness is still being evaluated for a series of microalloy steels, since rates of energy input and cooling during welding are typical of linepipe fabrication; a series of heat-affected zones was simulated preparatory to studies of stress-corrosion-cracking susceptibility in linepipe welds; the heating/cooling conditions to optimize the properties of the heat-affected zone in flash butt welds were determined on a number of welded rail steels.

Effect of Nitrogen on Weld Notch Toughness

This project was undertaken to evaluate the effect of nitrogen on the notch toughness of weldments prepared in low sulphur, 'clean' steels for line-pipe and offshore structures.

The project has been delayed because of a problem in producing steels with low sulphur content and a range of nitrogen levels. Experimental steels produced by the electroslag casting were not consistent in composition. A number of steels will be prepared using the new PMRL vacuum-melting and casting furnace which should be available in the 1984/85 fiscal year.

When suitable steels become available the microstructure and notch toughness of simulated weld heat-affected zones will be assessed.

Heat-Treated Rail

Experiments to determine the effect of microstructure and hardness on the wear resistance of rail made good progress. Disks of chromium-molybdenum rail steel were heat-treated in a three-by-three matrix to microstructures of pearlite, bainite and tempered martensite at hardnesses of Rc38, Rc42, and Rc45. The disks were tested in a special-purpose rig designed and operated by the Tribology Laboratory, NRC, Vancouver. The rig simulates the heavy-duty wheel/rail contact stresses developed by unit trains.

The work revealed that dry wear rates of rails with tempered martensite or bainite structures decrease significantly with increasing hardness in rails on the high side

of track but that rails with pearlite microstructures are relatively unaffected. Pearlite microstructures offer the best wear resistance to dry wear, but lubrication decreases the wear rates of rails with all microstructures by up to two orders of magnitude. The microhardness of rails increases sharply very close to the worn surface at specific points across the width of a rail. Extensive work on a transmission electron microscope indicates that an ultrafine grain size and inter-carbide spacing develop very near the surface. Detailed observations on a scanning electron microscope demonstrate the great importance of inclusions in producing surface cracks. Measurements have been made in an attempt to quantify the effect of inclusions on initiating and promoting cracks.

Other work in this project, which has focused on developing a superior premium rail, has taken two directions. The first has been to simulate inline quasi-isothermal processing of rails in a fluidized bed to determine the conditions necessary to produce a rail of high hardness and strength in Cr and Cr-Mo containing steels. The simulated work is complete with results promising to be of industrial significance. The second study has been directed towards evaluating the effects of varying levels of vanadium, nitrogen, and aluminum on the microstructures and mechanical properties of chrome alloy premium rail steels. The results indicate that the production of pearlite microstructures can be controlled to give a cost-effective increase in yield strength at 'normal' nitrogen concentrations in the steel.

Marine Materials

A review of cast steels potentially suitable for making controlled pitch propellers for icebreakers has indicated that there are several such steels commercially available.

Experiments have been carried out to date on plates of carbon-manganese steels to determine the feasibility and the optimum conditions for normalizing hot-rolled steel as it comes off the mill. The attractive features of such a process are productivity and the conservation of heat (in the hot-rolled plate).

Five steels were specially made for the project and were rolled into plates of specified thickness. Experiments carried out in muffle furnaces at temperatures to simulate on-line process indicated that good, all-round mechanical properties could be expected from plate processed in this manner. The results are to be confirmed by further experiment on-line with the PMRL experimental rolling mill.

Experimental welding of a fracture-tough steel currently in use for shipbuilding continued pending the delivery of experimental steels ordered for this project from Canadian steel companies. New equipment for high-energy welding experiments has been received and weld simulation studies have been started on two steels aimed at correlating coarse-grain heat-affected zone properties with prior microstructure and thermal history.

Naval Materials

This project has been carried out with financial support from the Department of National Defence (DND), although the work is also of interest to the Canadian Coast Guard Service (CCGS), Canadian Stone Marine Ltd., and others in the foundry and ship-building industries.

CCGS icebreaker propellers, cast in manganese/nickel/aluminum (Mn-Ni-Al) bronze, have low fracture toughness, particularly in heavy sections, although separately cast test specimens of the material show it to be tough. As a result, there have been several examples of propeller damage on Canadian icebreakers and it is the purpose of this project to investigate this problem. To this end, research has focused on identifying the microstructure associated with low impact properties and on attempting to develop an industrially feasible heat treatment that improves properties. The foundry responsible for the propellers has cooperated in the work by permitting PMRL staff to measure the cooling rates of propeller castings. With a knowledge of the rates of cooling in different locations of a propeller casting, specimens of continuously cast Mn-Ni-Al bronze with different aluminum and manganese contents have been homogenized at 900°C and cooled in the furnace at different rates to simulate the thermal history in different locations of a cooling casting. The microstructure of some of these specimens has been characterized already and their tensile and impact properties determined. Experiments aimed at developing a restorative heat treatment have been carried out.

In other work on Mn-Ni-Al bronzes the corrosion fatigue behaviour of alloys containing 12% and 14% Mn was studied on contract at École Polytechnique, Montréal. Results show that the lower Mn alloy has better corrosion fatigue resistance in sea water.

"Sonoston" is the trade name given to a high-damping propeller bronze developed to reduce the underwater noise associated with propeller vibration. This work characterizes the alloy in such respects as foundry properties, the heat treatments necessary to optimize mechanical properties and damping capacity, best welding procedures and consumables, corrosion fatigue behaviour, and was begun originally at the request of the Department of National Defence. The foundry characteristics and mechanical properties of the alloy have been determined and some damping capacity measurements have been made on contract to Whiteshell Nuclear Research Establishment, Pinawa. It has been confirmed that a specific damping capacity of 10% can be obtained in this alloy after aging. However, when subsequently stored at room temperature, the damping capacity decreases by almost 50% in a period of about one month.

