CANMET REVIEW 1979-80

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Cover photo: Elliot Lake Laboratory Manager, Dr. Reino Tervo, stands under a 4-million pound capacity press used for testing the compressive strength of large specimens of rock

FOREWORD

Since the appointment of its first director in 1901, the Canada Centre for Mineral and Energy Technology has continued its key role in research and development and the transfer of information and technology on minerals and mineral fuels. Over the years the branch has greatly expanded its facilities and diversified the scope of its activities, but the principal goals have remained unchanged: to ensure that advanced technology is available to help Canadian industry make ever greater contributions to the national economy, and to provide the technical knowledge base needed for the formulation and achievement of national policy objectives.

In the context of the nation's drive to reduce dependence on imported oil, emphasis in recent years has been placed on research related to the production of liquid fuels and electricity from alternative fossil fuel sources such as heavy oils and low-grade coal. Research on the efficiency of processing and utilizing fuels addresses the government's conservation objectives. The branch is also involved in major projects to demonstrate advanced energy technologies in several Canadian locations.

The shift in priority from minerals to energy has reduced the resources available for mineral-related projects. Under the matrix management system, however, the shift has been effected without serious disruption to normal operation of facilities or personnel. At present, the Minerals Research Program focuses on the development of advanced technologies that are efficient and economical, but at the same time protective of the environment and of the health and safety of the workers involved and of the population at large.

The branch discharges its information and technology transfer mandate in many ways. The formal Information Program, encompassing computer-aided documentation and traditional information dissemination methods, combined with the informal information transfer and publishing activities of the research staff, constitute an increasingly more visible and indispensable complement to the R & D activities proper. Technology is also transferred through licensing agreements, through workshops and seminars, and through extensive cooperation with industry.

D.F. Coates
Director-General

INTRODUCTION

This review presents highlights of the research and development carried out at, or sponsored by, the Canada Centre for Mineral and Energy Technology during the 1979/80 fiscal year. CANMET operates under a matrix management system in which management of the two research program offices - Minerals and Energy - interacts with line management in planning, controlling and evaluating projects. This review is organized according to program structure rather than functional units, thus drawing together related research activities taking place in the various laboratories.

Under matrix management, program directors are responsible for project selection, planning in cooperation with laboratory management, allocating resources on a broad scale, monitoring progress and reporting results. Line management is responsible for implementing projects, monitoring and evaluating work performance, and monitoring operational control of the five functional units - Mining Research Laboratories (MRL), Mineral Sciences Laboratories (MSL), Physical Metallurgy Research Laboratories (PMRL), Energy Research Laboratories (ERL), and Technology Information Division (TID). Line management determines how, where and by whom the work will be done, including the acquisition of expertise and equipment.

The text that follows reflects several important trends in the activities of the branch. The key roles of contracting-out, joint projects and other forms of government-industry cooperation are apparent.

The proportion of work performed under contract continues to increase and now represents about 25% of the branch budget. The current federal government emphasis on energy development has meant an expansion and diversification of CANMET's Energy Research Program. This has been effected by various means including participation in demonstration projects, initiation of major contracting-out programs such as in coal conversion and expansion of in-house facilities.

In both the Minerals and Energy Programs previous heavy commitments to certain fields such as heavy oil upgrading and pit slope design are being reduced or modified as the technologies are transferred to industry and new priorities are identified. However, although the nature of the various activities may change, the branch's prime functions remain the same: to ensure the availability and effective, environmentally acceptable utilization of mineral and energy resources; to develop advanced technology; and to ensure that public and private sector organizations have the technical information to formulate and achieve national, regional and industrial goals.

CANMET MANAGEMENT 1979-80

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Deputy Director-General — V.A. Haw

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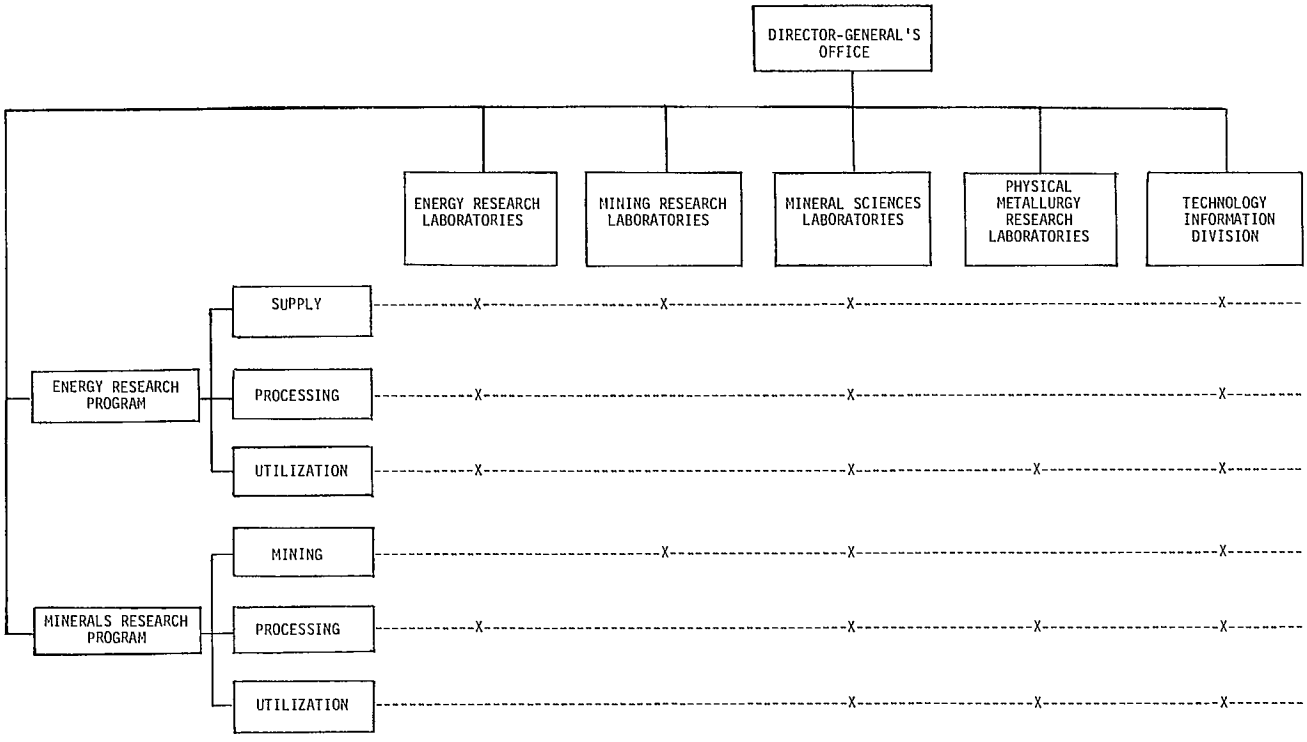

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ENERGY RESEARCH PROGRAM

The Energy Research Program of CANMET is concerned with two departmental activities: Energy Sources (Supply, Demand and Substitution), and Energy Research and Technology Development. As CANMET is an applied research and development organization, by far the greater effort, in terms of both funds and personnel, is directed at the latter. Most of the work deals with fossil and nuclear fuels in keeping with CANMET's traditional expertise. The highlights for 1979-80 are outlined below.

In cooperation with provincial governments and industry, the department is assessing the quality and extent of the energy resources available for various purposes in Canada. To this effort CANMET contributes its considerable scientific and technical expertise. This year it made a major contribution to the departmental publication, "Coal resources and reserves of Canada". The branch's annual economic and engineering evaluations of operating and projected uranium mines once again formed an important part of the department's assessment of uranium supply and demand. For low-grade petroleum resources such as oil sands and heavy oils, characterization information is being gathered that will help improve processing methods in addition to providing data on the nature of the resources. All this resource and reserve assessment work is supported by extensive analytical laboratories, which combine traditional methods and facilities in use over many years with modern sophistication.

Dealing principally with fossil and nuclear fuels, the technology research and development activities are wide-ranging - from improved mining methods to the quality and use of refined products. This work features day-to-day formal and informal interaction with industry, other government agencies, research centres and universities. There is a growing emphasis on contract research, and joint programs are common. The objective is to ensure that the technology is available to meet future Canadian mineral and energy needs as efficiently and economically as possible, with special attention to environmental concerns and occupational safety.

To help conserve limited supplies of non-renewable energy resources such as oil and gas, CANMET is involved in a number of projects. Fluidized-bed combustion, for example, promises to be an excellent means of burning low-grade fuels such as coals and solid wastes while controlling sulphur emissions. The development of a design for such a facility to be located in the Maritimes is the subject of a cooperative project with the Department of National Defence. Combustion of coal mixed with oil may also assist Eastern Canada in its drive to reduce dependence on oil imports. A continuing program of evaluating a variety of Canadian coals for combustion behaviour and emissions is also underway.

Research on automobiles has revealed the inadequacies of conventional engine technology in terms of efficiency and emissions during winter. In home heating, work is directed toward more efficient oil- and wood-fired appliances. A retrofit kit for oil furnaces could reduce oil consumption by as much as 20%.

In coal mining research, the branch has continued its work in the Western coal fields on the special problems that they pose for miners. Instrumentation for such tasks as ground control and subsidence measurements plays a big part in these studies. Health and safety of miners is also an important concern, and in this regard CANMET's expertise has been recognized through requests to provide expert witnesses in the investigation of a fatal explosion in a Cape Breton colliery. The mining equipment certification service, established at the request of provincial mines inspectors, was augmented by the installation of an hydraulic fluids flammability testing facility.

Coal utilization continues to be a growing priority area for research. Increasing attention to coal quality for thermal or metallurgical uses has added impetus to the coal preparation work. The presence of large amounts of fines and high oxidation levels in Western coals and the potential preparation problems they present are receiving attention at the Edmonton laboratory.

Coal, when converted to coke, is an essential ingredient in steelmaking. To the benefit of both coal- and steel-producing areas, the branch has for many years worked with industry in examining the quality of coals and blends, as well as developing improved cokemaking processes, particularly as applied to Canadian coals.

The potential for coal to supply liquid and gaseous fuels is being addressed through an extensive coal conversion research program, most of which is carried out through contracts. This contract program has been in operation since 1976, and has generated excellent data on a var-

iety of topics. In its own laboratories, CANMET has commissioned coal gasification equipment and is constructing liquefaction equipment.

Hydrocracking technology, which has been demonstrated at the pilot scale and is now being transferred to Petro-Canada for commercialization, is a major contribution to oil-sand and heavy-oil research. This technique promises improved yields with less waste production than currently-used, carbon-rejection processes. This work is supported by essential studies on improved catalysts.

Nuclear energy has for many years been a major subject of federal government research. Mineral processing specialists have established a tradition of investigative research into better ways to recover uranium from a variety of ores. Recently the processing studies have also been directed to the recovery of valuable byproducts including thorium, and the reduction of potential environmental contaminants, particularly radionuclides, in the effluents. Metallurgists have also been studying the behaviour of pressure vessel steels in heavy water plants.

Energy transportation, an all-important consideration in the Canadian geographical context, has also formed part of the Energy Research Program. Nine years of research on materials for oil and gas pipelines has led to creation of a body of expertise on the metallurgical qualities of linepipe steels. The growing interest in coal pipeline transportation is also being addressed through studies on the effects of slurry transport on coal properties and on the problems of slurry separation.

During fiscal year 1979/80, the CANMET Energy Research Program involved 334 person-years and expenditures of $\$15.5 \times 10^6$. Some 75 research contracts were awarded to outside organizations to augment the work done in branch laboratories.

ENERGY SOURCES: SUPPLY, DEMAND AND SUBSTITUTION

The first essential step in the development of a resource is to determine its location, quality and quantity, and the likelihood that it can be recovered under current technological and economic conditions. Energy resources, or the amounts of material in place, are estimated from geological surveys and exploration which generate location and quantity data together with limited quality assessments. For fossil and nuclear fuels, CANMET, in cooperation with departmental economists, extends these assessments to the determination of reserves, a subset of resources which takes into account additional quality considerations and technical and economic constraints.

Based on its long experience with the chemistry, mining, and utilization of energy resources such as coal, peat, uranium, oil sands and heavy oils, CANMET plays a vital role in the federal government's efforts to determine what resources we have and whether they can be feasibly recovered, keeping in mind the requirements of particular end uses. One subject of particular interest is the inevitable need to look to lower-grade resources as high-grade deposits are depleted; quality variations in such resources require special consideration in connection with particular utilization modes.

Analysis and Characterization of Petroleum Resources

Oil-sand bitumen and heavy oils are leading alternatives to conventional crude oil, but differ from it in many important respects. Characterization studies on these materials and their derivatives is therefore an important adjunct to research on liquid fuels production, as well as being a way of establishing the quality of the resource base. The work includes development of analytical procedures and technology for the economic removal of nitrogenous compounds which cause catalyst deactivation in upgrading processes.

Separation of nitrogenous components from unprocessed bitumen and from the coker kerosene of Athabasca bitumen was investigated during the year, using inexpensive sorbent materials and industrial wastes of Canadian origin. Chemically pretreated materials gave removal levels of up to 90%. A preliminary patent search has been completed and a patent application is being written.

Polynuclear aromatic hydrocarbons constitute a considerable amount of the aromatics in bitumens and heavy oils. Compositional information about these compounds can help in efforts to minimize hydrogen consumption in primary upgrading processes and to minimize coke formation in the reactor, as well as indicating the degree of further upgrading required to obtain desired products. Scientists have developed a normal bonded-phase, high-performance, liquid chromatographic method for separation of polynuclear aromatics according to ring number in the molecule. The system was applied to a large number of individual hydrocarbons and to the aromatics in Lloydminster and Medicine River oils of the Alberta Basin.

Scientists also completed a series of characterizations of the various components in Lloydminster oil and its thermal and catalytic hydrocracking products. Such studies help assess product quality and provide insight to reaction mechanisms. Work was also begun on synthetic derivatives from Cold Lake and Venezuelan feedstocks.

Sulphur compounds occur in high levels in heavy oils and can reduce refining capacity and increase product cost. Market specifications also require that sulphur in processing products be kept within certain limits. As part of continuing research in this area, CANMET is investigat-

ing the effects of changing hydrocracking conditions on the sulphur-type distribution in the light gas oil of Lloydminster and Cold Lake hydrocracked products.

Development of improved analytical methods is a key element in the characterization work. This year a hydrocarbon procedure was devised as a reliable way of determining olefin content in distillate fractions, especially in those higher than naphtha. Work on improving the compound-type analysis of bitumen and its products was focussed on liquid chromatography with ultra-violet detection to replace time consuming gravimetric quantitation.

The oil and gas analytical laboratory performed some 16 000 determinations on 3330 gaseous, liquid and solid samples from in-house projects and outside organizations. Outside clients include provincial governments, utilities, provincial mines inspectors and a variety of public and private sector organizations. In methodology development, the laboratory has begun a program to adapt or modify techniques for the analysis of coal liquefaction samples.

Uranium Reserves and Production

Each year a report is prepared for the department's Uranium Resource Appraisal Group (URAG) based on engineering and economic evaluations of operating and projected mines. The data are included in the department's annual assessment of uranium supply and demand. CANMET's concern is with mineability and productive capacity, and extends to the development of better assessment methods. The annual compilation by URAG helps form the basis for national policies on nuclear energy.

Much of the data are gathered through visits to operating and projected mine and mill sites and discussions with company staff. Specialists from CANMET compare company-supplied information with their own estimates and include both in their report to URAG. Minimum economic or cutoff grades are established after evaluation of mining and economic factors. The productive capacity of each property over time is estimated to give a projection of total Canadian uranium production.

To assist in mineability studies contracts were awarded during the year to develop mining cost models and standard approaches to mine economic evaluation.

Determination of mill productive capacity adds another dimension to the projections. This work is carried out by mineral processing experts. There are presently six operating uranium mills in Canada and three more are being planned. Recent expansion and process improvements have increased productive capacity. In new properties, the more complex mineralogy will demand more complex metallurgical circuits. During the year staff also coordinated a survey of Canadian mills for the Nuclear Energy Agency (Paris) and the International Atomic Energy Agency (Vienna).

Coal and Peat

Canada has vast resources of coal, located mainly in Western Canada with smaller deposits in the Maritimes. The growing role of coal for a variety of uses in both the domestic and export markets requires that a detailed knowledge base of coal extent and quality be available to researchers, policy-makers, and coal producers and consumers. Coal is a highly variable substance, and big differences in quality and deposit characteristics are to be found.

For many years a program of coal resource and reserve assessment has been maintained and this year a major contribution was made to the publication, "Coal resources and reserves of Canada", issued by the department's Energy Policy Sector. The combined expertise of a multi-disciplinary team goes into the preparation of CANMET's contribution.

Assessment of the national coal resource base by federal authorities is facilitated by cooperation with provincial governments and coal-producing companies. In the Canada/Saskatchewan coal inventory project, coal analyses were completed and a report describing the methodology used in the quality assessment was published under contract by the Saskatchewan Research Council. Work in the Canada/Nova Scotia inventory featured analysis of offshore samples and quality assessments at potential surface mining sites for thermal coal onshore. The importance of including coal quality considerations is stressed in all quantitative resource and reserve assessments, not only those carried out by exploration and production companies. For commercially-produced coals, coal specialists published up-to-date information on chemical and physical characteristics.

Mining specialists contribute to the knowledge base by helping determine the quantity and quality of coal that can be recovered with current technology under existing economic circumstances. With publication of resource and reserve estimates by the department this year, they are now concentrating on documenting reserve estimation methodology. A report on reserve assessment criteria used by coal companies is in the final stages of preparation.

In its mineability work the branch has entered into an agreement with the Alberta Energy Resources Conservation Board to cooperatively evaluate the Bonner and Moore mine simulation model. A report was also produced discussing the potential for bucket wheel technology in coal mining on the plains.

Another report identifies criteria for selecting underground mining methods. On the basis of this work an initial selection of mining methods suitable for Western coal fields will be undertaken. Reports on available underground computer models and critical factors in underground coal mining in Western Canada are in the final stages of preparation.

An important aspect of work on the manufacture of

metallurgical coke is the evaluation of coals for use in technical-scale coke ovens. Canadian metallurgical coal is a major export item and is being used increasingly by Canadian steel companies which have traditionally relied on closer American sources.

An important part of the cokemaking work is to determine relationships between coal characteristics and resultant coke properties. A study in the newly commissioned ovens at the Edmonton laboratory has shown that coke strength rises significantly as the coal ash content is lowered from 8.5 to 5.5%. This study will help determine the ash level to which a coal can be economically beneficiated. Studies of high-temperature coke strength, coke reactivity to CO_2 and strength after reaction have indicated that coal impurities, such as alkalies, and apparent relative density affect coke strength at blast furnace temperatures.

Technician conducting test to measure the free swelling index of a hard coal by heating it in a covered crucible. This and other coal properties are being determined to assess the quality of coals for cokemaking

The solid fuels analysis laboratory performed more than 23 000 determinations on 2300 samples. Ultimate, proximate, ash, calorific, trace element and other analyses are carried out using the latest techniques. The laboratory also participates in the development and writing of analytical standards for the American Society for Testing and Materials (ASTM).

Peat - Canada's peat resources are large but as yet have not been tapped for fuel. The search for alternatives to oil has heightened interest in this resource and a contract study has indicated that peat might be a competitive power plant fuel in northeastern New Brunswick. A technical and economic feasibility study of a 40-MW peat-fired thermal power station for that area is near completion under contract.

ENERGY RESEARCH AND TECHNOLOGY DEVELOPMENT

Technology stands out as a major factor in the provision of energy supplies. New or improved technology will be essential in the transition from today's heavy reliance on conventional oil and gas to tomorrow's energy supply mix in which oil sands, heavy oils, coal, and nuclear and renewable energy can play a larger role. One of the principal tasks is to ensure that the best technology is available to meet national energy goals, and that information about this technology is available when and where it is needed. The branch's historical emphasis on fossil fuels continues, complemented by expanding interest in conservation, environmental protection, renewable energy sources, and transportation and storage.

Conservation Technology

Work aimed at conserving energy covers several ways of reducing consumption of non-renewable resources such as oil and gas: utilization efficiency, interfuel substitution, energy recovery and energy storage being the main subjects of current research. The technology development work is coordinated with the energy conservation efforts of many other public and private sector agencies.

Coal Combustion in Conventional Equipment - Coal is receiving increasing attention as an alternative to oil to provide industrial and process heat and steam for power generation. Emphasis has been placed on providing industries and utilities with information that will enable coal to compete with oil in terms of ease of combustion, heat transfer and environmental emissions in conventional equipment such as boilers, cement kilns and reheating furnaces. In connection with this effort, the branch's combustion scientists have evaluated selected thermal coals to improve the possibility of export sales.

In one of a series of standardized tests to determine the heat and flame characteristics of thermal coals, a sample of Obed-Marsh coal from Alberta was burned in the branch's refractory-lined calorimetric tunnel furnace with good results.

Staff also began a series of tests in collaboration with Ontario Hydro to assess the effect of various modes of limestone addition to control slagging of lignite ash. With three Bienfait lignites from Saskatchewan, slagging tendency increased with sodium content. Limestone additions are currently being studied.

A second collaborative project with Ontario Hydro dealt with a blend of Pennsylvania, Byron Creek, and Coal Valley coals, which are available to the utility's Nanticoke generating station on a long-term contract. Combustion performance and the slagging and fouling potential of the ash were assessed.

When coal is beneficiated for metallurgical pur-

poses, the rejects may contain a large amount of combustible material. There is interest now in the possibility of using these rejects for their heating value. A collaborative project was undertaken this year with industry to investigate the combustion performance of reclaimed material. Gaseous emissions were acceptable, with fly ash precipitation likely to be more difficult than with lower-sulphur coals. Combustion and fouling behaviour were similar to those of Coal Valley coal.

The pilot-scale coal combustion work is supported by laboratory studies that consider the influence of petrographic constituents of the coal. Using a newly-constructed vertical combustion furnace, laboratory scientists have developed a correlation between petrographic analysis and the combustion efficiency of coal blends in terms of carbon carryover into the fly ash. In related work, X-ray diffraction analysis revealed that Hat Creek coal from British Columbia contains the clay material smectite, which is converted to mullite during combustion.

High temperature furnace for preliminary assessment of the combustible behaviour of thermal coals prior to pilot plant combustion trials

Control of Combustion Products - Because of environmental concern over coal use, the control of combustion products such as atmospheric emissions is part of many coal combustion projects. In addition to the environmental assessment activities connected with numerous test burns carried out in the pilot plant, CANMET is involved in projects where environmental protection is the principal goal.

In an on-going collaborative project with Ontario Hydro, scientists have found that fly-ash resistivities from low-sulphur coals can be reduced to preferred ranges by coal blending and limestone addition. Limestone also helps control slagging. The resistivity affects the performance of electrostatic precipitators, and the performance of a pilot-scale precipitator has corroborated the resistivity findings.

Combustion scientists have also been involved in a cooperative field project with industry on plume dispersion. Among the findings reported during the year are that more complex predictive models are required in the Rocky Mountain foothills where air turbulence is high. Also, plume spread parameters are, in general, much wider horizontally and usually much thinner vertically at the greater downwind distances than standard reference methods predict. This significantly influences the prediction of ground-level impact concentrations for environmental assessment.

Combustion of Coal-Oil Mixtures - A collaborative project with the New Brunswick Electric Power Commission initiated in 1977 is the major demonstration project in Canada for the application of coal-oil mixtures to utility boilers. Such mixtures offer the possibility of increasing the use of coal without major modifications to conventional oil-fired boilers. This may be particularly important in the Maritime provinces where coal is available but dependence is on imported oil. The work is being done at the Commission's Chatham station in the 10-MWe No.1 unit, using Minto coal.

Earlier work established that pump and nozzle erosion due to the abrasiveness of the ash presented a major problem with a 10% by mass coal-oil mixture. In 1979, scientists incorporated a spherical agglomeration process to beneficiate the coal before mixing. Special burner nozzles were also evaluated for resistance to abrasion.

The third phase of the project will include further evaluation of the agglomeration process and

Spherical agglomeration, a novel coal beneficiation technique is being applied in a demonstration project for combustion of coal-oil mixtures

a study of the use of water-in-oil emulsions to reduce the amount of light oil needed. The coal content of the mixture will also be increased to 40% by mass.

A second project at the Ontario Research Foundation, cosponsored by CANMET, two provincial agencies and two companies, covered coal beneficiation, mixture preparation, combustion performance, slagging and fouling characteristics and emissions. Three coals - Pennsylvania, Coal Valley and Prince Mine - were evaluated. In tests with a 30% by mass mixture and a 30% coal/20% water mixture, both a Vortometric burner developed by the Foundation and a standard Peabody burner performed well, although the Vortometric burner produced a highly swirled flame with some wall flame impingement.

Automobile Fuel Efficiency and Emissions - Since 1973 scientists have been studying the effect of ambient climatic conditions on automobile fuel consumption. For this work a series of contracts has been awarded to Shell Canada Limited for closely-controlled chassis dynamometer tests under varied climatic conditions.

In the fourth phase of this program, five engine types were tested: 4-cylinder gasoline engine with three-way catalyst exhaust system; 4-cylinder, turbocharged, 2.3-L gasoline engine; V8 gasoline engine with variable venturi carburettor; 4.3-L North American V8 diesel; and 3.0-L German 5-cylinder turbocharged diesel.

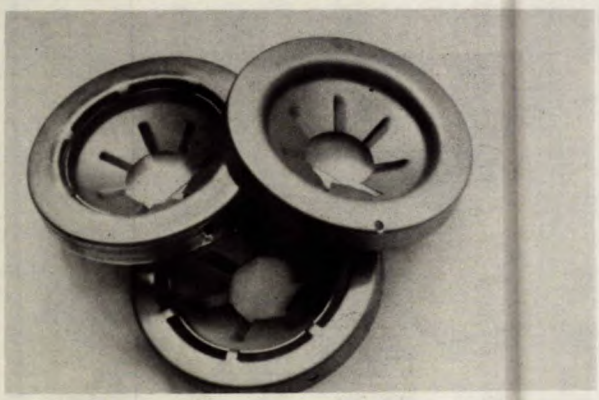
Although at 25°C all five vehicles met Canadian emission standards for carbon monoxide and hydrocarbons, the diesel-powered vehicles gave much better performance at winter temperatures. The diesels also showed less fuel economy degradation and better driveability at the low temperatures.

In another study using vehicles supplied by the Department of National Defence, road tests showed that exhaust system traps collect about 80% of the lead emissions from vehicles using leaded gasoline. Such traps offer the possibility of using lead to increase octane rating rather than incurring the refinery energy penalties now required to produce unleaded gasoline.

Domestic Oil Heating - A domestic oil furnace retrofit kit developed by CANMET consisting of a retention head, delayed-action solenoid valve, smaller nozzle and positive chimney damper, has been shown to reduce oil consumption by as much as 20%.

In 1979 the research staff participated in the development of a CSA standard for such kits. They also conducted six two-day retrofitting seminars for provincial officials and oil company representatives and prepared a detailed booklet entitled "Efficient residential oil heating systems" for servicemen, designers and builders. The manual, which has been acclaimed by the industry, is being widely distributed by the Conservation and Renewable Energy Branch of the department.

Typical conventional domestic oil burner heads for oil-fired domestic heating



Range of retention heads for different firing rates for domestic oil burners; if retrofitted to conventional burners, fuel consumption could be reduced 15-20%

Because of concerns expressed by one province over the effects of the higher flame temperature of retention head burners on combustion chambers and heat exchangers of existing furnaces, combustion scientists measured metal temperatures in two warm-air furnaces considered to have potential for overheating, one with a stainless steel combustion chamber and the other with ceramic. The tests showed that no overheating problems should be encountered provided the stainless steel is lined with ceramic fibre and the maximum allowable firing rate is reduced by one size. Both these requirements are now in the appropriate CSA standard.

Water-Oil Emulsions - One of the many energy conservation strategies suggested for oil-fired boilers is the use of a water-in-oil emulsified fuel. Tests in CANMET's package boiler showed that gas-borne soot emissions were essentially

unaffected by the use of emulsions and any catalytic combustion reactions attributed to the water were considered insignificant. Boiler efficiency deteriorated with increasing water content. CANMET considers that such emulsions are unlikely to be a viable energy conservation or emissions control strategy.

Industrial Process Heating - A cooperative project was undertaken this year with the Ferrous Energy Research Association, an organization comprising Canadian steel producers, to investigate the performance of typical industrial steam-atomized, residual-oil burners. Steam-oil ratio was shown to have a significant effect on heat transfer and emission characteristics of the flames, with steam temperature and burner hardware being insignificant variables.

Burner Development - CANMET represents the department in an International Energy Agency project to elucidate the mechanism of nitrogen oxide formation in pulverized-coal combustion. Canada, the United States, Denmark and Sweden are funding exploratory burns in a California laboratory on some 50 world coals, eight of which are Canadian. Depending on results, these trials might lead to an expanded project.

In another study being done under contract, the Canadian Gas Research Institute is developing a low-calorific gas burner suitable for dirty gas. Laboratory flame stability tests have led to design of a prototype which will be field tested in the coming year.

Fluidized-bed Combustion - Among the many emerging technologies for efficient, environmentally-acceptable use of coal, fluidized-bed combustion (FBC) is considered by many experts to be the most promising. The technique involves burning coal or other fuel, in a bed of inert material through which air is directed such that the bed is "fluidized", or behaves like a boiling liquid. It is of potentially great benefit to Canada.

Simple uncooled beds are already in commerical use as incinerators for high-moisture materials such as wood waste and sewage sludge. More complex cooled combustors integrated into steam boilers are still under development, and offer the following benefits:

- ability to control SO_2 emissions, and thus acid rain, by adding limestone when burning high-sulphur coal;
- ability to burn coals with high moisture and ash contents and low reactivity;
- economic advantages in both large and small units;
- in pressurized units, a means for more efficient coal-to-electricity cycles.

As these advantages are consistent with Canadian environmental concerns, fuel types and energy needs, fluidized-bed technology has been given high priority.

To introduce the technology to Canada the federal government has assumed a substantial part of the financial risk in five demonstration projects supported by a pilot-scale R & D program.

The major project is to demonstrate an atmospheric FBC boiler in cooperation with the Department of National Defence at the CFB Summerside heating plant. Two competing firms have completed conceptual boiler and plant designs, one drawing on American technology and the other on British. Detailed designs and price quotations were commenced early in 1980. Each firm has identified a Canadian source for the boiler, thus putting two Canadian firms in a position to manufacture the equipment. The design fuel is a 5% sulphur coal from Cape Breton, with wood chips as a supplementary fuel capable of supplying up to 30% of the heat input at any load. The target date for commissioning the first boiler is the end of 1982.

The two conceptual designs, which are substantially different, were prepared by Foster-Wheeler Limited for American technology and a team consisting of Integ Limited and Coal Processing Consultants (CPC) for British. As the Integ-CPC team has no manufacturing capability it was replaced by a licensee, Dominion Bridge Co. Ltd., for detailed design and price proposal. Two other related contracts were issued during the year. Integ has almost completed a solid waste disposal study on the quantity, nature, environmental effects and potential uses of the bed residue. Foster-Wheeler is carrying out pilot-scale tests with the design coal, wood chips, and limestone.

The second project is to demonstrate the technology at the industrial scale, at which conventional pulverized-fired equipment with the necessary flue gas desulphurization equipment is uneconomical. A boiler at the Chatham station of the New Brunswick Electric Power Commission was selected, based on its size, for a conceptual design study of retrofitting the boiler for fluidized-bed combustion of coal and wood chips. The study, sponsored by the Canadian Electrical Association, indicated that the retrofit plan would reduce capacity by 40% with no economic advantage over new conventional equipment. As an alternative the department through Supply and Services Canada, has invited expressions of interest for a conceptual industrial-scale design package including design capability, fabricating capability in Canada, and a Canadian end user willing to provide a portion of the capital cost.

In the third project, the department is cofunding with the Nova Scotia Power Corporation a site review study by an engineering firm for a possible 150-MWe demonstration unit. Utility applications of FBC would help reduce dependence on foreign oil in the Maritimes. The unit would be linked to existing turbogenerator equipment.

Coal washery rejects are the proposed fuel in the fourth project. Washed metallurgical coal must be dried before it can be sent to market, and natural gas has traditionally been the dryer fuel. If it is possible to use the rejects it

would offer obvious energy conservation and economic benefits. CANMET is cofunding a contract study with Luscar Limited of a conceptual design and economic analysis for an atmospheric FBC at Luscar's Coal Valley operation. The study should be complete by November 1980.

The potential fifth project, currently being considered by B.C. Hydro, is based on the use of pressurized fluidized-bed combustion in a combined-cycle power generation scheme. The pressurized FBC alternative was identified as most promising in an earlier joint project. The combined-cycle concept, which can reduce fuel requirements by 10%, will require 10-15 years of development before it can be used commercially in Canada.

In support of the demonstration work, pilot-scale studies are being conducted or funded to obtain design data about fuel behaviour, sorbent properties, materials problems, and effects of bed conditions on performance. During the year tests were run with a subbituminous coal from Highvale, Alberta, with Minto, N.B. bituminous coal and, on a cost-shared basis, with oxidized Line Creek coal supplied by Crowsnest Resources. The work to date has revealed inherent problems related to feed systems, cooling, heat transfer measurements, bed lining, and size, which are being corrected in a new unit now being built.

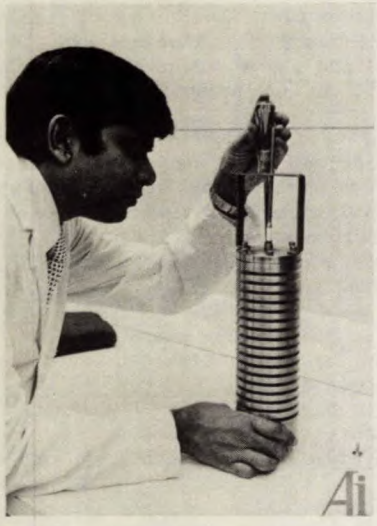
Supplementary pilot-scale FBC work is also being supported through a contract at Queen's University. This research deals mainly with characterization of Canadian limestones and dolomites for sulphur fixation and the effects of sorbent additives in enhancing sulphur capture. The unit to be built at Queen's will be identical to the one at CANMET.

Pilot scale atmospheric fluidized-bed combustor with water cooled tubes used to study combustion characteristics of coals and other solid fuels and to characterize limestones for sulphur retention

Energy Storage - Work on storage systems to be used in industrial or domestic solar energy applications is being sponsored in cooperation with the National Research Council. The New Brunswick Research and Productivity Council has received a contract to develop a domestic system with a fused salt hydrate as the storage medium.

CANMET's expertise in materials science and technology is being applied in the storage of electrical energy. This work is focussed on the development of solid state electrolytes with the required conductivity and thermal shock resistance.

The fast-ion conductor, beta-alumina, is a key component in a variety of energy systems including certain batteries and fuel cells, thermoelectric generators, electrolyzers and specific-ion pumps and monitors. Following successful development in-house and by McMaster University under contract of fabrication methods for beta-alumina materials, a contract was awarded to a company to develop industrial applications including a prototype thermoelectric generator. Continued work at CANMET has resulted in successful fabrication of beta-alumina cylinders using the economical unit process of spray drying. Work was also started on development of a recently-discovered sodium-ion conductor known as "nasicon", which is a potential alternative to the beta-aluminas and a strong candidate for use in the sodium-sulphur battery. A process was developed by which high-quality nasicon can be routinely produced by wet-chemical means to reduce impurities and improve reactivity. Related work is aimed at filling in gaps in knowledge of the thermal and electrical characteristics of electrolyte materials.