The microstructures, mechanical properties and damping capacity of samples from two propeller blades, supplied by the Defence Research Establishment Atlantic (DREA), Halifax, are being determined.

As a demonstration project, a Ni-Al bronze valve casting, supplied by DREA, Halifax, has been weld repaired with the 'low-aluminum' filler wire developed in earlier work at PMRL. Microstructures of the weld-repaired areas have been assessed in both the as-welded and post-weld heat-treated conditions.

CONSERVATION AND RESOURCE ASSESSMENT

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 mineral commodities, namely vanadium, chromium, manganese, zirconium, lithium and phosphate rock.

In response to increased interest in industrial minerals by industry and by provincial and federal governments, a task Group was established in CANMET to review industrial minerals, particularly with regard to R & D needs and problems of the industry, and 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.

Four projects were identified: the improvement of processing methods for the recovery of minerals and mineral products from developed and non-developed resources of select industrial minerals; the study and development of improved methods for the production and sizing of ultra-fine mineral materials for specific applications; the study of mineral filler requirements for Canadian industry and the development of technology for processing minerals to provide material acceptable for this market; and cooperative research projects with provincial governments and with industry in mineral areas identified as having potential for development and exploitation.

Mineralogical Studies of Marginal and Complex Ores

Work continued on the determination of the mineralogical character of the complex zinc-lead-copper sulphides ore of the New Brunswick and other fine-grained complex sulphide deposits, to provide technological data related to the mining and processing of such deposits to assist in assessing their economic exploitability.

In the Buchans area of central Newfoundland the study of the mineralogy of altered volcanic rocks around the Lucky Strike orebody was continued. A detailed examination was made of samples from the massive sulphide deposit, which is comprised of four separate orebodies and is quite distinct and apparently metallurgically different from the main orebodies at Buchans.

A study was carried out on the mineralogy of a large massive sulphide deposit containing significant amounts of copper and cobalt that occurs in a remote part of northern British Columbia. The deposit is similar in some respects to the massive sulphides of the Bathurst area of New Brunswick, particularly the Caribou deposit, which has been intensively studied.

Research in automatic image analysis applied to resource assessment and mineral processing has been successfully transferred to operating plants with large economic benefits. The techniques have refined and are being exploited by the installation of a system assembled for the purpose that incorporates scanning electron microscopy, energy dispersive X-ray analysis and data-processing software. The techniques developed have been extended to the study of impurities in a lead concentrate and phase relations in materials extracted from a lead blast furnace.

A successful study was carried out on the crystal structure of a new mineral from a large base metal deposit in a remote part of northern British Columbia. It has a hollandrite-type structure and may provide information useful in the development of 'synroc' for the storage of nuclear wastes. The crystal structure of tungstite ($WO_3 \cdot H_2O$) was also solved. This mineral, a minor constituent of many tungsten deposits, has been known but little understood for about 80 years.

Canadian Silica Resources

Work continued on a project to characterize and assess Canadian silica deposits that have potential for the economic recovery of silica 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, 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.

The first phase of this study, Ontario, was completed and a report published.

The second stage, Quebec, is in progress. In cooperation with the Quebec Ministry of Natural Resources,

sandstone/quartzite samples from seven areas are being studied as potential sources of material for glass manufacture and foundry applications. Beneficiation procedures, following reduction to sand, include attrition scrubbing, magnetic separation, froth flotation and acid leaching.

Precious Metals Recovery from Ores and Tailings

CANMET continued to develop new technology for the recovery of precious metals from Canadian ores, tailings and residues to assist governments and the mining industry in assessing the economic exploitability of these resources.

R. Craig, Chemist, analysing metal in ores with an atomic absorbtion spectrophotometer

The study of the distribution of platinum group elements (PGE) and other minor constituents in minerals of ores and processing products was continued. Emphasis was placed on the development of methods of in situ micro-analysis by Particle-Induced X-ray Emission (micro-PIXE) and Secondary Ion Mass Spectroscopy (SIMS). Research continued on the development of improved methods for recovering gold from tailings and difficult ores. There has been a considerable increase in the effort directed to developing placer deposits and investigations have been started to improve the methods of processing them. In addition, research has been started on a suitable economic and environmentally acceptable method for recovering the gold contained in arsenical ores.

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, in slags.

Most concentrates of copper, nickel and lead sulphide ores are treated by pyrometallurigical 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.

Electrochemical apparatus for the determination of thermodynamic properties of arsenides in the laboratory of Jim Skeaff, Research Scientist

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.

The recovery of nickel and cobalt from electric and reverberatory furnace slags by smelting with pyrrhotite mineral was studied. The effects of temperature, time and amount of pyrrhotite addition were investigated and preliminary results indicated the possibility of collecting substantial amounts of nickel and cobalt from the slags in the molten iron sulphide phase. The kinetics of the process, however, seem to be slower for the reverberatory furnace slags than for the electric furnace slags. The study will lead to optimization of the various experimental parameters and to further understanding of the kinetics of the process.

Samples from different heights in the lead furnace of the Brunswick Mining and Smelting Corporation Limited were studied to determine the reactions within the furnace and to assess the behaviour of phases during smelting. The results indicated very specific reaction zones and gave satisfactory results on which to base future research.

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 a chemical gypsum for cement production was completed during the period under review.

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, nota-

bly 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 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.