Evaluating a prototype thermoelectric generator of unique design incorporating CANMET-developed beta"-alumina materials that are highly conductive to sodium ions. Conversion efficiency is expected to be nearly double that of existing generators

Oil and Gas Technology

Like its work on minerals and coals, CANMET's involvement in petroleum and gas research is related primarily to the development of marginal or low-grade resources that may not be economically attractive in the short term but have long-term potential or regional value. Thus for many years studies have been carried out on the oil-sand and heavy-oil deposits of Western Canada.

Now that these resources are being developed commercially work is continuing to ensure that the technology available addresses national energy and environmental objectives. The most visible aspect of this work has been the CANMET hydrocracking process for bitumen and heavy-oil upgrading, but the research also includes oil sands mining, bitumen/sand separation, emulsion-breaking, and supporting catalysis and materials research.

Oil Sands Mining - A study conducted in 1977-78 identified a need for fuller understanding of the engineering behaviour of oil sands to better assess the potential of different mining technologies. Three subsequent contracts have been completed on mining characteristics of Waterways limestones, bitumen content analysis, and computer modelling for stress and strain analysis. These formed the basis for successful de-briefing and technology transfer seminars. A survey of industrial research needs has also begun.

Bitumen/Sand Separation - Pilot plant development of the Magna International cold water/solvent process for separation of bitumen from oil sands has been completed on a cost-shared basis. An independent technical/economic assessment has recommended advancement to a demonstration scale. If successful this process could reduce energy and tailings ponds requirements and produce a less environmentally hazardous effluent.

Demulsification of In situ Wellhead Emulsions - The recovery of heavy oil using in situ methods yields relatively stable systems of oil emulsified in water. For economic and technical reasons it is important to separate the oil and water phases as cleanly as possible. A continuing cost-recovery project with Texaco Canada Inc. has involved monitoring changes in the emulsions produced, evaluating demulsifiers and optimizing demulsification conditions. The best separation achieved during the year was 20% water in the oil phase and clean water containing no oil. In contract work at the University of Western Ontario, progress has been encouraging with several bacteria found to produce highly effective demulsifiers.

CANMET has also developed a method to clean "black water" using inexpensive Canadian waste materials. This method has formed the basis for a patent application.

CANMET Hydrocracking Process - Hydrocracking is a process that can be used to upgrade heavy crude oils, bitumen, refinery residuals and coal liquids. These feedstocks generally have a high content of pitch or vacuum residuum which has high sulphur and metals contents. The product of many years of research, the hydrocracking process breaks down the pitch portion to distillable materials and gives higher distillate yields than the competing processes which are based on coking or carbon rejection. Three patents on the process have been awarded and 18 other applications have been filed.

In 1979, CANMET signed an agreement granting Petro-Canada exclusive worldwide rights and licence to use, practise, commercialize, exploit and sub-license to others the CANMET hydrocracking process. The agreement will also serve as a basis to achieve the following goals:

- development of the process to the point of commercialization within five years;
- maximization of Canadian industrial participation in development and ultimate licensing;
- professional development of CANMET personnel through hands-on participation in commercialization of a new technology;
- fair sharing among participants of potential revenues from licensed applications;
- maintenance by CANMET of adequate control over its intellectual property in respect of the process; and
- reasonable sharing by the participants in new intellectual property developed under the agreement.

In collaboration with a task force, Petro-Canada has made advances in process evaluation and marketing. Three major reports have been made to date: a technical evaluation, commercial projections, and preliminary economic evaluation. The company is currently seeking joint venture partners for design and construction of a demonstration plant.

Three distinct activities are under way at CANMET with respect to this process: in-house research to strengthen the patent position, to investigate new applications, and to develop new concepts; contract work to determine process economics, to optimize process elements, and to aid in scale-up; and technology transfer efforts to help the process licensor with development, commercialization and marketing.

The in-house pilot plant program in 1979/80 was aimed at developing a strong technology data package, with all experiments being planned to facilitate rapid commercialization. Increased capacity was added with completion of a second 160-L/d pilot plant in September 1979. Several feedstocks were evaluated at conversion levels above 80%, and several experiments were conducted to obtain long-term operability data. The results showed the flexibility of the process to various feedstocks at high conversions, and its long-term operability and flexibility at low gas rates. Success was also achieved in a series of experiments on fast start-up. Empirical and

semi-theoretical correlations were developed to predict pitch conversions at various operating conditions.

Several contracts were awarded to evaluate various aspects of the process. Contract work was completed by Shell Canada Limited and Imperial Oil Limited on assessing the potential of CANMET hydrocracked products to yield standard refinery streams and on the hydrotreating of naphtha fractions. As the economics of the process will be enhanced if the pitch fraction can be disposed of cheaply, a contract was awarded to determine the feasibility of gasifying the pitch to produce hydrogen. Results of another contract study suggest that product quality obtained by hydrotreating the naphtha and gas oil distillates is better than that obtained from fluid coking. A final contract dealt with the economics of using coal rather than synthetic crude as a make-up fuel.

A key activity in hydrocracking technology transfer was the loan of branch scientific personnel to the process licensor, principally for the preparation of pilot-plant work statements, data collection and demonstration plant requirements.

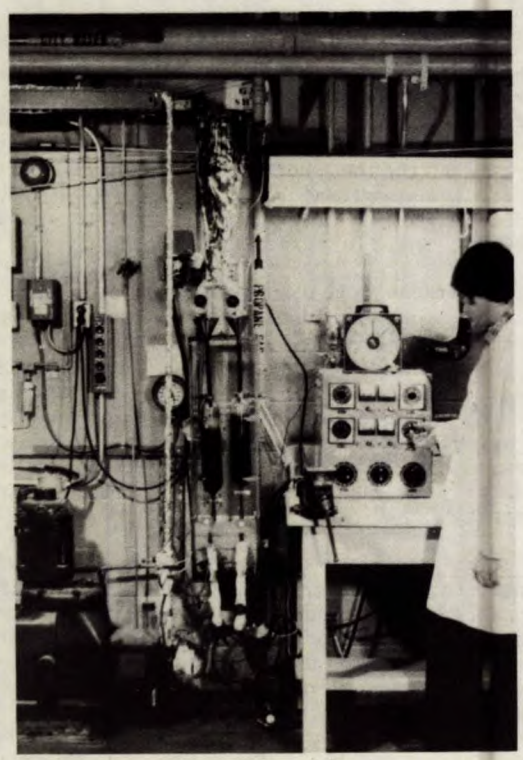
Metallurgists also carried out research on material requirements for hydrocracking reactor vessels. The studies showed the metallurgy of the 2 1/4 Cr-1 Mo pressure vessel steel and the type 347 stainless steel weld overlay to be complex. In particular, post-weld heat treatments must be carefully specified to reconcile the benefits it offers with possible deleterious side effects.

Catalyst Development - Rapid catalyst deactivation is a well known problem encountered in the catalytic approach to bitumen or heavy-oil upgrading. In support of the hydrocracking pilot plant work outlined above, high-pressure bench-scale equipment is maintained to explore new approaches. The emphasis is on the development of catalysts with a longer effective life or lower costs.

Tests carried out during the year showed some promising trends in catalysts containing sodium molybdate. This work led to a patent application on the use of alkali promoters. Experimental work with promoters of molybdenum trioxide/alumina catalysts was also completed; a pronounced promoting influence was observed in hydroprocessing of heavy gas oil, with only a marginal effect with bitumen feed.

A series of tests was initiated to evaluate the use of carbon monoxide as an extender of hydrogen in bitumen hydrocracking, as hydrogen supply would be a costly part of a commercial operation. Carbon monoxide present in a concentration of 10% in hydrogen did not affect product quality. The tests will be repeated at 50% concentration.

Other work in the catalysis laboratory deals with the potential of a high-pressure continuous-flow microreactor for testing high-pressure gas-solid



Research on the properties and behaviour of catalysts is an essential element of research on the upgrading of bitumen and heavy oils; shown is the feeding mechanism for an apparatus for testing catalyst properties by a simulated aging technique developed at CANMET

systems, and the practicality of solvent regeneration of catalysts. An X-ray photoelectron spectrometer was acquired for studying valence states of various metals on the surface of catalysts at various stages of deactivation. Knowledge of valence state could be important in developing catalysts with greater deactivation resistance.

Catalytic Pitch Gasification - The principal by-product of the CANMET hydrocracking process is a variable amount of pitch, the material that boils above 524°C. Ways to use the pitch within the plant have been looked at to increase the energy yield. The main technique of interest is gasification to produce hydrogen required by the hydrocrackers. In previous work a bifunctional catalyst was developed that is capable of catalyzing the pyrolytic and steam-char reactions. To extend this work, the staff have designed and built a continuous fluidized-bed gasifier with a capacity of 20 g/h.

Materials for Oil Sands Tailings Pipelines - Separation of bitumen from oil sands currently uses a hot-water process that results in large quantities of abrasive slurries requiring pipeline transport to disposal areas. To help overcome problems of wear in such pipelines CANMET has been evaluating candidate materials under

simulated industrial conditions. Eight selected steels were tested during the year.

Although abrasion-resistant steels might be advantageous at higher transport velocities at points of severe wear, the desirable design approach is low velocity in large diameter pipes to reduce the need for costly special steels. The decision is ultimately a trade-off between the cost of special steels and the replacement cost of conventional steel pipes.

Coal Technology

In the national interest, a program of research on coal technology has traditionally been maintained, even during the industry's period of decline in the 1950's and early 1960's. The result is that when interest in coal grew in the 1970's, the branch had a head start and was able to quickly expand its research and development programs in the many aspects of coal technology from mining through processing to utilization.

It is now the leading centre of coal research expertise in Canada, its aim being the efficient development and use of the national resource with due regard for occupational safety and environmental quality. Private sector involvement is a notable feature of the program, which covers mainly mining, preparation, carbonization and conversion. Coal combustion is a major part of the conservation technology work described above.

Coal Mining Technology - Working out of the branch's Western Office in Calgary, scientists and engineers are carrying out a program of field work to study the problems of mining in Western Canadian coalfields. The program features continuing mutual assistance and cooperation with coal producing companies.

Ground Control - Some of Canada's best metallurgical coal deposits are located in mountainous terrain in Western Canada. These deposits present special challenges to coal miners who must cope with steep seams of variable thicknesses with surrounding strata whose behaviour is difficult to predict and control.

Much of CANMET's ground control research is carried out in North America's only hydraulic mine, located in southeastern British Columbia. The work includes strata control and subsidence measurements, as well as geological investigations. A report on the geology in the vicinity of the hydraulic mine has been drafted. A contract study concluded that smaller roadways using alternative support systems could be advanced more rapidly than the drivage method now used.

Strata control with roof bolts was the subject of a series of tests at a new mine. Other contracts covered the adaptation and development of geophysical techniques for Canadian coals and the feasibility of punch mining in the highwall of an open pit.

Health and Safety in Coal Mines - Coal mining has traditionally been a hazardous occupation. Through research, however, the health and safety record of coal mines has improved markedly in recent years. In Canada, CANMET plays a leading role in this research. The main hazards of concern to its scientists are the risk of explosion and fire.

The release of methane in underground coal mines is a problem as old as coal mining itself, and together with dust presents one of the major hazards and causes of economic losses. The problem is expected to become more acute as production increases in the West and in the deep, gaseous mines of Cape Breton.

During the year, monitoring of the methane emission pattern at a Western mine continued. A preliminary study using sealed samples indicated methane desorption from Devco's No. 26 and Lingan coals to be 8.2 and 6.8 m^3/t. Staff also participated as experts in a federal inquiry into an explosion in a Cape Breton colliery. A new project was also launched to develop and demonstrate a comprehensive environmental monitoring system for underground coal mines and to evaluate methane control technology as a long-term solution to the emission problem.

There are four aspects to branch research on the explosibility of coal dust: minimum ignition temperature, minimum explosible dust concentration, minimum ignition energy, and expected pressure rise. Scientists determined minimum ignition temperatures in a furnace to be about 480°C for Cape Breton coal dust, lower than for Western coals. The ignition sensitivity of Cape Breton coal is also higher. The effect of methane on minimum explosive dust concentration will be greater in Cape Breton coal than in a standard American sample. Completion of the explosibility index for Canadian coals, and work on peak pressure determination, are planned for the coming year.

Provincial mines inspectors, particularly in the coal producing provinces, depend on CANMET's certification services and advice on the use of equipment in explosive gas atmospheres. Related research is carried out to solve specific problems and to maintain expertise. The information and experience gained is passed on by participation in relevant standards committees; for example, this year the branch hosted a meeting of a technical committee of the International Electrotechnical Commission, and staff participated in several Canadian Standards Association and Instrument Society of America meetings.

The certification service was set up at the request of federal and provincial mines ministers. The branch now operates Canada's only laboratory conducting explosion tests on equipment for use in explosive gas atmospheres. Forty-two certificates were issued during the year for electrical and diesel equipment and fire-resistant materials.

This year the laboratory facilities were augmented by completion of a test chamber for fire-resistant hydraulic fluids. The chamber includes equipment for spray-ignition testing and wear-

conditioning of the fluids. The staff also plans work on flame length and persistence and on the effect of freeze-thaw cycles and wear on relative flammability.

Coal Preparation - Coal is not homogeneous, but a highly variable material containing impurities such as mineral matter and sulphur, which can cause problems or increase costs in utilization. In its exports of metallurgical coal, for example, Canada must meet stringent market requirements for coal quality. Thermal coals may also require beneficiation to avoid operating problems and adverse environmental impact in combustion.

Coal preparation research is aimed at development of preparation technology suited to particular Canadian coals and markets. Because coals vary so widely from deposit to deposit, a major element of the work is characterization of these coals.

Availability of a versatile pilot-scale test facility is essential to ensure that appropriate preparation techniques are developed and applied to Canadian needs. Reliance on imported technology has in the past led to extremely high costs and inefficient operation of certain Canadian washeries for years after start-up. CANMET operates such a pilot plant at its Edmonton laboratory. The installation is being modified to improve its capabilities; such modern equipment as a Batac jig and oil-agglomeration will shortly be added.

During the year, tests confirmed that a continuous ash-monitoring system being developed for washeries can measure ash content in the 21-32% range within 0.6% of the value obtained by the standard ASTM method. In other tests, early results with minus 600-µm (28-mesh) coal (fines) in the compound water cyclone indicated that under otherwise constant operating conditions, an increase to as high as 50% slimes [minus 149 µm (100 mesh)] in the feed could result in some improvement in the sharpness of separation.

The Canadian Explosive Atmospheres Laboratory (CEAL) checks over a flameproof continuous mining machine, in a program to monitor the production of certified equipment and materials for underground mines

The graduating class of the first CEAL training course for the maintenance and repair of flameproof and intrinsically safe mining equipment held in Ottawa, 1980.

This unexpected result has led to further tests that may help in designing fines circuits and recirculating process water. Handling of fines is an important problem as they are present in large amounts in Western Canadian coals.

High oxidation levels also complicate the processing of Western coals. A literature survey showed that little or no work has been done to characterize or quantify the degree of oxidation by directly measuring changes in bulk and surface properties of coals in surface-dependent processing. This is now the subject of a cost-shared project with a large resource company.

Exploratory studies of beneficiation by oil agglomeration showed a direct relationship between degree of grinding and ash content reduction of a Western metallurgical coal. Reduction from 20 to 5% ash was attained by grinding to 10 µm.

Both design of new preparation plants and "tuning" of existing plants to achieve optimum performance would be substantially easier if the processes involved could be modelled. CANMET has launched a five-year program to collect data and create empirically based computer models to predict performance of given preparation circuits, knowing the characteristics of the raw coal. These models will be developed jointly with industry, and promise to be of great benefit in the expanding coal preparation field.

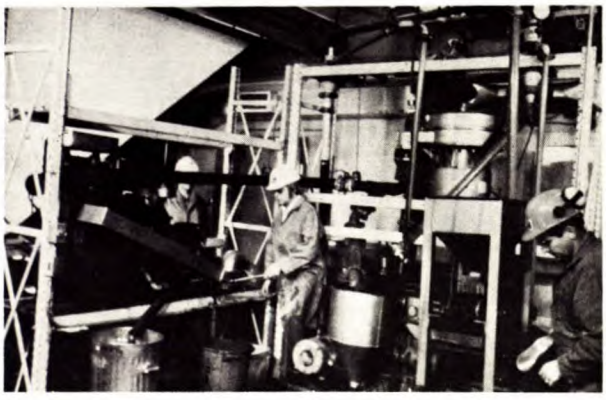
Beneficiation of coals in washeries produces

large amounts of effluent process water that is contaminated by ash, sulphur, unrecovered coal and other rejected coal constituents. This water must be treated to remove these contaminants, whether the purpose is to recycle or to dispose of the water. This need is being addressed in a series of conducted or sponsored studies.

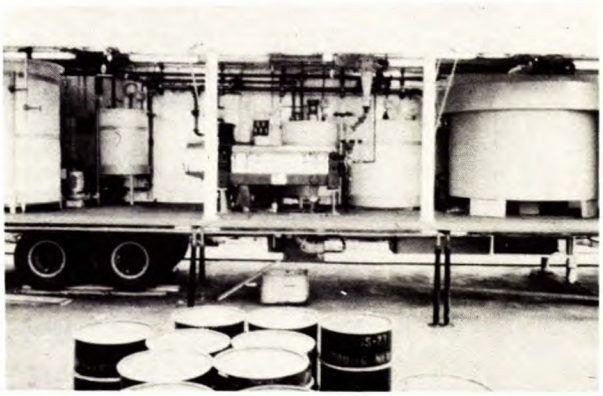
Development of reliable solid-liquid separation techniques has been hampered by a lack of understanding of the mechanisms of flocculation, settling and other processes involving particle-system interactions with or without reagents. Chemical characterization of system components such as flocculants or other chemical additives, washery waters and suspended particulates is an important research need.