An initial literature review on alkali-resistant fibre was undertaken and completed, and as a result appropriate samples of materials were prepared, tested and reported upon.

The large increases in fuel prices have 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)

Advances continued to be 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.

A system of software demonstrations has been developed to permit access of the EMR computer to remote industrial users to test a series of programs covering various elements of computer-aided process evaluation and optimization, namely: sampling, material balance computation, modelling, simulation and laboratory utilities. The system is accessible through DATAPAC, a national data communication network. Work was started on a system allowing the recording of the display of a computer terminal on a video-cassette recorder. This will provide easier program documentation and training aids. A 5-day workshop on process evaluation and optimization was held in October 1983, at Lac Delage, Quebec. The preliminary sampling of the Victoria Junction Coal washery was started late in 1983 with flowrate measurements by lithium tracer and a two-day seminar on sampling. In-house efforts were directed toward making user access to programs easier. The material balance program BILMAT was upgraded to include a conversational file editor and automatic array dimensioning. A conversational regression program (STAMP) was developed to run on a CDC and an IBM computer and in its present version, it includes simple and multiple linear regression, polynomial and stepwise regressions.

Iron Ore Processing

CANMET researchers continued to identify methods for improving grade and quality of iron ore concentrates, quality of pellets, lessen environmental impact and improve process control.

Canada is well endowed with iron ore resources and policy makers have assumed that Canada will therefore remain a major supplier. However, in recent years it has become increasingly apparent, in a buyer's market, that Canada cannot assume it can compete in each and every market. High labour and energy costs have made pellets less attractive then sinter feed to a blast furnace. There is a need to improve efficiency, reduce energy input costs and improve product quality and recovery.

Work on alkali additives to pellets has progressed and a report is in progress. Flotation studies are being done as another possible means of alkali removal. The roast leach aspect of removing alkali, reported last year as very promising and possibly patentable, has been given a lower priority due to the depressed state of the industry, but a final report and feasibility study will be completed in the next fiscal year.

Three reports were completed on water treatment for recycle and disposal under the co-authorship of EPS and CANMET which are still in review process.

To improve homogeneity of feed to the concentrator and for better quality control, a comparative study between chemical and geostatistical control techniques will be done on contract.

Many meetings have been held between CANMET, Centre de Recherches minerales, Gouvernement du Québec and the Quebec-Labrador producers, concerning a new cooperative iron ore project to carry through until the year 1989. It is felt this new venture will avoid a redundancy of R & D and add a much greater stimulus to the industry which at present is in a very depressed

state. Areas for R & D have been identified and finalization of plans are in progress.

Design, Development and Evaluation of Equipment

CANMET continued with its programs concerned with the design, fabrication and testing of the continuous process development unit (CPDU) and equipment not available commercially; the testing and performance evaluation of commercial mineral processing equipment; and comparison of the performance of alternative equipment designs.

Continuous Process Development Unit (CPDU)

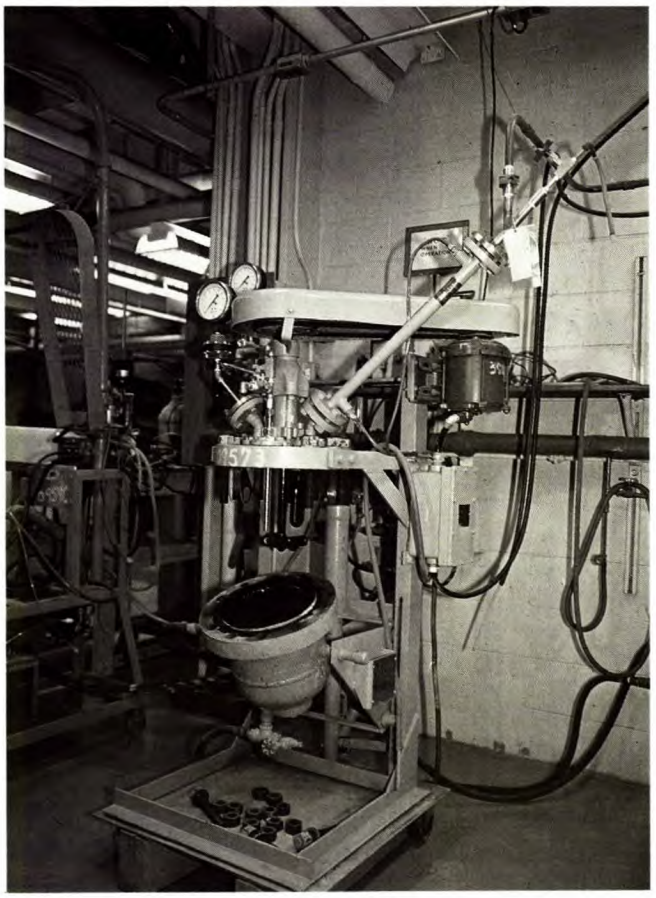
Good progress was made in rendering operative older items of equipment such as crushers and screens, grinding mills, air separators, colour separators, etc., and several new items of equipment were purchased including flotation cells, a Mozley hydrocyclone, a ceramic-lined pebble mill and a Kipp-Kelly air table.

A contract to design, develop and test a mechanical device that will perform basic bar and hammer tasks in mine-mill-smelter operations was initiated during the review period.

Hydrometallurgical Lead

Research work continued on the project to develop a hydro-metallurgical process for the recovery of lead, silver and other valuable components from typical Canadian lead sulphide concentrates and from lead-bearing residues generated in other processes. This project is being carried out in cooperation with the Canadian lead-smelting industry and the USBM. The process is based on chloride leaching and lead electrolysis.

Conventional lead-smelting processes may be unable to meet the proposed in-plant hygiene specifications for lead and cannot readily handle some of the lead residues produced by processes treating complex sulphide bulk concentrates. Chloride processes for lead will give a lead chloride ($PbCl_2$) product which might be amenable to fused salt electrolysis or aqueous $PbCl_2$ electrolysis to recover the lead and regenerate the chlorine. Sulphate processes will result in a lead sulphate ($PbSO_4$) product which could readily be converted to $PbCl_2$ by brine leaching. There is an incentive, therefore, 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.



Flotation bank and on-stream analyser

The research work is being undertaken on four fronts: the investigation of leaching reactions in regard to lead, silver and arsenic minerals; the solubility of silver and lead chlorides; the purification-regeneration of leaching solutions; and electrolytic lead recovery.

Metal Extraction and Refining

New Brunswick has the largest reserves of zinc, lead and silver in Canada and the economic exploitability of these resources has been severely hampered by the complexity of the ore-bodies. It has been demonstrated that high recoveries, which are essential for the economic viability of many of the N.B. 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 by-products from the bulk concentrates, while minimizing environmental problems associated with the removal and/or disposal of pyrite and sulphur dioxide.

Three processing options have been selected for producing high-value refined products. The relative technical and economic merits of a ferric chloride extraction process are being investigated at CANMET. Two sulphate extraction processes are being investigated, primarily at Sherritt 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 Industrial Expansion (DRIE), with CANMET as scientific authority.

Work on a CANMET/Sherritt-Gordon shared cost contract, designed to resolve problems associated with pyrite/sulphur agglomeration when the Pressure Sulphuric Acid (PSA) leach process is applied to bulk concentrates, was successfully completed during 1983. A report will be issued by Sherritt in 1984.

Plans for the design and construction of a 10 tpd pilot Sulphation Roast Leach (SRL) plant near Chatham, N.B. have been approved. Construction is scheduled to be completed by March 1985. The cost of the plant will be financed primarily by DRIE (N.B.). A technical advisory committee has also been established with CANMET and industry representation. Operation of the pilot plant on feed materials, recommended and supplied by industry, is scheduled for April 1985.

Leaching tests based on the Ferric Chloride Leach (FCL) Process were conducted under various conditions and a contract has been awarded to review FCL processes, to evaluate progress to date and to design a flowsheet with a view to a pilot demonstration plant.

Other projects undertaken or continued during the period under review included: sulphate control during leaching operations; solvent extraction of zinc from iron chloride leach solutions; silver recovery; silver cementation from cuprous chloride electrolytes; copper and zinc electrowinning from chloride electrolytes; CANMET/Cominco joint program on zinc electrolysis; solution studies; ferrous chloride oxidation; and analytic development.

Dry-Way Chlorination-Oxidation of Complex Ores

Research work continued on the project undertaken to demonstrate an anhydrous chlorination process capable of recovering, as marketable products, at least 95% of the metal values and sulphur from the complex sulphide bulk concentrate made from a complex New Brunswick ore.

A key step, referred to as deferrination, in the pyrometallurgical chlorination process is the elimination of all or most of the iron content of the chlorination product. High iron concentrations in subsequent leach solutions would be a major interference in metal recovery procedures such as solvent extraction or electrowinning. A promising method for iron control is by the formation and evolution of ferric chloride vapor involving the injection of an excess of chlorine into the melt after the metal sulphides have been completely converted to liquid metal chlorides and gaseous sulphur by stoichiometric chlorine injection. Studies were initiated wherein mixtures of metal chloride reagents were used to simulate a typical chlorination product.

An investigation was carried out to determine whether low-temperature chlorination of sulphide ore utilizing sulphur monochloride (S_2Cl_2) was a technically feasible alternative to the pyrometallurgical route which involves chlorine gas injection to a melt. It was determined that chlorination at approximately 100°C for 30 min provided good metal extraction. Removal of excess sulphur monochloride from the product was accomplished by passing a stream of nitrogen at 70°C, for one hour, over the material. With a suitably short retention time in the chlorination vessel, the extraction of iron could be minimized without affecting extraction of the copper, lead and zinc.

Hydrometallurgical Processes 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 sulphur dioxide (SO_2) emissions. Although reductions in SO_2 emissions 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 review of the literature on the hydrometallurgical extraction of copper and nickel from sulphide ores has been completed and is being re-edited prior to issue in final form. Based on an initial detailed consideration of 51 processes, the review selected only 14 processes for final evaluation with almost sole emphasis on copper. The review identified specific areas of R & D which are required to advance the prospects for commercialization of these processes.

Further evaluations of the Great Central Mines (GCM) process have been carried out to determine the process viability in Canada, particularly for copper producers such as Hudson Bay Mining and Smelting. A report has been written and a paper presented documenting the comparative benefits of the process, based on the premise that high purity cathode copper can be produced directly. However, pilot-scale R & D will still be required to verify technical feasibility.

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.

Although heap leaching is widely practiced, it is not entirely suited to Canadian climatic conditions; however, 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.

During the period under review, research work continued on bacterial leaching of sulphide ores and the biohydrometallurgical removal of silica from alumina ores. The inaugural meeting of the Mineral Leaching and Metal Recovery Bio-technology Research Network (BIOMINET) comprising Canadian universities, mining companies and technology development organizations linked together to further the use of biotechnology in the mining industry was held on October 13-14, 1983 at CANMET. A steering committee was selected and a survey was developed and circulated by this committee to determine the amount of interest in various biotechnology areas.

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.

Investigations of the available literature and exploratory bench-scale testing have not indicated any promising lines of research that might be pursued to further the economic recovery of vanadium from the tar sands bitumen prior to ashing of the tar, so this line of investigation will be discontinued.