A continuing program of flocculant research has the aim of helping to meet this need. During the year, some 20 commercial flocculants were evaluated for washery effluent treatment. Of these, the most effective were 20-30% hydrolyzed anionic polyacrylamides with molecular masses of about 5×10^6. In continuing contract work on flocculant characterization, Raylo Chemicals Ltd. acquired a laser-scattering instrument for determining molecular-weight distribution of polymers. A prototype of a two-cylinder automatic settling apparatus was also completed.

A major achievement has been the completion of a mobile demonstration water treatment plant. This unit, mounted in a semi-articulated trailer, includes cyclones, a centrifuge, a thickener, and twin tanks for feeding flocculants, as well as holding tanks for feed water. Designed to take part of the effluent stream from working preparation plants, the unit will both demonstrate CANMET-pioneered advances in the field, and allow coal companies to select the best treatment for their particular effluent. In future, the plant will spend several months at major washeries; ultimately, computer controls for automatic operation will be added.



At its Edmonton laboratory, CANMET operates pilot-plant facilities indluding this mini-plant based on a 10-cm compound water cyclone for studying coal beneficiation



Removal of fine solids from water is a major problem in coal preparation and mineral processing; pilot-scale water treatment unit developed at CANMET is housed in a trailer for transport to industrial sites

Preparation work also includes a continuing evaluation program of the preparation potential of Canadian coals. Coals from Judy Creek, Alberta and the Quintette property in northeastern British Columbia were evaluated this year.

The large amount of fines associated with Western Canadian coals is an important concern in the design of handling and washing facilities. Scientists have been working on ways to predict the quantities of fines produced in mining and handling. Measurement of pressure changes upon the release of methane gas gives information about coal microstructure and could therefore be the basis of a simple predictive method.

Some success has been achieved in beneficiation of Canadian coals by high-gradient magnetic separation. The promise shown in wet separation of a Maritime coal was extended through a study which revealed that dry magnetic cleaning is almost as effective as the wet method. This finding opens up possibilities for dry beneficiation of coal - particularly fine, high-sulphur coal that has been practically impossible to clean by any dry process known to date.

In a study of a non-conventional coal flotation method, using sodium sulphate rather than kerosene as a collector gave comparable results while improving process kinetics. Contracts were also let on fluidized-bed cascade beneficiation and chemical comminution.

In research on erosion and corrosion control in coal washing plants, five proprietary inhibitors were evaluated in a preliminary study and it was found that one reduced the wear rate. A test installation is being used to compare the performance of steels and to evaluate the effect of washery variables on material wear.

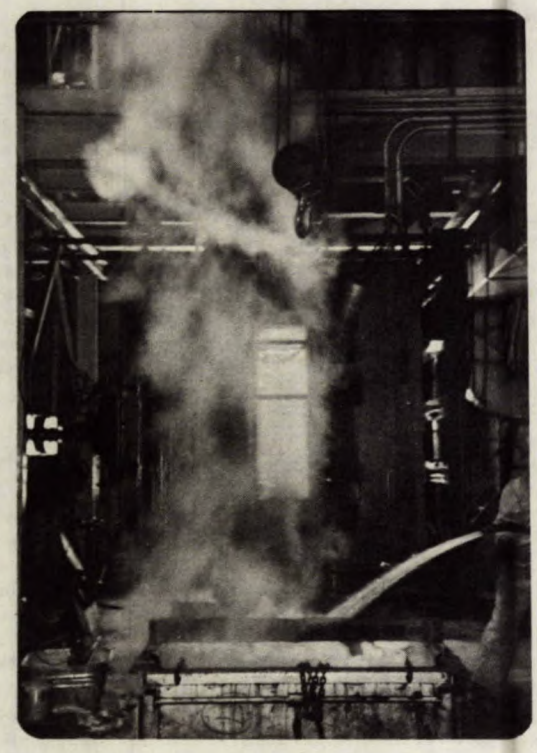
Carbonization - Coke, one of three essential

Laboratory scientists are investigating methods of predicting the amount of fines likely to be produced in mining highly-friable Western coals

ingredients in the blast furnace along with iron ore and limestone, is made at steel plants by heating coking coals in large slot-shaped ovens. Blast furnace coke should be high in carbon content, low in impurities, and physically strong. Few single coals can produce coke with these specifications and metallurgical coals are usually blended. Even so, only about 35% of Canadian coal production is of metallurgical quality, and 90% of that is exported. Canadian steel mills obtain most of their coal from nearby American sources.

For many years a program of carbonization research has been conducted in cooperation with major coal and steel companies through the Canadian Carbonization Research Association. The program involves research and development in conventional and non-conventional cokemaking, and characterization of coals and cokes to ensure that coal exports are competitive, to increase the use of domestic coals, and to reduce coke consumption in the blast furnace by improving coke quality. Coals are analyzed and evaluated through laboratory methods and by simulated industrial coking in technical-scale ovens. CANMET is currently determining how closely results in these ovens, which are shorter and shallower than industrial ovens but of similar width, correlate with industrial-scale results.

Work on conventional cokemaking is related largely to the characterization of coals for resource assessment, and was described earlier in this review. In addition, fundamental studies of coal constitution are carried out to help understand the behaviour of coals during processing. For example, nuclear magnetic resonance investigations during the past year have revealed that the aromatic rather than the aliphatic structure of coal is attacked first during weathering by low-temperature oxidation. This is direct evidence of the nature of the transformations occurring during the oxidation of coal in relation to



Test ovens evaluate coals for cokemaking; hot coke has just been discharged from oven and is being quenched by a jet of water

coking characteristics. The relationship between the oxidation level of the maceral vitrinite and its reactive nature plays an important role in utilization processes. Western Canadian coals tend to be highly oxidized.

Another study provided insight into the behaviour of the maceral semi-fusinite during coking. Semi-fusinite is present in large amounts in Western Canadian coals and is considered inert by Japanese and European standards. The study showed that semi-fusinite can exhibit the characteristic swelling property of coking coal.

Scientists are also studying several advanced techniques to improve coke properties and to broaden the range of coals that can be used in cokemaking. One project has shown that pitch and solvent-refined coal additions to Western Canadian coal charges improve both strength and high-temperature properties of the resultant cokes. Petroleum cokes improve the strength properties attainable with highly fluid Eastern coals.

Briquetting a portion of the coal charged to coke ovens is now used industrially in Japan where it allows cheaper coals in the blend. In one study, this technique was shown to improve coke strength from production blends of Canada's four major steel companies, and to allow for use of increased amounts of poor- and non-coking materials.

Coal Gasification - Coal, Canada's most plentiful fossil fuel, is a potential source of gaseous fuels to help meet demand as natural gas reserves diminish, or to supply fuel gas to regions that have ample coal resources but no indigenous natural gas. The current definition of natural gas reserves in Canada indicates that substitute natural gas is a distant requirement, and attention is being focussed on production of gas with low or medium heating value. High-efficiency, environmentally acceptable, coal-to-electricity conversion schemes involve gasification of Canadian coals to produce a fuel gas for use in power turbines and steam boilers. Gasification can also be the first step in certain liquid fuel production schemes.

The coal gasification research program has two components: contract research and in-house studies. The objective of the in-house work is to develop methodology for classifying Canadian coals with regard to established gasification technology. Atmospheric gasification equipment was commissioned early in the year and four Canadian coals were examined. Preliminary results indicate that the rates of gasification and formation of gaseous product are sensitive to parameters such as temperature and gasifying medium. These parameters can be used for a comparative study of coals of different ranks and from various sources.

Work is also under way to install a high-pressure thermobalance reactor. In the meantime, staff have computerized a set of equations developed by the Institute of Gas Technology used to calculate coal reactivities under various conditions, based on the thermobalance results.

In the contract work, the second phase of a major project with the Saskatchewan Power Corporation on coal-to-electricity using Shaunavon coal is nearing completion. In this study a number of gasification technologies are being assessed to select the most appropriate. One key stipulation of the study was that it take into account the shortage of groundwater in the Shaunavon area. After a preliminary review it was determined that only Lurgi and Shell-Koppers gasifiers will be considered in detail.

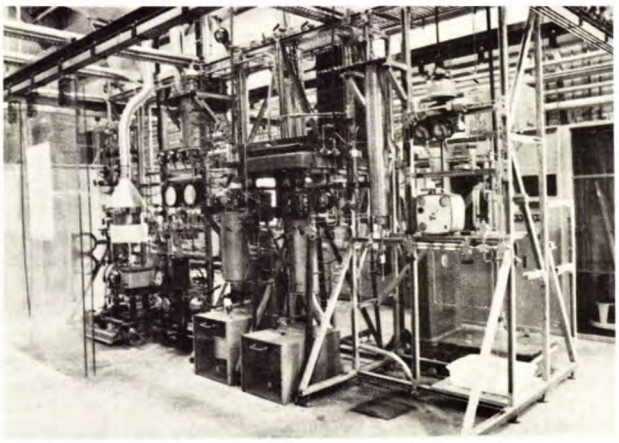
Contracts have been awarded to two universities and a provincial utility to continue the study of fundamental gasification characteristics of specific Canadian coals and three major forms of gasification technology: fixed-bed, fluidized-bed and spouted-bed. The study by the utility has particular emphasis on the Shaunavon coal mentioned above. Other contracts deal with petrographic analysis and the identification of research opportunities in molten salt gasification.

Coal Liquefaction - Liquefaction research is also split into contract and in-house research. Three projects constitute the in-house program: a continuous liquefaction unit, a continuous hydrogenation unit, and studies of coal liquefaction chemistry. Construction of the bench-scale liquefaction unit was completed, with commissioning expected early in the next fiscal year. The first priority for this unit will be to assess the coprocessing of bitumen or heavy oil with coal, as a unique Canadian option.

The high-pressure hydrogenation equipment will have a capacity of 4.5 L/d and will be used to investigate the upgrading of coal-derived liquids and recycle solvents. Design has been completed and key components have been ordered.

Nine new contracts were awarded during the year for a total value of about $950 000. These contracts represent a substantial expansion of the scope of the liquefaction program, covering hydropyrolysis, supercritical gas extraction, use of bitumen as a liquefaction solvent, simultaneous hydrogenation of coal/heavy oil slurries, oxygen removal, petrographic analysis, low-rank coal liquefaction, and a technical assessment of

Atmospheric fixed-bed coal gasification rig in the left background with gas analyzing equipment in the right foreground



A view of the recently-installed continuous coal liquefaction unit

six major technologies. The following examples are highlights from this program.

A study was carried out by the Sandwell Beak Research Group to evaluate the potential of Athabasca bitumen and a bitumen-derived heavy oil as solvents for the liquefaction of a variety of Canadian coals. These batch autoclave tests were run at various ratios of carbon monoxide to hydrogen as reducing gas and in the presence of selected liquefaction catalysts. Further tests are being carried out to clarify some of the results from this study, but initial indications are that bitumen can serve as an acceptable solvent for the liquefaction of some coals. A similar study by Saskatchewan Power Corporation using Lloydminster heavy oil as solvent will be completed in the fiscal year.

Investigations into the flash hydropyrolysis of a variety of Canadian coals were carried out by the chemical engineering departments at McGill and Waterloo Universities. These studies were aimed at developing a precise feeder system for solids, at using fluidized-bed reactors for coal liquefaction, and at determining the effects of coal type and hydrogenating agent on the yields and composition of products. Initial results were promising but final reports have not yet been received.

Nuclear Energy

Utilization of the energy value of nuclear fuels such as uranium involves a series of steps from resource assessment to power generation. The lead role in this work is taken by Atomic Energy of Canada Limited, a government-owned corporation, where the emphasis is on the power generation step. CANMET, because of its tradition of expertise in mining and metallurgy, assumes a large share of the responsibility for ensuring that future reactor fuel supplies are produced as efficiently and inexpensively as possible, with due regard for potential environmental consequences. The uranium resource assessment work was described earlier in this review. Its research on uranium mining and environmental protection is described later under the Minerals Program. The discussion below deals with the recovery of uranium from ores, and the critical need for high-quality materials for heavy-water plants.

Uranium Extraction - Uranium processing has been of major interest for CANMET since the early days of Canada's nuclear program. The aim in current research is to improve the existing uranium extraction technology by removing hazardous radionuclides (e.g., Ra^{226}, Th^{230}, Pb^{210} etc.) from the effluents and by extracting potentially valuable byproducts, such as thorium and rare earths. Reduction of operating costs is also important because possible environmental restrictions might otherwise render operations uneconomic. New approaches such as bacterial leaching are also studied. A supportive but also essential element of the program is the development of improved methods of chemical analysis.

Two major uranium extraction projects are under way. The first deals with sulphuric acid leaching followed by ion exchange or solvent extraction to improve recovery of metals and economics, and to produce effluents that are environmentally acceptable. The second is concerned with alternatives to sulphuric acid technology that will improve uranium and byproduct recoveries and minimize the environmental impact of mill operations.

As in all of the mineral and energy research, there has been emphasis on low-grade resources. In one study, low-grade ores from Copconda and Burnt Lake, analyzing 0.006% U_3O_8, were assessed for amenability to bacteria-assisted leaching. The tests, using minus 2-mm (10-mesh) material, indicated that both ores are leached when iron is added to the bacterial leach medium. The high-grade but extremely complex Saskatchewan ores that contain arsenic and nickel are being studied as well.

Scientists have also been working to optimize the conditions for solvent extraction of uranium and of precipitation in the mill circuits. In solvent extraction the interest is in the mechanism of crud formation and in ways to prevent its formation or treat it to recover valuable organic extractants, thereby removing organic contaminants from the tailings. In continuous tests in a mixer-settler circuit, crud was produced in both extraction and stripping circuits. There appears to be uranium precipitation in the strip circuit similar to that obtained in the mill operation. The problem of excessive amounts of silica in the ion-exchange/precipitation circuit, which can lead to the formation of a stable emulsion in subsequent refining, is being addressed in another study.

A cooperative project is also being conducted with Eldorado Nuclear Limited to develop and test, on a pilot-plant scale, a process to recover U_3O_8 from Beaverlodge mine water, while demonstrating single-stage continuous ion exchange in a deep fluidized-bed column on a large scale. The first pilot-plant run decreased the U_3O_8 from 9 to 3 ppm and produced an eluate containing 0.9 g U_3O_8 per litre. Improved elution is expected to improve extraction and thus decrease the uranium level presently being discharged to the tailings pond. Yellowcake was produced at the site.

Removal of "poisons" such as silica, elemental sulphur, molybdenum and tetrathionates from anion exchangers used in uranium processing is the subject of another study. Sodium carbonate and calcium hydroxide are being examined as alternatives to the more costly caustic soda for removing tetrathionates.

The alternatives to sulphuric acid technology being pursued include continuous high-temperature chlorination, hydrochloric acid leaching and chlorine-assisted leaching.

The chlorination work has been done in a vertical

Solvent extraction column used in pilot-plant uranium processing studies in the Mineral Sciences Laboratories

2.5-mm diameter shaft furnace with a capacity of 1 kg ore per hour. The furnace consists of an upper section maintained at 400°C to maximize the chlorination of uranium and a lower section at 600°C to maximize chlorination of radium. Dry ore is gravity-fed into the furnace at the top and the calcine is discharged at the bottom, while a bottom-fed chlorine and nitrogen stream supports and agitates the bed. Calcines produced are leached in dilute hydrochloric acid. Tests to date on an Elliot Lake ore have resulted in 95% extractions of uranium, pyrite and radium.

A series of bench-scale hydrochloric acid leach tests was conducted on Elliot Lake uranium ore. From the data it appears, depending on the type of uranium mineral, that hydrochloric acid leaching requires an oxidant for uranium extractions. Radium and thorium are leached as well but are unaffected by oxidants. The effects of different oxidants such as molecular oxygen and sodium chlorate appear to depend on acid concentration and temperature. Various sequences of two-stage leaching produced tailings containing 0.002% uranium, 0.006% thorium and 10-25 pCi radium per gram. Chlorine-assisted aqueous leaching has been found to favour uranium and thorium extractions over radium irrespective of temperature and retention time in high-sulphur Elliot Lake ores.

Isolation of radium-226 from chloride-leach liquors is required because its gamma radiation is a public health hazard. CANMET has demonstrated that ion exchange technology can remove 99% of the radium.

The costs of hydrochloric acid leaching have also been compared with conventional sulphuric acid processes. The hydrochloric route is generally more expensive, but this is compensated to some degree by more acceptable tailings and byproduct recoveries.

Material for Heavy Water Plants - Heavy water towers, large pressure vessels constructed of plain carbon steel, face corrosion problems resulting from the presence of hydrogen sulphide dissolved in water at elevated pressures and temperatures. In work supported by the Atomic Energy Control Board, CANMET is investigating the effects of the atomic hydrogen released by corrosion at internal surfaces. The hydrogen diffuses into the steel shell where it can cause blisters and fissures or degrade mechanical properties. In tests this year, tensile specimens statically loaded in hydrogen sulphide solutions did not fail when subject for 1000 h to stresses as high as 90% of the yield stress, but did fail at or above the yield stress.

Electricity

As part of the national effort to develop alternative energy forms, investigation is proceeding on the direct conversion of solar energy to hydrogen by photoelectrolysis of water, or to electricity using semi-conductor electrodes, as a less expensive alternative to photovoltaics. In particular, molybdenum and tungsten sulphides as electrode materials are under study. Tests have helped elucidate the electron transfer reactions that occur at the electrodes. The work involves development of ways to synthesize the materials.

Renewable Resources

Canada is blessed with a variety of forms of energy on which it can draw in the drive to reduce dependence on conventional oil and gas. Among these are renewable resources such as wood and wood wastes, which can make a substantial contribution to local or regional needs in certain areas. CANMET is taking part in an expanded federal government effort to make better use of such resources. Of particular interest are forestry residues which contain energy equivalent to 6% of national crude oil consumption.

Wood Gasification - Research into the production of fuel gases from wood and wood wastes is being promoted through in-house research and contracts.

The contracts are supporting the development of two wood gasification schemes. In Saskatchewan a 78-kW Imbert gasifier/motor/generator set for electricity generation was commissioned during the year. The electricity generated was used to power an electric resistance furnace. A two-year test program is scheduled. In the first year the plant will be fully tested in a laboratory setting; in the second year it will be tested for electricity generation at a remote community of 10 to 20 customers. In British Columbia, a gasifier installed at Westwood Polygas Limited was operated successfully for 6.5 d. Fuel gas containing 5.95 MJ/m^3 (160 Btu/ft^3) was produced at 8440 MJ/h (8×10^6 Btu/h).

A small bench-scale project was also conducted to assess the potential of gasification of biomass to synthesis gas and to evaluate the role of catalysts in the process. Using waste material stripped from full-tree chips during the debarking process, the researchers concluded that potassium carbonate is an effective catalyst. Below 700°C, the conversion rate is not influenced by the potassium carbonate catalyst or by steam. With steam, the rate increases markedly above 700°C because of the onset of the steam-carbon reaction. Either steam or the catalyst causes major changes in product distribution. Both increase the selectivity of the formation of carbon monoxide and hydrogen. The catalyst is equally effective whether added as a dry powder or impregnated as an aqueous solution.

Wood for Space Heating - Concern among homeowners over the cost and security of supply of conventional heating fuels has led to a dramatic increase in heating with wood. The lack of objective data on which claims about woodstove efficiencies can be based has prompted the development of a technique for measuring efficiency and to compare the relative performance of generic types. Results indicate that sidedraft and horizontal-baffle designs offer greater efficiency and less creosote formation than conventional stoves. Field trials have also shown that, properly installed, a good sidedraft stove can reduce fossil fuel requirements for the homeowner.

Researchers also compared the performance of a dry hardwood (maple) and compressed wood briquettes in three woodstove types. The briquettes tended to generate more hydrocarbon and carbon monoxide emissions in an airtight box stove, and presented an overheating hazard in a non-airtight stove. The two fuels performed equally well in a Scandinavian baffled stove.

Combustion of Wood Wastes - In a collaborative study with industry, studies were conducted on the comminution and combustion performance of pelletized wood waste in a pilot-scale, pulverized fired boiler which normally burns coal. The low bulk density of the wood led to plugging of the pulverizer but this is unlikely to be a problem in full-scale equipment. The pellets burned well but only with oil support. Emissions were low.

Energy Transportation

The geographical features of Canada, such as the great distances and difficult terrain, present serious challenges to engineers involved in transporting energy to market. This is particularly important when new sources of supply are being developed in remote locations. The potential of such sources in meeting future energy needs has helped provide the impetus for work on coal, gas and oil transportation. In addition, the work addresses the more general, persistent issues of transportation cost reduction, safety and reliability. Special needs are also being considered, such as the use of coal-water slurries for hydraulic mining and moving coal from mines to centrally-located washeries.

Coal in Slurry Pipelines - The focus in CANMET's work on coal slurry pipelines is on its effects on coal properties and on separation of the coal from the slurry. Two Western Canadian coals were exposed this year to a variety of common inorganic corrosion inhibitors such as sodium hydroxide, sodium silicate, potassium dichromate and lime.

Under experimental conditions that match or exceed the severity of pipeline conditions, the caking properties of the coals, or their agglomerating and softening tendencies, were not significantly affected. However, the coking properties such as free swelling index, dilatation, and softening point degraded quickly.

The possibility of transporting coal in oil in under-utilized oil pipelines is raised from time to time. The technical feasibility of separating the slurries to recover the oil for refinery feed remains to be thoroughly explored. Potential contaminants of the recovered oil include oxidized organic constituents and inorganic material such as clays. The coal must also meet end use requirements. The separation envisioned would likely comprise a mechanical step - filtration or centrifugation - followed by fluidized-bed evaporation of oil from the cake.

Filtration in a filter press at 400 kPa produced a cake containing about 15% oil. The cake was washed with varsol to aid evaporation. A preliminary assessment showed that centrifugation is likely to be much cheaper than pressure filtration, and that fluidized-bed evaporation would be feasible at temperatures low enough to prevent the destruction of caking properties.

CANMET is coordinating Canada's contribution to an IEA investigation of transporting coarse coal up to 50 mm in size in water pipelines. Such coarse coal transport would have the advantage of eliminating the crushing associated with presently-practised fine coal slurrying, and would substantially reduce the cost of drying the coal after transport.

Coarse coal-water slurry transport could be of particular value in moving coal from new mines to existing railheads, particularly in the 50-100 km range. It also has potential for transporting coal mined underground to surface. Current work includes testing a variety of coals in a major pipeline test loop run by Saskatchewan Research Council, and evaluating a sensor to measure slurry density, and hence volume of coal moved, without disturbing the flow.

Materials for Natural Gas Pipelines - Nine years of research has led to the creation in the public sector of a body of expertise on the metallurgical properties of line-pipe steels. Dissemination of this knowledge in the form of information and advice, whether to policy-makers, regulatory agencies, industry or the general public, is a principal objective. During the year, as Canada's two line-pipe mills moved incrementally closer to a fully viable, commercial Grade 70 product, CANMET's work continued. Work

was done on weldability, residual stresses, uniformity, corrosion, toughness and chemical composition.

One highlight of this research during the year has been finding that impact energy as determined by the Charpy V-notch test, exhibits anomalously high values that are not duplicated by more fundamental tests. Because the Charpy test is routinely used by manufacturers and test laboratories for toughness evaluations, efforts are being made to resolve this anomaly without making line-pipe specifications unduly complicated.

The attractive combination of mechanical properties and weldability that make high-strength, low-alloy (HSLA) steels suitable for line pipe depends on certain specific and synergistic effects of steel composition and rolling schedule. Research that still needs to be done on this subject is the effect of molybdenum, niobium and vanadium additions which is of particular interest in the context of the limitations of Canadian rolling mills. A contract has been let to a Canadian university to pursue this line of research.

Integrity of Existing Oil and Gas Pipelines - The recent occurrence of several pipeline failures has added significance to work on stress corrosion cracking (SCC) of existing pipeline materials. Unlike hydrogen-induced cracking, which is being studied in connection with new natural gas pipelines, and which can occur on the internal or external surface, SCC can begin only on the outside. It is usually brought on by a combination of the presence of bicarbonate and carbonate or nitrate ions, an electrochemical potential, and a change of strain. The dependence of SCC on these factors is being studied.

Metallurgists are also investigating the effects of mechanical change on pipeline service life, in an effort to provide a rational basis for inspection standards. During the year, controlled dents were imposed on 508-mm (20-in.) pipe, which was then cyclically pressurized to 80% of the circumferential yield stress. Although the dents "popped out" in the first few cycles, no failure occurred in 10 000 cycles.

Laboratory where line-pipe samples are cyclically pressurized to determine the effect of dents, scrapes and gouges on service life

MINERALS RESEARCH PROGRAM

The CANMET Minerals Research Program (MRP) contributed during the past year to three activities of the department's Minerals Program as follows:

1. MINERAL RESOURCE DETERMINATION ACTIVITY
   - Sub-activity - Technical Evaluation
2. MINERAL TECHNOLOGY DEVELOPMENT ACTIVITY
   - Sub-activities
     - Development and Mining
     - Processing
     - Utilization
     - Conservation
     - Environment, Health and Safety
     - Transportation
3. ADMINISTRATION OF THE CANADIAN EXPLOSIVES ACT ACTIVITY
   - Sub-activity - Authorization and Testing

The objectives of the three main activities as defined by EMR are:

(a) To provide an adequate knowledge of Canada's mineral resources for the development of policies and programs regarding the exploitation of those resources and to encourage and facilitate their orderly development.

(b) To ensure the availability to Canada of adequate technical capability for the supply, processing, and use of minerals.

(c) To administer the Canada Explosives Act in the interest of public safety.

More specific objectives for R & D efforts are given in the following accounts of work done in support of the sub-activities.

MINERAL RESOURCE DETERMINATION

CANMET's Mineral Resource Determination activity provides necessary data to determine the economic recoverability of known mineral deposits based on present and anticipated future technology.

Technical Evaluation

The work in this sub-activity is concerned with determining the quantity and quality of mineral reserves and with Canada's ability to produce them. In CANMET this is done by providing information and data on the mineralogy, mineability and processability of metallic and industrial mineral resources throughout Canada.

Platinum Group Minerals - As part of the study to determine the mineralogy and distribution of the platinum-group elements from different areas and rock types, samples of a low-grade disseminated Cu-Ni deposit in the Lac des Isles region, Ontario, were investigated. The findings were reported, and in conjunction with data on mineral associations and size variations will guide more detailed mineralogical studies and beneficiation tests.

Characterization studies on the platinum-group tellurides of the Stillwater Complex were completed and published. Two new palladium tellurides were identified in the investigations. Work is continuing on mill products and mill tailings from the Sudbury area to determine the reasons for high losses of platinum-group elements and possible methods for reducing these losses.

New Brunswick Massive Sulphide Deposits - Characterization of these deposits in terms of generalized variations on a regional scale have been completed and detailed studies of individual deposits are in progress. Work on the Caribou deposit has shown that the East Sulphide body contains a very high proportion of its pyrite as sulphide clasts presumably derived from sulphide bodies lying to the northwest. The South Sulphide body was metal ratios that differ from those in the East body, and has significant lateral zonation of metals and minerals. An image analysis investigation was initiated to obtain quantitative

Quantimet analysis for determining size distribution of ore particles

investigation was initiated to obtain quantitative data on the size distribution and characterization of exsolved chalcopyrite particles in sphalerite from the South and East bodies, and to determine whether these particles have an effect on sphalerite recovery during ore dressing.

The distribution and mineralogical forms of the valuable trace elements - silver, cadmium, indium and cobalt - have been determined for the milling circuit at Heath Steele Mines Ltd., Newcastle, New Brunswick. Silver is carried by tetrahedrite-tennantite, galena, Ag-Sb sulphosalts or Pb-Bi-Sb sulphosalts with approximately half the silver reporting to the lead or copper concentrates and the remainder to zinc concentrate or tailings. Cadmium, mercury and indium occur mostly in solid solution in sphalerite and consequently follow zinc in the milling circuit. Cobalt and arsenic exist primarily in pyrite, arsenopyrite, pyrrhotite or Co-Fe sulpharsenides and tend to follow pyrite to the tailings.

Alumina from Non-Bauxite Resources - An inventory of domestic resources of fly ash, clays and coal rejects containing more than 25% alumina has been completed. Reports were issued on high-alumina clay (kaolin) and highly kaolinitic shales associated with the Hat Creek coal deposit in British Columbia. Work is continuing on the evaluation of nepheline seyenites and Eastern Canadian anorthosites as potential sources of raw materials for the production of alumina. Literature surveys on both these sources have been published. Limestone resources, required for processing of non-bauxite alumina, are similarly being appraised.

Mineral Technology Development

This activity encompasses all of EMR's responsibilities for performing, funding and coordinating mineral research and development in Canada as well as aquiring foreign technology and transferring it to industry. CANMET is a major contributor 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.

Development and Mining

The objective of the Development and Mining Subactivity is to generate and promote technology for increasing efficiencies in operating mines other than coal. Investigations in 1979 included studies on methods for improving the efficiency of pillar recovery and of deep mining operations, and studies on the feasibility of storing nuclear waste underground.

Open Pit Mining - About 70% of the ore mined in Canada is produced by open pit mining. It accounts for almost all of the iron ore and asbestos as well as substantial proportions of lead, zinc, and copper ores. Slope angle is perhaps the most important design parameter in open pit mining because it determines the amount of waste rock to be removed along with the ore, which in turn establishes the cut-off grade and the economics of the operation. For a large, deep, open pit, steepening the slope angle by only one degree could reduce the amount of waste rock excavated over the life of the mine by about 20 x 10^6 tonnes and result in a saving of $10 million.

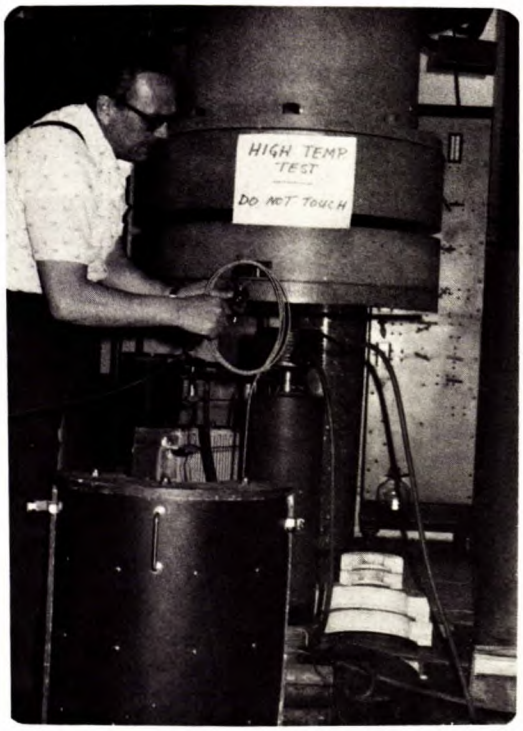
In 1972, CANMET initiated a five-year project to develop improved open pit mining procedures. The project has been a cooperative venture between industry and the federal government with much of the development work being performed under contract by Canadian mining companies, consulting engineers, and universities. The output is a comprehensive pit slope manual, completed in 1978. To date over 21 000 copies of the chapters and supplements have been sold. Audio-visual packages were prepared covering all 10 chapters and their presentation to the industry, as part of technology transfer, is continuing. Currently, revising and updating some of the chapters is under way.

CANMET has published a report summarizing the research conducted on a cooperative project with Texasgulf Canada at the Kidd Creek mine, during 1973 to 1978. This mine originated as an open pit operation and converted to underground mining without leaving a crown pillar separating the two operations. This case history describes all phases of the investigation used to analyze the stability of the pit slope and underground pillars.

Underground Mining - Although underground mining accounts for only 30% of the ore in Canada, it is important in the production of base metals - nickel, copper, zinc and lead - most of which are produced from underground mines. CANMET has been involved in the ground control and safety aspects of underground mining for a number of years and present research is involved with problems in deep mining, pillar recovery, and with mining methods utilizing backfill.

As a result of fewer mines being developed an increasing portion of ore production will come from deeper levels at existing mines. To stabilize ground movement, Canadian base-metal mines normally convert to cut-and-fill mining methods below about 1 000 m. However, conventional cut-and-fill is generally a high cost mining method with low productivity. The use of bulk mining methods, such as blasthole stoping, at these depths would reduce costs and increase productivity, allowing for the extraction of lower grade ores. The application of these bulk methods has been limited due to the uncertainty of controlling ground conditions.

In cooperation with three of the largest mining companies, CANMET has initiated a program to acquire knowledge of the stress regime associated with any proposed mining configuration at depth. This information is required to assess instability and predict problems in achieving optimum mine design. Falconbridge Nickel Mines Ltd. is conducting a feasibility study on new mining methods



High pressure triaxial load cell used by the Rock Mechanics Laboratory to test rocks under simulated high temperature conditions

at depth, and will also be undertaking a bulk mining trial at a depth of 1 400 m at its Onaping mine. Inco Tech is under contract to compile case histories from Inco's Sudbury mines on the design of blasting patterns for large hole drilling in blasthole stopes. Norcomp Division of Noranda Mines Ltd. undertook a contract to develop a conceptual design for a computer program for mine layout selection.

In 1979 a committee was formed under CANMET chairmanship with Rio Algom Ltd. and Denison Mines Ltd. to investigate regional stability in the Elliot Lake mines. The two companies mine the same orebody on adjoining properties separated by a 12-m wide boundary pillar. The companies require guidelines on mining layouts and sequence of extraction near the boundary so that mining operations of one company will not be detrimental to those of the other. Modelling studies were initiated to evaluate stress distributions for the complex geometries involved at various stages of mining. Four joint industry-CANMET technical reports were issued and guidelines were formulated for mining and pillar recovery operations along the boundary. Work is continuing on in situ pillar stress monitoring and finite element model simulation of proposed sequences of extraction and backfilling.

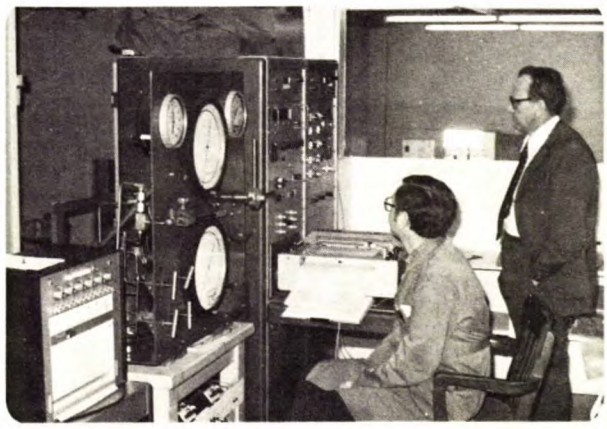
Activities related to tunnelling were undertaken as a result of recommendations made by the Organization for Economic Co-operation and Development (OECD). Projects such as a bi-monthly awareness service and a Canadian Tunnel Register are underway, and Canada's representation within the International Tunnelling Association (ITA) has been established.

Diamond Drilling Research - The branch continues on a modest scale to support technology development in diamond drilling. One of the problems that confront drillers during winter is the freezing of waterlines. Field tests in 1978 of a waterline heater, built on contract to industry specifications, were unsatisfactory. In 1979, a new waterline heater, designed and manufactured under contract, was tested with promising results. Further tests are planned to establish the unit's performance under practical working conditions.

Field testing is continuing with the previously developed light-weight mobile drill carrier and data-logging instrumentation. In addition, a new project was initiated to study problems associated with excessive noise.

Underground Nuclear Waste Repository - Concern has been widely expressed about management of radioactive waste from nuclear power stations. The major problem is the long life - in the thousands of years - of some radioactive substances. Storage in underground excavations 1 000 m or more below surface has been proposed.