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 was undertaken, 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.

Headway has been made in all these areas of research during the period under review.

Tin Recovery From Base-Metal Tailings

CANMET initiated a research project to develop methods for the recovery of tin from base-metal sulphide flotation tailings that are more efficient alternatives to the inadequate gravity concentration methods now in use.

Tin occurs in varying amounts in many Canadian base-metal sulphide ores. Three operations in particular, Kidd Creek Mines, Brunswick Mining and Smelting Corp., Ltd. and Heath-Steele lose over 7000 tonnes of tin metal per year, worth about $90 million. Only Kidd Creek mine has a tin recovery circuit utilizing state-of-the-art gravity concentrations but operations have been suspended because the very low tin recoveries obtained (less than 10%) do not cover operating costs. Even the development of a method for recovering only a modest 30 to 40% of the tin in the tailings would result in a substantial increase in economic return.

The project commenced with an intensive survey of world literature on tin concentration methods to formulate a research strategy. The most promising recovery methods for fine cassiterite are dissolved air flotation and other processes which depend on surface properties such as two-liquid flotation, spherical agglomeration and selective flocculation.

A mineralogical study was carried out on samples of Kidd Creek mill products obtained on a visit to the plant. The results show that about 85% of the cassiterite in the mill tailings occurs as free grains ranging in size from 4 to 37 αm, with most being in the 9 to 18 αm size range. The free cassiterite grains recovered in the tin concentrate were in the same size range as those in the tailings and are too small to be effectively recovered by the current state-of-the-art gravity concentration methods employed.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

Certification and Technical Advice

The Certification and Technical Advice project of the Explosives Authorization, Testing and Research subactivity has been developed to fulfill the requirements of Section 14 of the Canada Explosives Act. During the 60 years in 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 continuously developed. The expertise in Explosives Safety Engineering is developed in-house through contact with manufacturers' research laboratories, contracted re-

search projects, in-house development projects and international contacts. Because of the proprietary nature of commercial formulations, results of individual examinations for authorization remain confidential.

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

Research Activities and Results

During the year, 184 new explosives were examined for authorization. These involved some 2013 sample units of work. Corresponding figures for 1982/83 were 159 and 1838, respectively, and for 1981/82 were 233 and 2059.

The increased number of samples submitted for laboratory examination during 1983 reflected the slight improvement in the economy. Significant increases were noted for high explosives (Classes 1, 2, and 3), ammunition (Class 6.1) and fireworks (Class 7.2.1).

There were no major accidents in manufacturing during the past year requiring the laboratory's involvement. At the request of industry, an explosive cutter developed to remove the heads on roof bolts was evaluated and slightly modified to cut reinforcing cables used underground for roof stabilization. The laboratory gave evidence in a court case involving illegal use of explosives. The effect of potential new coatings for prilled ammonium nitrate on the thermal stability of the ammonium nitrate was evaluated using the accelerating rate calorimeter and the laboratory was involved with several explosives' manufacturers and the RCMP for the interchange of analytical methods for explosives.

The laboratory cooperated with industry in designing a number of experiments for determining the likelihood of a propellant crossing over to detonation. A series of tests on rocket motor igniters were observed so that a suitable U.N. classification could be established. Based on these test results, a submission will be made to the U.N. to establish a new entry for these devices. Assistance was also given to industry in measuring noise levels generated by certain military pyrotechnic devices.

During the year, the laboratory completed the installation and evaluation of X-ray equipment for the non-destructive testing of various explosives articles. This equipment adds a new dimension to explosives testing in that malfunctions can be traced to design defects or changes that have occurred because of rough handling or transportation. The equipment was used to identify possible manufacturing defects in bombardo boards that could have resulted in a number of these boards blowing up during fireworks displays. No defects were found and discussions were held with the manufacturer to identify other potential causes for these occurrences.

Explosives Research and Development

Canada is working with other countries under the auspices of the United Nations to develop a unified, international classification system for dangerous goods, including explosives. Current planning is for the Canada Explosives Act to be amended to adopt the proposed new standards by 1987. CANMET is evaluating the proposed new standards, based on a hazard assessment system, together with test procedures used in other countries, against the current Canadian standards, which are based on a chemical classification system and CANMET test procedures to ensure that no significant changes in explosive classification would result. CANMET is acting in a lead agency role together with parallel agencies in other countries in this international evaluation of the proposed new standards. This work is planned to be completed by 1986.

Scientist using an accelerating calorimeter in the Explosives Research Laboratory

New emulsion explosives are being developed by Canadian industry. These explosives must be characterized, health and safety hazards identified and quantified, and reliable test procedures for routine evaluation developed. This is part of an ongoing effort to upgrade explosives test and evaluation procedures.

Due to the cost and complexity of testing bulk samples of explosives for safety characteristics, CANMET has concentrated for several years on the development of computerized-modelling capability to evaluate such parameters as detonation sensitivity, fume generation and propagation properties, based on chemical constituents of explosives. This modelling work has reached the stage where field verification using large samples is necessary. This work will be phased in over the next five-year period.

During 1983/84, Canadian Explosives Research Laboratory (CERL) continued to study the thermal stability of explosives using its accelerating rate calorimeter (ARC). The laboratory completed its evaluation of pure high explosives including PETN, ROX, TETRYL, TNT and nitroguanidine. Work was initiated on the reactivity of

various metals with ammonium nitrate. Preliminary results indicate that several metals react at temperatures significantly below the melting point of the ammonium nitrate. This study is being pursued.