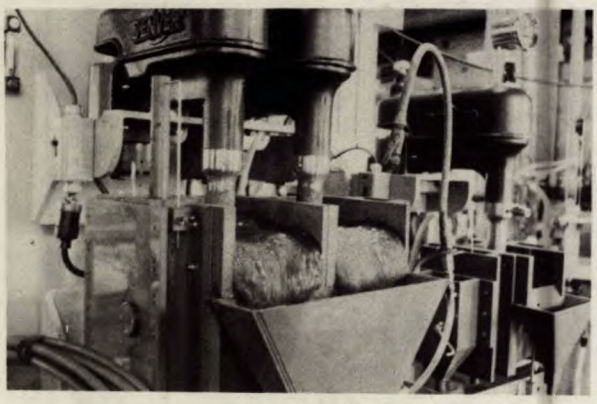
CANMET, in conjunction with the Geological Survey of Canada and the Earth Physics Branch, is working with Atomic Energy of Canada Ltd. on finding a suitable location in hard rock and designing an underground nuclear waste repository. CANMET's part of this study is to rank the potential repository sites on the basis of mechanical and thermal properties of the rocks and to assist in the design by conducting heater simulation tests. Methods for determining the thermal and mechanical rock properties have been formulated, the neces-



Instrumentation panel for high temperature and pressure triaxial test equipment

sary testing equipment has been assembled and pilot tests are being carried out. In addition, contract studies on borehole plugging and shaft sealing are in progress to assure that technology is available to ensure adequate isolation of the high level nuclear waste.

In addition to the two sites on crown land currently under investigation (Whiteshell and Chalk River), a third site (Atikokan) has been added. Characterization of the basic mechanical properties of the three sites has been completed. In situ heater tests at the Creighton mine had to be temporarily suspended due to public opposition. Construction of an underground test facility in the Lac du Bonnet formation at Whiteshell, Manitoba has been proposed and is being actively pursued.



Froth flotation cells in operation at the Mineral Processing Laboratory

Processing

Research in this sub-activity is directed toward developing and promoting technology to increase the recovery of and to upgrade marketable products from Canadian mineral deposits. This is achieved by generating and advancing new and improved processing techniques and equipment with particular attention given to minimizing adverse effects on public health and safety, and on the environment.

Production of Concentrates from Complex Base Metal Sulphides - Some producing mines treating complex fine-grained zinc-lead-copper-silver sulphide ores are presently recovering an average of only 65% of the contained metals. CANMET research is designed to develop processes to increase this to at least 85% and to permit the exploitation of other known deposits dormant because of similar metallurgical problems. Ores of this type generally occur in New Brunswick but are not confined to the East - major orebodies are also known in Ontario and the Yukon. A conservative estimate, including increased recovery and production from dormant deposits, indicates that the success of this project could over the years add \$12 x 10^9 in metals recovered to the Canadian economy.

CANMET research is based on the concept of producing a bulk concentrate with a minimum recovery of 90%. During 1979 studies continued into the flotation behaviour of these complex minerals. Mill products from Brunswick Mining and Smelting (BMS), Heath Steele and CANMET's Ore Processing Laboratory were subjected to thorough examination. Collected data included chemical analysis, mineral identities and quantities, size analyses, flotation circuit material balances and mill recoveries. Similar investigations continued on mineral behaviour during grinding and on chalcopyrite exsolution in sphalerite.

Modelling and simulation studies continued on new grinding and classification schemes for New Brunswick sulphide ores. The computer program MATBAL I for calculating material balance was adapted and applied to the milling circuits at BMS and Heath Steele, and to the in-house continuous process development unit (CPDU). Testing the effect of simulated circuit changes indicated two areas of simulator application - evaluation of minor circuit changes to improve operation and the assessment of major changes such as the addition of a new grinding stage. The simulator was also useful in analyzing variable interactions in grinding circuits.

Classification experiments continued on a 102-mm Krebs hydrocyclone to study effects of various operating conditions on the equation parameters for hydrocyclone performance. With the acquisition of the Microtrac particle size analyser, work commenced on developing an empirical method to determine the content of minus 2-µm material and size distribution on a wide range of samples.

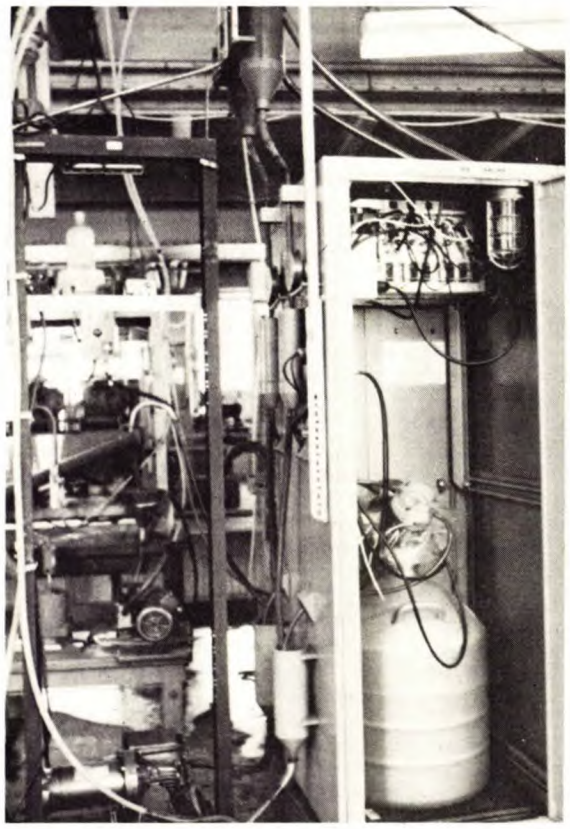
Employing the CPDU installation, continuous testing of these fine-grained base metal ores was carried-out. Bulk flotation of BMS ore at a grind of 80% minus 30-µm, versus the previous 70%, with a doubling of rougher flotation capacity, resulted in a marked improvement in zinc recovery. Tailing assays were cut in half from 0.94% zinc to 0.47% zinc. Conversely, silver recovery was unaccountably lower by 5%. On a cost recovery basis, bench scale testing and CPDU processing of a Portuguese ore for Sherritt Gordon were completed. Flotation procedures for this fine-grained massive sulphide ore were patterned on the BMS scheme, and a copper-lead-zinc bulk concentrate was produced for hydro metallurgical extraction research by the contractor.

A selective flotation scheme for BMS ore, based on extensive batch testing carried out previously, was investigated on a continuous scale in the CPDU mini-plant. The concept was to produce a low-grade zinc concentrate of 40% zinc and a low-grade lead concentrate of 30% lead, and combine them to form a bulk concentrate with the desired grade of 30% zinc. Improved zinc recoveries were anticipated as flotation conditions could be optimized for each of the selective flotation stages. Batch testing confirmed the viability of this method, but in mini-plant runs the improved recoveries,

over straight bulk flotation, could not be reproduced. CPDU continuous processing tests on two other flotation schemes also produced inferior results compared with batch testing. These inconsistencies were attributed to an unrepresentative ore sample being employed in CPDU runs, that produced a larger quantity of unliberated pyrite-sphalerite middling particles than previously encountered, despite the fine primary grind of 80% minus 30-µm.

Valuable operating experience was gained during the current project and the small-scale plant fulfilled the purposes for which it was designed: to test the feasibility of batch processing methods on a continuous basis and to produce small lots of concentrate for metallurgical extraction research. Approximately two tonnes of bulk concentrate were provided for downstream process testing.

In support of these studies considerable development work was accomplished on applications for the INAX analyzer. Accurate batch analysis procedures were evolved for the determination of uranium-thorium in uranium ores, sulphur-iron in coal, and zinc-lead-copper in complex base-metal sulphide ores. Applicability of this X-ray fluorescence equipment to on-stream analysis was also evaluated during CPDU runs on BMS and Portuguese ore. Solids content and element concentrations at various stages in the beneficiation process were determined.



On-stream X-ray fluorescence analyzer in the continuous process development unit (CPDU)

Extraction and Refining Processes for Metals Recovered from Complex Base Metal Sulphide Concentrates - To recover the metals from bulk concentrates produced from complex sulphide ores, CANMET has selected for evaluation four processing options for producing high value refined products. The relative technical and economic merits of two processes are being investigated at CANMET as long-term options. Two short-term options are being investigated at Sherritt Gordon Mines and at the New Brunswick Research and Productivity Council (RPC) by means of DREE-financed contracts under the federal/provincial "General Development Agreement" for resource development with CANMET as scientific authority.

Sulphate Extraction Processes - Investigations of a brine leach process for recovering lead and silver from the leach residues of the Sulphation Roast Leach (SRL) process were completed at RPC under the DREE agreement. A detailed report was issued and approved which included an updated economic evaluation of the SRL process for the recovery of zinc, copper, lead, silver and cadmium from a New Brunswick bulk concentrate.

Further work was carried out by Sherritt Gordon Mines Ltd. on the Pressure Sulphuric Acid (PSA) process to verify the technical feasibility of the process which had been in question. Although these tests were relatively successful, some problems still remain which will require further investigation, particularly those related to lead and silver recovery and copper recovery from high copper content bulk concentrates.

A second contract was awarded to CE Lummus to carry out an updated technical and economic comparison of the SRL and PSA processes based on the latest RPC and Sherritt data. Although the update showed that most of the technical constraints had been removed, particularly from the SRL process, there was no significant difference in the overall economics of the two processes. If, however, sulphuric acid could not be marketed from an East coast location, the PSA process would be more economical.

CANMET in-house investigations contributing to the development of sulphate extraction processes consisted of: lead/silver recovery from SRL process leach residues by physical separation techniques; factors affecting the formation of lead jarosite in the PSA process; iron removal from zinc leach solutions; zinc and copper electrolysis; and economic evaluations. Results of these studies have been or are being published.

Ferric Ion Leach Extraction Processes - CANMET investigations on a ferric ion leach process for the recovery of metals from bulk sulphide concentrates were continued during the year. Prelimin-

ary leaching tests were carried out on CANMET bulk concentrate produced from BMS ore. At temperatures above 100°C and leaching periods longer than three hours, zinc, lead, copper and silver dissolved in the hot ferric chloride solution. The optimum ratio of Fe^{3+} to concentrate required for dissolution was determined, the testwork indicating that slight acid additions were necessary to prevent iron hydrolysis. Preliminary findings suggest that silver and copper could be recovered by hot cementation techniques.

In conjunction with ferric chloride leaching, the feasibility of solvent extraction and cementation techniques were evaluated for solution purification. Reasonable separation efficiencies were obtained employing solvent extraction for the separation of iron, zinc and copper in acid chloride media. Further work is required before a flowsheet can be developed. Zinc dust cementation studies for the removal of cobalt, copper and lead from zinc chloride electrolytes were completed and reported. In addition, basic studies on the characterization of the crystal structures of several ferric chlorides, hydroxides and hydrates in solution complexes were also completed.

Test work on zinc electrolysis in chloride media indicated that smooth compact dendrite-free 24-h zinc deposits could be electrowon from zinc chloride electrolyte using a diaphragm cell. The effect of total chloride ion concentration, metallic impurities (Cu, Co, Ni, Fe, Sb, Pb) and variations in electrolysis conditions on the structure and plating efficiency was also investigated.
A fundamental study was initiated to determine the electrochemical parameters for the dissolution of chalcopyrite, sphalerite and galena in ferric ion media. The results will be correlated with data on the chemical leaching of these minerals in ferric ion solutions.

Ferric sulphate leaching was tested on a pyritic Zn-Pb-Cu ore by percolation leaching with acidified ferric sulphate solutions. Zinc and copper were leached, lead was oxidized, but not dissolved, and pyrite was essentially unattacked. High zinc extractions were achieved after leaching for a few months, and substantial zinc concentrations in solution could be produced by recycling the oxidized solution. The leaching rate was generally controlled by the transport of ferric sulphate oxidant. Zinc extractions increased with increasing ferric ion concentration or flow rate, but were essentially independent of the concentrations of sulphuric acid, ferrous sulphate, cupric sulphate and chloride ion. Leach rates were also insensitive to the height of the ore column, after a minimum height had been exceeded.

Bench-scale facility employed in ferric ion leaching studies

Potentially useful metallic alloys for the ferric ion leach process were tested for corrosion resistance. Three stainless steels - types 304-L, 316-L and 904-L - three high performance alloys - Incoloys 600, 625 and 671 - and nickel 201 were found susceptible to pitting, crevice and general corrosion when in contact with ferric-ferrous chloride leach solutions at room temperature. Zirconium, molybdenum and titanium-zirconium alloys at a temperature range of 22°C to 78°C and bismuth at up to 50°C were passive in the environment, whereas at higher temperatures up to 106°C very high corrosion rates and crevice effects were observed. Tantalum, niobium, titanium and titanim-palladium alloys maintained excellent corrosion resistance to the aggressive ferric-ferrous chloride environment under all test conditions. Studies are currently being conducted on the effect of impurities in the leach solutions on the corrosion resistance of these materials.

Dry-way Chlorination/Oxidation Extraction Process - CANMET investigations on the dry-way chlorination/oxidation (DWC) process continued during the year. Besides effecting high metal recoveries, this process offers the additional advantages of producing elemental sulphur and ferric oxide, thereby circumventing SO_2 emission and pyrite disposal problems respectively. The process consists of a sequence of steps - chlorination, oxidation, leaching, solid-liquid separation, solvent extraction, purification and electrowinning.

In bench-scale tests, extractions of 98% of the zinc, copper, and lead contained in bulk concentrates were achieved by chlorination at 300°C for one hour. To counter the exothermic heat generated by the reaction between chlorine and the sulphides, chlorination with sulphur monochloride, an endothermic reaction, was evaluated and found satisfactory. Gaseous ferric chloride also proved to be an acceptable chlorinating reagent.

During 1979 extensive modifications were made to the twin-screw reactor to accommodate installation of the oxygen reactor in the continuous chlorination mini-plant.

Laboratory scale investigations continued to optimize the operating conditions for submerged lance and flash chlorination techniques and to provide data for preliminary costing. To date, the results have been encouraging and indicate

that chlorination of the Brunswick concentrate at 500° to 800°C, with or without NaCl additions, should be technically feasible.

As part of the DWC process investigations, studies were conducted on: the oxidation of the chlorinated calcine to convert ferrous chloride to iron oxide; ferric chloride dechlorination employing a fluid-bed dechlorinator; and design of an off-gas collection system to separate off-gases into individual products.

Potentially useful metallic alloys and ceramic coatings for the DWC process were tested for corrosion resistance over the temperature range of 450° to 500°C. To date, none have proved to be completely acceptable for all operating conditions.

Basic chlorination studies, employing differential thermal analysis (DTA), were performed on New Brunswick bulk concentrate and synthetic mineral mixtures. The difference in the DTA diagrams for the two products was attributed to the mineralogy of the concentrate where a significant portion of the galena was locked in with other minerals and was not readily available to chlorination. DTA testwork on New Brunswick concentrate in undiluted chlorine gas indicated that substantial chlorination occurred up to 250°C when a protective molten chloride layer was formed. The volatilization of ferric chloride above 300°C disrupted this layer and exposed the remaining sulphide to chlorination.

Solutions produced by the DWC process must be purified to selectively recover the zinc, lead, copper and silver as high purity products. During 1978 investigations continued on solvent extraction techniques for the separation of these metals in the process leach liquors. Bench-scale and preliminary continuous-scale testing in mixer settlers was completed and an apparently technically and economically feasible flowsheet was developed. Copper is first extracted with Acorga P5300, followed by tributyl phosphate (TBP) for the recovery of zinc and Adogen 464 for lead. However, if lead is removed by crystallization from a cooled liquor prior to solvent extraction, the process can be modified as follows. Copper is removed in three stages of extraction with Acorga P5300, followed by scrubbing and stripping. Zinc is then extracted from the copper raffinate in six stages with TBP. A patent application for this process has been filed.

Apparatus for investigating metal recovery by solvent extraction techniques

Hydrometallurgical Lead Process - In cooperation with the Canadian lead smelting industry and the United States Bureau of Mines, CANMET has launched a new project directed towards the development of an hydrometallurgical lead process. Based on chloride leaching and fused salt electrolysis, the new process would recover lead, silver and other valuable components from typical Canadian lead sulphide concentrates and from residues generated in the extraction and refining processes being developed for complex zinc-lead-copper bulk concentrates.

It is unlikely that conventional lead smelting processes will meet the proposed in-plant hygiene specifications for lead, nor can they readily handle the lead residues produced by processes designed to treat complex sulphide bulk concentrates. Chloride processes would result in a $PbCl_2$ product that could be advantageously processed by fused salt electrolysis or by aqueous $PbCl_2$ electrolysis to recover the lead and regenerate the chlorine. Sulphate processes result in a $PbSO_4$ product which could be readily converted to $PbCl_2$ by brine leaching. Thus, the incentive is to develop and evaluate leaching, purification and electrolysis techniques for recovering lead from $PbCl_2$ produced from these various sources. The principal stimulus is the hygiene problem, although the flexibility to treat lead residues from a variety of extraction processes is an obvious advantage.

In this first year of the project, CANMET investigations were confined to basic studies in analytical methodology, solubility determinations, solution purification and chloride electrolysis.

Analytical methods were developed and reported for the determination of various ionic species in lead chloride-sodium chloride leach solutions. Development work is continuing on procedures for analyzing hydrometallurgical lead process residues, designing automatic solution sampling systems and developing methods for continuous monitoring and determination of Fe^{2+} in leach solutions.

Solubility determinations were made for silver chloride (AgCl) and gypsum ($CaSO_4$) at temperatures ranging from 20° to 100°C in ferric chloride solutions. The AgCl data is of importance to the recovery of silver present in lead sulphide ores and concentrates, from chloride leach solutions. The $CaSO_4$ results are applicable to the control of sulphate levels in ferric chloride leaching

solutions, where sulphate is removed by precipitation of gypsum.

Sulphate buildup during the leaching of sulphide concentrates in ferric chloride solutions will present severe operating problems. Jarosite precipitation is being investigated as a means of controlling both sulphate and iron concentrations in such operations. Preliminary investigations on jarosite formation from concentrated chloride solutions containing low concentrations of sulphate were completed and the results have been published.

As part of the solution purification investigations, a study on the cementation of cobalt from synthetic zinc chloride solutions has been completed. The purification of lead chloride solutions by cementation techniques is also being studied. Both basic and practical aspects of silver and copper cementation from lead chloride leach solutions are being examined.

An evaluation of fused salt electrolysis as a route to electrowinning lead has also been completed. Based on this survey, compositions and temperatures suitable for fused salt electrowinning were selected. The results of this evaluation and survey have been published.

Zinc is a common impurity in lead concentrates and a buildup of zinc chloride in the hydrometallurgical lead process solutions would be expected. Zinc can be removed by the aqueous electrolysis of its chloride. CANMET has initiated a study to investigate the parameters - solution composition, temperature, current density, deposit morphology, etc. - affecting the recovery of high purity zinc from aqueous chloride media, and to determine the conditions, cell design and materials of construction that could be employed for a commercial cell. A diaphragm-air sparging cell has been designed and constructed. Smooth, compact, dendrite-free 24-h zinc deposits have been electrowon at 95% current efficiency from aqueous zinc chloride electrolyte. Further investigations are being conducted on the effects of various metallic impurities and additives on the morphology and orientation of these 24-h zinc deposits.

Processing of Ferrous Ores - CANMET research in iron ore processing is aimed primarily at improving process technology to enhance Canada's competitive position in world markets. In conjunction with the Canadian Steel Industry Research Association (CSIRA), some fifteen problems were defined, related to iron ore recovery, grade, pellet quality, energy consumption and environmental impact. During 1979, representatives of the Canadian iron ore producers met as the Iron Ore Technical Task Force to discuss priorities among these problems. The top priorities were identified as: tailings-removal of colloidal iron, water recycling, and fine ore recovery; concentrate-alkali and phosphorus removal; ore characterization and variability; pelletizing characterization of bentonite, process improvement and substitute binders.

CANMET work in 1979 was constrained by the availability of professional personnel. Heat balance and material balance programs were made available to the iron ore companies, and an effective liaison on heat balances was developed between one company and Waterloo University. One company initiated field trials of techniques developed by CANMET for the removal of colloidal iron from "red water".

An initiative to organize a cooperative research group in electric arc furnace technology has been delayed awaiting a review by CSIRA.

Bentonite is a common concern to Canadian iron ore producers due primarily to rising costs and deterioration in quality of the Western types. Another problem area outlined by the Iron Ore Technical Task force was that of ore variability. These two problems are currently being investigated.

The iron and steel industry is dependent on high quality coke for use in blast furnaces. A major concern is the high cost of coke which requires premium grades of coal. An ironmaking process has been developed in which composite iron ore-coal pellets are smelted to produce liquid iron. Theoretical and bench-scale studies have determined the manner in which individual composite pellets react, their compositional limitations and the chemical compositions of the resultant slag and iron. The theortical basis for this process has been developed and preparations for hot-model "pilot-plant" trials are continuing.

Processing of Industrial Minerals

Alumina - Canada's aluminum industry is completely dependent on imported bauxite or alumina as the raw material. To guard against possible interruption of supply due to political sanctions or unrealistic prices, CANMET is participating in a joint program with the U.S. Bureau of Mines to evaluate processes for producing alumina from domestic resources. Both acid and alkali leach processes are being investigated on various domestic sources, such as anorthosite, clays, coal rejects, and fly ash.

Work on the development of aluminum acid extraction processes for coaly waste, anorthosites and fly ash continued during the year. Laboratory work on the acid extraction of aluminum from fluidized-bed ash of Hat Creek coal waste was completed and a report issued. The work involved a study of combustion temperature and its effect on aluminum extraction in hydrochloric or sulphuric acid. Various leaching parameters such as time, temperature, acid concentration and particle size were investigated.

Based on the determined leach parameters, work continued on the HCl gas sparge process. Low temperature calcination at 400°C followed by water leaching was devised to reduce the Mg and Cr impurities. Phosphorus was the one impurity that remained over target concentration in the process.

Solvent extraction and ion exchange are being investigated as potential methods of separating

these impurities. A flowsheet for the entire process was developed.

Specification-grade alumina could not be made with the HCl-gas sparging process employing fluidized-bed ash as feed. Consequently, a process was developed wherein crude alumina was produced by an HCl process and purified by a caustic process. This caustic process is similar to the Bayer process except that the digestion temperature and pressure is lower and that silica removal is not required. Precipitation of aluminum trihydrate resulted in an alumina product that met all purity specifications for cell grade alumina. Work on this process in continuing.

Leach tests on the extraction of alumina from a number of Ontario anorthosites were completed. Extractions varied from 18% to 88% indicating that not all anorthosites are amenable to acid dissolution. Alumina was also leached from samples of three Canadian fly ashes with either hydrochloric acid or a mixture of hydrochloric-hydrofluoric acid. Depending on leaching conditions, between 29% and 75% of the total alumina was extracted.

Alkaline extractions of alumina by the lime-sinter and modified lime-sinter processes, were performed on two samples of coaly waste from the Hat Creek deposit in British Columbia. The modified lime-sinter process employs the addition of some soda ash. The relative extraction efficiencies of these processes were found to depend on the quality of combustible material in the sintering charge. When the ash content in the coaly waste was greater than 30%, the modified lime-sinter process gave better alumina extractions.

These two alkaline processes were also tested on five Ontario anorthosite samples. A sample from the deposit near Parry Sound yielded the best alumina extraction of approximately 85%. Nepheline seynite from the French River deposit in Ontario provided an extraction of 60% by the lime-sinter process. Both investigations were reported.

Additional studies on the alkaline extraction processes involved detailed investigations on aspects of the lime-sinter process as applied to the Lac St. Jean, Quebec, anorthosites; examination of leach residues from the modified lime-sinter process and their possible utilization; and research on silica removal from sodium aluminate liquor.

These processes, using non-bauxitic raw materials for the production of alumina, were compared with the Bayer process for bauxite. Because of the energy content that can be utilized for combustion during calcination, The Hat Creek coaly waste, when treated by the HCl-caustic extraction and purification process, or by the modified lime-sinter process, compared favourably with bauxite in the Bayer process.

Mineral Insulation - Most of the mineral thermal insulation produced in Canada is made from relatively expensive imported raw materials. Only a small percentage is made from domestic low-cost materials. The process used for insulation production is not well advanced technologically and suffers from environmental and energy related problems.

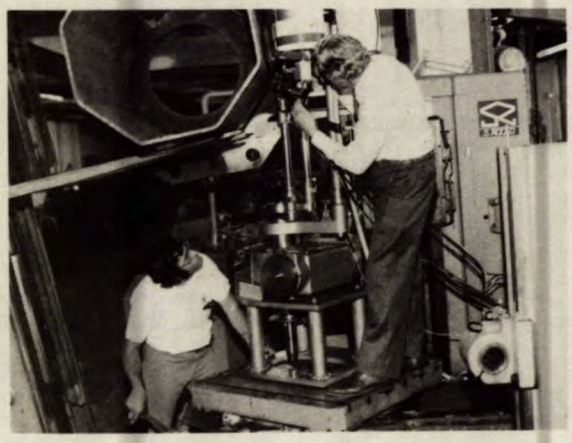
CANMET is investigating less energy intensive and more environmentally acceptable processes for producing mineral thermal insulation from indigenous inexpensive raw materials. Process parameters such as melting and fiberizing are being investigated using a recently installed submerged electrode resistance furnace. Viscosity relations of melted glass and the agglomeration and recycling of waste materials are being studied under contract. A review of published information on the distribution of materials suitable for production of mineral insulation is being prepared along with a survey of current information on processing. Mathematical analysis of the various melt parameters and their effect on surface tension have been completed.

Utilization

CANMET R & D on the utilization of mineral-based materials aims at improved international competitiveness in selected downstream products that depend on the resource base and have significant value-added components. Projects are designed to develop new uses, improve behavioural characteristics, and increase quality of mineral-based materials. Consequently, the range of work including metal-forming technology, metal-casting technology, mitigation of corrosion and wear, durability of concrete, and certification of reference materials, gives the Utilization Sub-Activity considerable diversity. The focal point for this mineral-based materials technology development is the first priority in Canada's evolving mineral policies - "Industrial development and diversification".

Integrity of Metallic Materials - The suitability for service of metallic structures depends upon the tolerance of the material to flaws which invariably exist. Welds, in particular welds in thick walled pressure vessels and oil pipelines where public safety and environmental damage are of concern, are a primary source of defects introduced in the manufacturing process. CANMET is pursuing the goal of improved integrity of metallic structures by developing non-destructive evaluation methodology for identifying, quantitatively, weld defects and by relating defect size and shape to resulting mechanical properties; particularly toughness as measured by destructive impact tests. Residual stresses in weldments, reduced toughness in heat-affected zones adjacent to weldments, and deterioration of weldments and parent metal due to environmental interactions, are complementary areas of technological concern in improving the integrity of metallic structures.

During the past five years, there have been a number of pipeline failures by a mechanism identified as corrosion fatigue. This phenomena is a function of the size of a flaw introduced in pipeline manufacture, e.g., depth of a weld-toe crack or concentration of an active corrosive agent such



Dual detector stress diffractometer is used to measure residual stresses in metal structures

as hydrogen sulphide (H_2S) and the number of stress "events" imposed on a line during service, e.g., operational pressure variations. In this first project year, basic data on fatigue crack growth rates of an X65 pipeline steel in air and in contact with sour crude oil were determined. Preliminary measurements indicated that crack growth rates increased with increasing H_2S content in the sour crude.

In cooperation with a nationally known pipeline operator, studies were intitiated into the effect of pressure variations on the fatigue life of pipe. Work to date has indicated that the original size of a flaw has a significant effect on the life of a pipeline subjected to pressure variations. This points out the need for detecting flaws and estimating their size with reasonable accuracy before a pipeline is put into service. CANMET is currently evaluating the effectiveness of various non-destructive methods for this task.

With the current emphasis on upgrading and refining of Canada's oil and energy resources, a demand has evolved for large, thick wall pressure vessels with improved corrosion resistance. Currently, Canadian industrial capability for fabricating these vessels does not exist in any substantial way. To fill this technological gap, CANMET is investigating fabrication technology and materials performance for these vessels.

In fabrication technology, welding plays a prominent part. During the past year, work funded by contract to review methods for welding very thick sections of steel commenced. In-house, a study of the effect of welding parameters on the integrity of stainless steel strip overlays on a 2.25% Cr-1% Mo base metal was also initiated. A contract, evaluating the effectiveness of ultrasonics in detecting and sizing defects, particularly welding defects, in heavy steel sections was let. In addition, the outlining of a conceptual design for an automated ultrasonic inspection system was initiated.

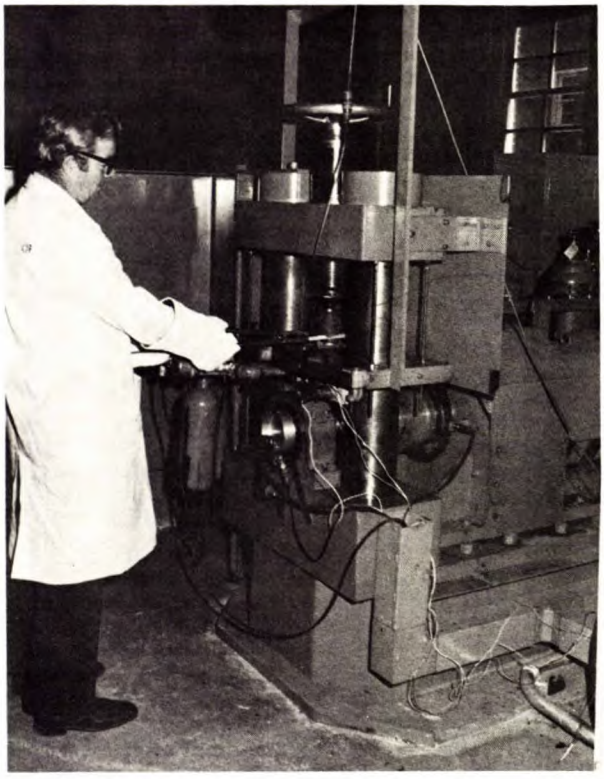
In work on materials performance, the effects of sustained exposure to elevated temperatures and hydrogen environments are being studied. The effect of roll forming on the mechanical properties of the base metal, the welds and the welded stainless overlay is also being determined. Although evidence of temper embrittlement - from long-term exposure to elevated temperatures - and a loss of ductility in the stainless overlay from exposure to hydrogen have been detected, early work suggests that neither effect is severe.

Corrosion of metals is an important mode of degradation of structures in service and CANMET has been conducting atmospheric corrosivity measurements in the Arctic. This research is designed to fill a gap in the engineering literature by providing baseline data on the corrosion behaviour of metals in the Arctic.

During 1979, mild steel "wire-on-bolt" atmospheric corrosivity specimens were evaluated after exposure for about one year at 40 locations in the Canadian Arctic and sub-Arctic. Lowest corrosion rates, in the order of 2-5 mm/a were recorded at inland sites, whereas within 1 km of the sea, corrosion rates of 21-34 mm/a were exhibited. These near-sea corrosion rates are comparable to those shown in southern Quebec and Ontario, e.g., 22-33 mm/a.

The magnitude that residual stresses can assume in an engineering structure and the significant role they can play in structural failures is being increasingly appreciated. It is equally important to determine residual stresses conveniently and non-destructively. CANMET's aim is to develop a prototype transportable dual detector instrument for measuring these stresses, that can be applied to a variety of larger, fixed engineering structures. During the past year, the design of a portable head has been refined and work statements for two contracts written. The first of these contracts is for a prototype design of a portable head which is translatable along three mutually perpendicular axes, and can be turned 360° about the normal to the specimen. The head is also capable of limited rocking movement. The second contract is for the data acquisition and processing electronic hardware which will give stress calculations in real time.

The fast developing family of high-strength, low-alloy (HSLA) steels have a remarkable combination of properties, e.g., superior low temperature toughness and weldability compared with plain, low-carbon steels. Nevertheless, in the heat affected zone of a weld (HAZ) some grain growth does take place and, as a result, toughness suffers to some extent. However, recent research has shown that additions of titanium and nitrogen to HSLA steels sharply reduce grain growth in HAZ's of welds, providing the steel has a suitable processing history. In a four-way cooperative program with a steel company and two universities, CANMET is contributing to the common goal of developing



A cam plastometer being used to determine the high temperature strength of experimental HSLA line-pipe steel

an HSLA plate steel with improved, as-welded toughness, through additions of titanium and nitrogen. In experimental steels made at CANMET, the size, shape, and distribution of refractory particles have been determined in the as-cast, rolled and welded conditions. The particle size distribution has been found to be a function of the titanium and nitrogen additions and preliminary metallographic studies indicate that growth in the HAZ of submerged arc welds is restricted.

Development of Industrial Mineral-Based Materials

Aggregates, Cement and Concrete - Energy and resource conservation through the development and use of less energy intensive materials of mineral origin are the objectives of the work on aggregates, cements and concretes. These materials are evaluated under exposure to normal and extreme temperatures and environments for use in frontier, off-shore, and nuclear construction by means of destructive and non-destructive testing methodology which in some cases is still in the development stage. The work also involves the development of mix proportioning methodology including mineral aggregates, fly ashes, and superplasticizers to produce high strength concretes and the determination of durability of these concretes under extreme temperatures. Specific examples are outlined below.

The effect of acidic Northern waters on durability and performance of concrete is being carried out in close cooperation with Hydro-Québec, Société d'Energie de la Baie James and Laboratoire de Béton.

Low temperature effects on the strength, development and elastic properties of various types of concrete are being studied to provide further information on the behaviour of concrete exposed to severe climatic conditions. Deep freezing of concrete, down to -40°C, generally produced large increases in strength. A similar investigation on the long-term performance of concrete at high temperatures is being conducted with a view to improving concrete behaviour in these conditions through compositional modifications.

In conjunction with Laboratoire de Béton, more efficient methods of testing the in situ strength of concrete are being developed. A 20-min colour film describing various methods of in situ testing of concrete, outlining advantages and limitations of various methods and summarizing CANMET contributions, has been prepared. The film is intended for use in universities and technical colleges and by the trade associations.

Superplasticizers are new types of chemicals which, when added to concrete, cause vast increases in its workability and simultaneously allow for large reductions in the use of water. The introduction of these water reducers has opened up new possibilities for the use of marginal aggregates and the development of high strength concrete. Current investigations include studies on the performance of superplasticizers in high-alumina cement concrete and on the production of high strength concretes using fly ash and superplasticizers. Superplasticized concrete performance under freeze-thaw cycling is also being evaluated. A report was issued on high strength semi-lightweight concretes incorporating superplasticizers. Plans are under way for CANMET and the American Concrete Institute to sponsor a second International Symposium on Superplasticizers in Concrete to be held in Ottawa in 1981.

Lightweight aggregates, their properties, applications and outlook are being investigated as an energy conservation measure. Potential sources are coal-mine shales, clays, slates, slags and fly ashes. A comprehensive report on the use of these aggregates in structural concretes and masonry units has been issued. Similarly, vermiculite, perlite and pumice are being studied as lightweight aggregates for use in non-load bearing insulating concretes.

Studies are continuing on the effect of normal and marine environments on the performance of concrete made with various combinations of portland cement, blast furnace slag, and fly ash. Under marine environments, portland cement/blast furnace slag concretes performed well. CANMET, in association with the American Concrete Institute, the U.S.

Corps of Engineers and the Canadian Society for Civil Engineering, is sponsoring a five-day International Conference on the Performance of Concrete in Marine Environment, to be held at St. Andrew's, New Brunswick, August 17-22, 1980.