As a result of difficulties encountered in relating propagation or air gap sensitivity of explosives from results determined in laboratory-scale tests to real-world situations, a series of studies were pursued to establish this relationship. A number of types of confinement were studied including sand, steel and concrete. The critical air gaps that were determined in steel and concrete for various diameters of explosives were much greater than expected. As a result of the interest shown by industry in this work and the potential usefulness of the information to mining applications, follow-up work is being planned under contract.

During the past year, the laboratory sent a delegate to a series of meetings of the United Nations Group of Experts on Explosives. These meetings were held at Morgantown, W. Va., U.S.A.; Geneva, Switzerland; and Bonn, Federal Republic of Germany. As a result of these meetings, a draft manual of tests has been assembled to accompany the U.N. Recommendations on the Transport of Dangerous Goods.

The development of an expendable impact pressure gauge is progressing. Some difficulty has been encountered in calibrating this gauge dynamically; however, it is expected that these problems will be resolved. Work is also progressing on drop tool impact measurement which is 75% complete.

The contract on the "Computer Model for Predicting Detonation Properties of Slurry Explosives" was completed. The work of this contract is part of CANMET's continuing efforts for the development of new standards for the certification of explosives. The goal of this contract was to develop a suitable model for calculating detonation parameters of slurry explosives.

MINERAL AND ENERGY TECHNOLOGY INFORMATION

Since 1975 all of CANMET's information-handling services have been centralized in one functional unit: the Technology Information Division (TID). Consisting of the Library Services Section, the Publications Section, and the Technical Inquiries and Documentation Section, TID is responsible for the production and dissemination of information concerning mineral and energy technology.

The technical information program encompasses the following activities:

1. Development of information resources by the identification, selection, evaluation and acquisition of technical information from world-wide sources that is related to CANMET's area of expertise. These resources are required in order to support CANMET's in-house research as well as its commitment to provide a national science-technology resource network.
2. Processing of information to ensure its effective access by CANMET's varied audiences. This entails the organization through cataloguing and classification of the Library's information resources, the development of various indexes and databases, and the editing and physical preparation of CANMET research reports.
3. Dissemination of information by the provision of library and information-retrieval services to CANMET staff, in support of their research endeavours.

Since CANMET's mandate includes the provision of technical information and advice to the government and to the Canadian public as well, TID also provides services to other government agencies and to the private sector.

INFORMATION RESOURCE DEVELOPMENT

In 1983-84 the Library acquired 1616 print monographs and 906 items in microform. Current subscriptions to periodicals in major world languages number 2591, an increase of 205 from the previous year. In all, 2727 new items were added to the Library's collection for total holdings of 208 604, as of March 31, 1984.

Long-planned alterations and renovations to the Library, begun early in March 1984, will help remedy storage and work space problems. The Bells Corners Complex Reading Room will be opened in either late spring or early summer.

INFORMATION PROCESSING

The Library's Cataloguing and Classification Unit nearly doubled its output over last year, due largely to the elimination of start-up problems with the computer-based UTLAS system and to increased staff familiarity with the system. A total of 3427 items were classified, catalogued and added to the collections, compared to only 1837 in the previous year.

Growth in public use of the Mining Technology Database (MINTEC) and the Mineral Processing Database (MINPROC) has far exceeded expectations, proof of the usefulness and ready acceptance of these information service products. During the reporting period, the MINTEC file increased by 1993 new records, for a total count of 26 728. MINPROC stood at 8656 documents on March 31, 1984, an increase of 1910 records over the preceding year.

Publication of the literary output of CANMET's scientists and contractors is one of the major activities of TID. During 1983-84, 909 reports were produced by CANMET. Table 1 summarizes the production by report category and source.

The Publications Section, TID, assisted the laboratories in their successful participation in Science Week '83 by the production of the many posters, signs and informational booklets. It also assisted the Office of Technology Transfer in the exhibits presented in Montreal at Promotech '83.

A valuable photographic resource of 800 slides depicting CANMET's facilities and activities was also accomplished in this year.

INFORMATION DISSEMINATION

In 1983-84 the Library loaned 70 705 items to CANMET staff.

The Interlibrary Loan Unit, which helps serve CANMET's commitment to the concept of a national science-technology information network, filled 4345 external requests for loans and photocopies, a decrease of 15%. Although the reasons for this decline are not yet fully known, there are two likely causes: the convenience of the on-line ordering facility offered by CISTI and CISTI's ability to accept deposit accounts against future orders, eliminating the need to process invoices separately for each order.

The value of the MINTEC and MINPROC databases, publicly available through QL Systems, is apparent in their reception by the Canadian public. During the reporting period, 3819 searches were done on MINTEC, an increase of about 25 per cent from last year. Searches on MINPROC numbered 1188 for an increase of 175 per cent over the previous year.

Table 1 — Printing of Reports by Category and Source
1983-84

CATEGORY	MSL	ERL	MRL	PMRL	CRL	RPO	OTT	ADM	TID	TOTAL
CANMET Reports	12	—	—	—	3	—	—	—	1	16
Journal Submission/ Oral Presentations		17	39	43	15					114
Divisional Reports	15	23	70	29	13	2			28	180
Internal Reports	1	4	11	7	1	1				25
Confidential reports		37	6	1	6					50
Contract reports				1						1
TOTALS	28	81	126	81	38	3	—	—	29	386

The Coal Database (COAL), available through the National Research Council's CAN/OLE system, is produced by cooperating member countries of the International Energy Agency. TID, which is responsible for the database in Canada, performed 209 searches on it in 1983-84. All together, 8498 public searches were done on this database during the year. The heaviest users were government agencies, followed by industry and universities, respectively.

The Coal Projects Database (COALPRO), a companion database to COAL and also produced by cooperating IEA member countries, was made available for public use for the first time in August 1983. There have been a total of 1429 searches performed on this database during the reporting period.

The Technical Inquiries and Documentation Section received 2811 major requests for information, a decrease of 4.7 per cent over 1982-83. Of these, 2232 were handled by TID's information officers, slightly more than the previous year. Table 2 provides a breakdown by subject and origin of inquiries.

Various products and services provided by the Technical Inquiries and Documentation Section include:

- Current Awareness Lists: monthly printouts, based on individually tailored interest profiles, listing recent additions to commercially produced databases. During 1983-84 there were 106 users of this service.
- MINTEC/Mining Technology Abstracts: a compilation of additions to TID's Mining Technology Database. Twenty-two issues of the bulletin were distributed to 122 recipients.
- Bibliography of Canadian Contributions in the Field of Rock Mechanics: an annual compilation by TID staff of technical journals, proceedings of symposia and conferences, and theses submitted to Canadian universities. The compilation is published in the Canadian Mining and Metallurgical Bulletin.
- Current Contents – East European Mining and Mineral Technology: a bi-monthly bulletin containing translated tables of contents of East European periodicals dealing with mining and mineral technology. Five issues were prepared in 1983-84 and distributed to 26 clients throughout EMR.
- Open File Reports: a bi-monthly report containing information on recent CANMET publications and research reports prepared by CANMET-sponsored contractors. In the reporting period, eight issues were distributed to 759 recipients throughout Canada.
- Catalogue of CANMET publications: an annual listing of all publications processed and released during the year. The Catalogue also provides bilingual abstracts of all reports and papers in the CANMET Reports, external Journal publications, and oral presentations. It is distributed to more than 1000 libraries, agencies and individuals interested in mineral and energy technology research.

Table 2 — Distribution of Technical Inquiries by Subject and Origin
1983-84

SUBJECT	(N = 2811)	ORIGIN	
Mining	25.4 %	CANMET staff	21.7 %
Mineral processing	17.8 %	Other EMR branches	3.6 %
Metallurgy	28.9 %	Other govt. agencies	9.7 %
Energy (incl. coal)	27.9 %	Colleges and universities	11.8 %
		Industry	32.5 %
		General public	7.6 %
		Foreign sources	13.1 %

TECHNOLOGY TRANSFER

During 1983/84 the Office of Technology Transfer (OTT) consolidated its activities in technology transfer, technology evaluation, policy support and project review, and monitored the activities in the special two-year START (Short-Term Assistance in Research and Technology) program. OTT managed a $600K START-funded technology program which included sponsorship of workshops and seminars, patent applications, special technology promotional events, such as Promotech '83 and the CANMET Open House, market research studies for CANMET technologies and technology assessment studies to guide CANMET research programs. OTT worked with line divisions to emphasize and plan technology transfer activities via the project authorization sheets, and assisted divisions with patent applications and handling of intellectual property.

Support to the Director General's office was provided through reviews of Cabinet memoranda and policy documents, responses to ministerial enquiries, compilation of weekly briefing notes to the Assistant Deputy Minister and the conducting of enquiries in various subjects on an ad-hoc basis.

Project review activities included completion of a commissioned cost/benefit analysis of the Pit Slope Study, completion of a social cost/benefit analysis of CANMET's efforts in 1967 on tantalum extraction, and initiation of a preliminary review of the economic nature and significance of thirty-five completed CANMET projects. Economic commentary on various issues related to publicly funded R & D was also provided.

The Technology Evaluation group provided CANMET's technical contribution to a major government-industry study on the economic, technical and environmental aspects of Canada's non-ferrous melter industry. This group assessed many technologies, including processes for metal extraction from manganese ore and iron ore in the Arctic; electrowinning of copper from chloride solutions; studies on leaching gold from tailings; and capture of SO_2 from smelter gases that resulted in two disclosures being assessed for patenting. Assistance was given in conducting economic assessments for an EMR-Indian Affairs study of Cyprus Anvil's Yukon zinc/lead mine and to an EMR study of Union Carbide's ferroalloy plant in Quebec. Projects for conducting computer simulation of coal liquefaction processes and evaluation of a lignite dewatering process were also initiated.

NATIONAL URANIUM TAILINGS PROGRAM

The first fiscal year of operation for the National Uranium Tailings Program (NUTP) was completed in 1983/84. All research and investigational work undertaken during this period was contracted to outside agencies, mainly in the private sector, with 34 such contracts being initiated during the year. Program objectives were finalized and strategic plans were completed for the five-year duration of the Program.

The focus of the Program is on the long-term management of uranium tailings, particularly the future behaviour of abandoned tailings after mine decommissioning. Predictions must be made concerning the nature and rate of release of contaminants that might lead to an incremental exposure of the public to radiation or other forms of toxicity. Mathematically based probabilistic models are the only way to predict future events and to quantify the uncertainty associated with them and, therefore, the development and use of these models are key activities in the Program. The results of the modelling work also provide general direction to the other Program activities.

Although modelling is the backbone of the Program, it depends on an information base that must be compiled from the results of research and measurement programs. These are studying the physical and chemical processes active in the tailings and the environment, together with the disposal technologies available, or under development, to control the release of contaminants into the environment. Program activities have focussed on these 'component' areas as well as on the development of an overall systems model that is intended to link all the components together.

A major activity in the Program has been developing a uranium tailings database which has been refined during the past year to make it more easily accessible. The database has been substantially improved with new categories of data, and a microcomputer software package was developed to facilitate the loading and retrieval of information from the main database. A contract was let to develop a method of evaluating the data into five categories of reliability.

Part of the output of the Program will be several manuals in the form of guidelines for government and industry personnel that will cover state-of-the-art practice in uranium tailings management. The past year has seen three of these manuals ready for publication: Procedures and Equipment Used in Sampling Uranium Tailings; Analytical Methods for Determining Radionuclides and Other Uranium Tailings Constituents; and Descriptions of Standard Reference Materials for Quality Assurance in the Analysis of all Materials used in Contracts for NUTP.

A major effort has begun on the development of a systems model that will demonstrate techniques for the probabilistic assessment of the long-term effects of uranium mill tailings in Canada. The first contract is a preliminary step in the development of such a model, using only one radioactive contaminant, radium-226, and a simplistic nine-compartment transport model for pathways between the source and humans.

A comprehensive study was undertaken to determine the costs of tailings management which resulted in a range of unit costs from $1.11 to $2.20 per pound of uranium oxide produced.

Other contracts that have been placed during the year and are at various stages of completion include:

- atmospheric investigation of radon dispersion with emphasis on the role of dust in transmitting radionuclides from tailings surfaces;
- the influence of vegetation on radon emanation from tailings;
- modelling contaminant migration in the acid ground-water plumes at uranium tailings impoundments;
- studies of kinetic controls of pyrite oxidation in pyritic uranium tailings;
- numerical simulation studies of the ground water discharge to streams from the surfaces of abandoned uranium mill tailings;
- the examination of the leachability of radium-226 from radium/barium sulphate sludges, particularly in reference to the influence of bacterial action;
- investigation of the performance of synthetic barriers for use in uranium tailings impoundments.

Preparations were also made to initiate a contract to monitor the performance of the subareal discharge method of tailings management at Key Lake.

A technical Advisory Committee was created during the year with representatives from the uranium mining industry, provincial and federal governments, and regulatory agencies. The Committee's principal purpose is to review future plans and assess progress of the Program. It will also advise on trends in tailings management that may affect the Program, identify gaps in existing knowledge, and otherwise provide input that may be of value to the eventual success of the Program.

APPENDIX A

CANMET PROFESSIONAL STAFF

DIRECTOR GENERAL'S OFFICE

W.G. Jeffery; B.Sc., M.Sc. (Leeds); Ph.D. (McGill); Director General
J.T. Jubb; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Deputy Director General

RESEARCH PROGRAM OFFICE

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F.D. Friedrich; M.Sc. (Queen's); Assistant Director, Energy Utilization
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Library

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M.T. Gagné; Bacc., M.Bibl. (Montreal); Librarian
J. Ho; B.A., B.L.S. (Ottawa); Librarian
K. Nagy; B.Sc., B.L.S. (McGill); Librarian
C.M. Nason, B.A., M.A. (Carleton), M.L.S. (Western Ontario); Librarian

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W. Kent; B.A. (Carleton); Database Manager
R.T. Blake; A.C.S.M. (U.K.), P.Eng.; Mineral Tech. Info. Off.
G. Tremblay; B.Eng. (Carleton); Documentation Officer
T.J. Patel; B.Sc. (Oregon State), M.Sc. (Washington State); Min. Proc. Abstractor
J.J. Krocko; B.Sc. (Alberta); Energy Info. Off.

Publications

M. Close; B.A. (Toronto), B.A. (Hons) (Ottawa); Section Head/Editor
J.L. Harcourt; Ed. Asst. (English)
L.J. Montsion; B.A. (Communications), B.A. (Languages) (Ottawa), M.A. (Carleton), B.Ed. (Ottawa); Ed. Asst. (French)

TECHNICAL SERVICES DIVISION

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OFFICE OF TECHNOLOGY TRANSFER

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ENERGY RESEARCH LABORATORIES

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Coal Liquefaction

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Coal and Coke Constitution

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Metals and Alloys

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Ores and Fire Assay

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Solution Chemistry

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J.A. Graham; B.Sc. (Carleton); Chemist

XRF, Radiometry and Fluorimetry

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Special Analysis

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Research/Special Projects

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E. Rolia; B.A. (UBC); Chemist
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Physical Chemistry

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Solution Purification

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D. Liang; B.Sc., M.Sc. (Queen's); P.Eng.

Leaching

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Mineral Processing Laboratory

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Ceramics

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V.V. Mirkovich; Ph.D. (Toronto); Res. Sci.
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(Ohio State), Ph.D. (Michigan); Res. Sci.
T.A. Wheat; Ph.D. (Leeds); Res. Sci.
A. Ahmad; B.Sc., M.Sc., Ph.D. (New Brunswick); Res. Sci.
A.K. Kuriakose; (Madras, India); Ph.D., M.A., B.Sc.; Res. Sci.
J.D. Canaday; M.B.A. (Arizona); B.Sc. (Oklahoma); M.Sc., Ph.D. (Guelph); M.Sc. (Calgary); Res. Sci.

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G. Zahary; B.Sc. (Alberta), M.Eng. (McGill); P. Eng.; Manager

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APPENDIX B

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INCLUSIONS AND RESIDUALS IN STEELS: EFFECTS ON FABRICATION AND
SERVICE BEHAVIOUR
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METALS AND ALLOYS (ICSMA-7)
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(member) ..... B.N. Nandi (ERL)

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ERL	Energy Research Laboratories	RPO	Research Program Office
MRL	Mining Research Laboratories	TID	Technology Information Division
MSL	Mineral Sciences Laboratories	NUTPO	National Uranium Tailings Program Office
PMRL	Physical Metallurgy Research Laboratories	OTT	Office of Technology Transfer

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