At the request of the Committee on Hydraulic Cements of the Canadian Standards Association (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 is coordinating the program. This will involve overall organization, the preparation and distribution of test samples, and the compilation, analysis and publication of the test data. This assessment will be carried out on a continuous basis for the next ten years.

CANMET is publishing a 500-page book entitled "Progress in Concrete Technology". This 18-chapter volume describes various aspects of current concrete technology, with seven chapters being contributed by CANMET personnel.

Toxicity of Ceramic Glazes - Tableware glazes are known to release the toxic substances, lead and cadmium. Under the Hazardous Products Act, "safe" glazes are defined as those releasing less than 7 µg/g lead and 0.5 µg/g cadmium, under specified test conditions. CANMET's efforts are being directed towards establishing the mechanism and rate of release of these toxic substances and providing the knowledge base necessary for the development of safe glazes for application on wares sold to Canadian consumers or produced for export. This work will also aid Canada in its proposal for international adoption of the Hazardous Products Act limits for safe glazes in specifications being prepared by the International Standards Organization (ISO).

Batch samples being analyzed with the energy dispersive X-ray fluorescence analyzer

Thermal Shock Resistant Ceramics - To improve the quality and reliability of ceramics in industrial use, CANMET has embarked on a project to investigate the causes of ceramic thermal cracking and to develop a sound theoretical basis for producing ceramics of improved thermal shock resistance.

Standards, Specifications, and Reference Materials - It is possible to go directly to the EMR publication "Mineral Policy Objectives for Canada" for the rationale of doing work in connection with standards, specifications, and reference materials. To contribute to the establishment of international specifications and standards for products in the mineral sector is one of the twelve strategic elements defined in the policy.

This work is of two kinds: the first being concerned with specifications and standards for castings, especially non-ferrous, and the second with the provision of reference materials and the development of new and more accurate analytical methodology. Work of the second kind is embodied in the Canadian Certified Reference Materials Project (CCRMP) and activities related to participation in the committee structures of the International Standards Organization (ISO) and the Canadian Standards Association (CSA).

Work on the effect of microshrinkage-type eutectic segregation on the properties of cast magnesium alloys has been aimed at developing both qualitative and quantitative standards for users and producers of cast magnesium alloys containing zirconium. In previous work, reference radiographs were established for various casting defects. These have been issued by ASTM as a supplement to the E155 specification. Current investigations centred on the relationship between tensile properties and defect size. For magnesium alloys QE 22-T6 and ZE 41-T5, tensile properties did not change as microshrinkage segregation increased from grade 1 to grade 4. Attempts to produce defects of grade 4 to grade 8 were unsuccessful.

The function of the CCRMP is to provide certified reference material otherwise not available. These are used for quality control and calibration purposes in industrial, commercial, and government laboratories in Canada. Whereas the emphasis in producing reference materials is on ores and related products, some soils and metallic alloys as well are currently in various stages of certification. In 1979, approximately 1300 units of reference materials were distributed to users in Canada and abroad. Additional reference materials including a suite of two lake-bottom sediments, a uranium ore, a nickel-copper-cobalt ore, a niobium ore, a lead-zinc-copper-tin ore, an iron ore concentrate, and zinc-aluminum alloys are being prepared for certification. As many as thirty laboratories have participated in the analysis of some of the materials being prepared for certification. Methodological information from these interlaboratory certification programs have been compiled to aid in the selection of the best analytical method for certain elements at various concentrations in a particular material. This information is being published and will be presented at the International Symposium on Production and

the Use of Reference Materials to be held in Berlin.

Work is also being conducted on the development of new analytical methods. The objective is to maintain an analytical service commensurate with CANMET's role as the national centre for mining and metallurgical research.

During 1979, investigations were conducted to determine: Bi, Mo, Sn, Cr in sulphide ores and concentrates; platinum-palladium by fire assay; small amounts of sulphate in process solutions; minor quantities of silicon in base metal concentrates; mercury using cold vapour technique; small amounts of uranium in ores; nitrogen in steels; major elements in non-ferrous alloys by atomic absorption spectrometry; and zirconium in copper-bearing alloys. Thirteen new and three revised analytical methods were prepared for inclusion in CANMET's methods manual, Monograph 881, which is being revised and updated. The new edition will be published in 1980. A new comprehensive manual for precious metal determination is being prepared summarizing CANMET's research and long experience in the determination of gold, silver and the platinum-group metals.

In conjunction with ISO activities, CANMET is engaged in development of international standard methods for the characterization of iron ores, revision of ISO manuals for sample preparation and iron ore sampling, development of international standards for analysis of nickel and nickel alloys, statistical evaluation of analytical data resulting from international testing programs, and application of statistical methods to various problems.

Further Processing of Metals - Research to encourage further processing of metals is directly related to the government goal of emphasizing industrial development and diversification in implementing a mineral policy. The R & D is covered by three projects embracing work on melting, moulding and casting technology, high strength copper alloys for shipboard systems and metal fabrication technology. During the year, CANMET designed and built horizontal continuous casting machinery producing a wide range of alloy steels and nickel-base alloys as 25-mm bar. The high quality of nickel-base rod produced has resulted in an agreement between Sherritt Gordon Mines Ltd. and CANMET to pilot the production of this rod at Sherritt's plant in Fort Saskatchewan, Alberta. CANMET personnel will train Sherritt operators in use of the machinery. This casting technique is also being assessed under a Cooperative Program with Industry (COPI) for commercial viability in steel manufacturing. Four applications were evaluated, with two showing excellent potential return on investment.

Quick-setting binder systems for moulding sand are finding greater acceptance in the foundry industry. Organic binders were initially favoured as they were relatively easy to reclaim and possessed good shake-out characteristics. Their toxicity

Electron microprobe capable of analyzing elemental concentration in solid particles down to 10 µm in size

and the surface contamination of the solidified castings have resulted in a trend towards inorganic binder systems. However, these binders are not readily reclaimable and are difficult to shake out. CANMET has been investigating non-petroleum based binder systems for improved shake-out characteristics. Very promising results were obtained with some of the binder systems evaluated and patent protection is currently being pursued. On the other hand, technical and economic evaluation of CANMET-developed inorganic non-bake sand systems indicated that these systems were not economically competitive with commercial non-bake binders. A similar evaluation of the CANMET rapid investment shell process for commercial investment casting found the process unattractive due to inadequate strength in the freshly deposited shell, making it susceptible to damage during handling.

Experimental work aimed at controlling the evolution of gas in magnesium castings with a vacuum pump has proven successful. Gas-free, dimensionally stable cores were produced when established relationships between core length, core diameter, pouring temperature and pump capacity were observed. Similar results were achieved with aluminum alloy castings but proved unsuccessful with copper-base and ferrous alloys.

The economics and market potential of CANMET's CANCOAT process for applying abrasion resistant coatings to steel castings is currently being evaluated under a COPI contract. Indications are that the greatest potential for the process is for castings with corrosion resistant coatings. One such application is for trawl net dragger shoes. These are currently imported, and CANMET has undertaken development work to produce them domestically. Further development of vacuum core technology included production of reliable steel and iron castings of CrC, WC and WC/Co, and steel ingots successfully coated with austentic stainless steel for experiments to produce clad sheet by hot rolling.

A double-spiral fluidity test casting was used to determine the effect of different mould materials and mould castings on the fluidity or castability of two commercial aluminum casting alloys. To verify the results of the fluidity test, a thin-walled casting was designed and produced. This test is now available to Canadian non-ferrous founders who may wish to supply the expanding market for thin-walled automotive castings.

The manner in which molten metal enters a mould cavity can have a marked effect on the quality of the resulting casting. Despite this, few foundrymen utilize good gating design in their moulding practice. Work has been undertaken at CANMET to improve gating design practice in the Canadian foundry industry. To achieve this, a computer model has been developed to predict the flow of liquid metal in sprues, runners and ingates. Good correlation was achieved between the actual and predicted manner in which iron and aluminum filled a horizontal runner/ingate system.

In work on gas in copper alloys, an apparatus was constructed to measure the gas content of these melts in the foundry. Testing indicated that the relative gas contents of short and intermediate freezing range alloys, such as aluminum-bronze and cupro-nickel, could be determined with sufficient accuracy and reproducibility to become an acceptable foundry process control instrument. Demonstrations of the applicability of the apparatus to commercial foundry operations are currently under way.

Related work on casting technology included projects on cast copper tuyeres, "black spots" in Mg-Zr castings, and grain refining methods in aluminum-free steel castings. The cast copper tuyere work was undertaken to assist Canadian foundries to switch from producing single-compartment cast copper tuyeres to two-compartment tuyeres and thus become competitive with off-shore suppliers. Black spots are being investigated to develop methods of eliminating these defects from Mg-Zr castings. In grain refining methods, the effect of heat treatment in the intercritical temperature range on the toughness of thick section (50-mm) plain carbon steel castings, with and without niobium additions, have been assessed. Conventional double normalized heat treatment produced superior toughness.

In the era of soaring energy costs, CANMET has instituted a program of identifying and quantifying opportunitites for energy conservation in metal melting, handling and heating operations. Three aspects are currently being investigated: ladle preheating with gas torches, liquid metal insulants and cupola melting operations.

Ladle preheating is critical in steel foundries as the difference between furnace tapping temperature and mould pouring temperature should be small. Tests in CANMET's experimental foundry with a commercial gas torch and a 250-kg ladle indicated that the most important variable in preheating efficiency was the use of ladle covers. Gas savings of up to 50% were obtained in tests of various covers. Tests to determine the effectiveness of various insulants used on the surface of molten steel in transfer ladles and tundishes indicated that the furnace power required to keep the metal temperature in the holding crucible constant could be reduced by 25% when insulants were used as a cover.

Improved efficiency of Canadian cupola melting operations offers direct and indirect energy savings through increased melting efficiency and reduced metal scrap. Accordingly, an industry-wide program was initiated to measure cupola efficiencies and to relate them to operating practices. All on-site testing has been completed with data obtained from 30 foundries across Canada. The findings indicate that approximately 20% of the cupola operations were efficient and little improvement could be obtained without substantial new investment, 60% could achieve small yet significant improvements through changes in operating practice, and 20% could achieve substantial gains in efficiency through changes in practice and repairs to malfunctioning equipment. Final reports describing specific losses in efficiency and suggesting corrective measures are being prepared for each foundry.

As part of the transfer of CANMET foundry research information to industry, two issues of the Canadian Foundry News Letter were published. Considerable interest has been generated by the publication with numerous requests received for copies of the CANMET reports listed.

To guide future research and development projects at CANMET, an assessment of the technological capabilities of the foundry industry was completed. The industry's major concern was to upgrade its technical competence by training more engineers and technicians.

Powder forging, a process that offers both materials and energy savings, has found little application in Canada. CANMET is currently examining the feasibility of producing tool steels by preform forging.

Research and development on high strength copper-nickel alloys and manganese-nickel-aluminum bronzes has continued with support from the Department of National Defence (DND). Two practical results of the efforts to date have been: a three day seminar/workshop on "Foundry Technology for Copper Casting Alloys" attended by 42 representatives from 25 foundries, and the casting of two sets of eight hydraulic manifolds for submarines by a Southern Ontario bronze foundry. These castings, required for routine refitting, were previously purchased by DND from Britain.

In the laboratory, welding studies on cupro-nickel alloys were completed and work on nickel-aluminum bronzes commenced. R & D aimed at improving the resistance of nickel-aluminum-bronzes to dealuminification was completed, and recommendations were made for controlling dealuminification in terms of optimum alloy composition and the heat treatment of castings.

Following DOT's decision to prolong the shipping

season in coastal waters, Coast Guard ice-breakers encountered more severe ice conditions resulting in several propeller failures. These propellers are made of manganese-nickel-aluminum bronze, and the evidence suggests that the impact properties of these alloys is lower than expected by supplier and user alike. As a result, CANMET has undertaken to determine the effect of composition and heat treatment on the mechanical properties of these bronzes.

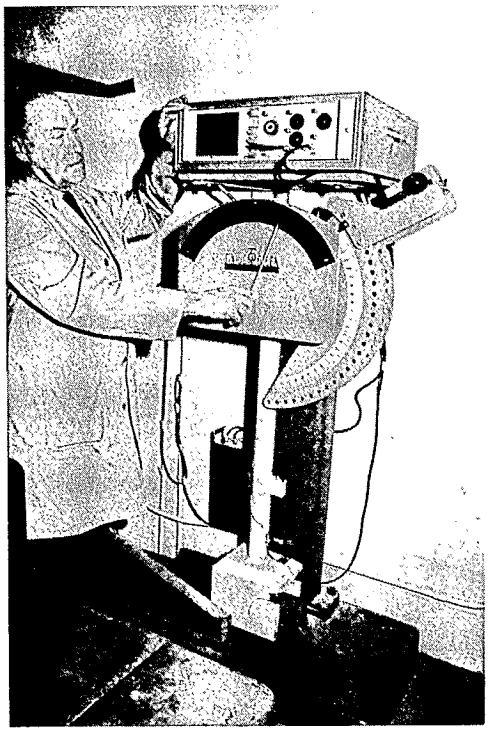
The increasing demand for higher strength, tougher steel products for the energy and transportation industries is creating the need for both higher-powered rolling mills and more effective use of existing facilities where possible. To optimize both product properties and productivity of rolling mills, it is necessary to predict the power requirements for various alloys and rolling schedules from measurements of metal flow stresses as a function of strain rate and temperature. To achieve this, the 460-mm rolling mill has been instrumented to measure various mill operating parameters such as power, separating force, time and temperature. Programs have been written to record these data using a minicomputer. During 1979, mill operating data were recorded for a wide range of high-strength steels, particularly dual phase and titanium-nitrogen (TiN) steels. Rolling data from laboratory simulation of the finish rolling schedule for an X-70 grade line pipe steel were collected for correlation with data from an industrial mill. A new computer program was also written to provide for on-line computation between passes of rolling power for a given thickness reduction. In addition, a two-day seminar, entitled "Analyses of Flow Stresses and Rolling Mill Schedules to Improve Productivity" held at CANMET, was well attended by representatives from industry, universities and government. Plans are under way to coordinate a second seminar.

The pipelines of the mid-to-late 1980's will probably require line pipe with higher mechanical properties than X-70 grade. One possible process to produce higher strength line pipe is to quench controlled-rolled plate directly off the mill. Previous results have shown that X-100 grade material can be produced using the CANMET rolling mill and quenching facilities. Work in 1979-80 was aimed at completing the characterization of mill weldability of direct quenched plate, determining the susceptibility of the plate to hydrogen cracking, and evaluating the preferred orientation of the plate.

Further aspects of metal fabrication technology currently under investigation involve determining alloy compositions and thermomechanical processing schedules required for more weldable, tougher, and abrasion resistant plate steels for the mining industry; evaluating quenched and tempered rods for use in grinding mills; and ascertaining the optimum consumables and welding parameters for mill and field welding of X-70 grade line pipe steel.

Conservation

The need for conserving minerals and metals, and consequently, energy, is self-evident. Conservation can be effected in the main by optimizing the use of metals in fabricated products, developing substitute materials, finding uses for what are now considered waste products, and increasing recycle ratios through technological innovation.



Instrumented Charpy V notch testing machine for determining impact energy of line-pipe steel as a measure of resistance to brittle fracture

Mineral Wastes - In an effort to publicize the extent and availability of primary mining and mineral processing wastes in Canada and to stimulate interest in their utilization, data are being compiled on their occurrence, physical and chemical characteristics, and potential uses.

Investigation of samples of waste rock and mill tailings from operting mines in the Atlantic Provinces was completed. The report on mining wastes in British Columbia has been distributed to mine operators in that province, to government agencies, and to individuals and companies having interest in these wastes and their re-use potential.

Information on metallurgical wastes from iron and steel manufacturing plants in Canada has been received and is being compiled. Various waste samples including slag, dust and sludge from these plants are being processed and analyzed.

One of the potential uses of mineral wastes is in mineral fillers. Field work and laboratory stud-

ies of select mineral waste samples for this use are nearing completion and a preliminary evaluation report is scheduled for early 1980.

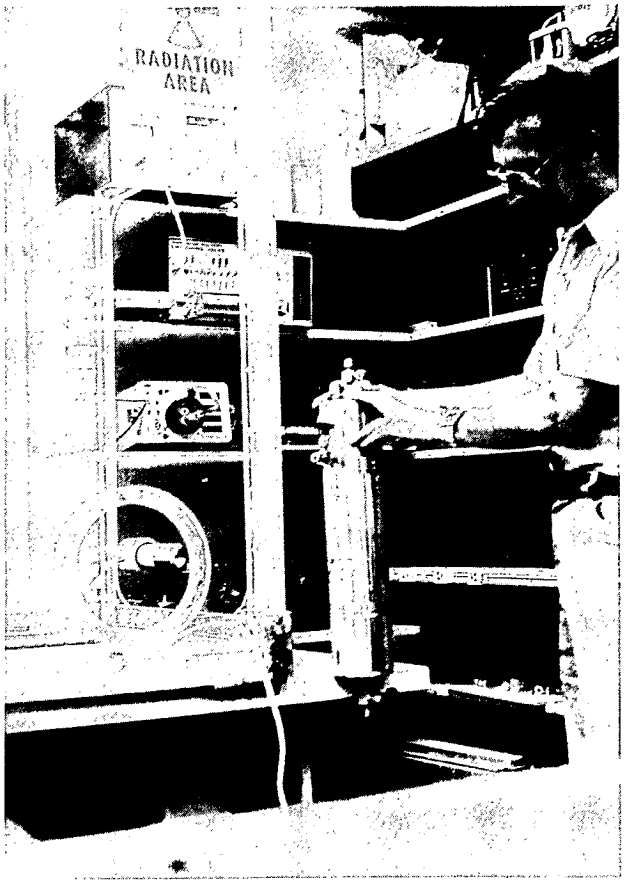
Environment, Health and Safety

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

Underground Environment - The objective of this work is to develop control methods capable of reducing levels of dust, radiation, various fumes, and noise in underground mines so that workers' average levels of exposure are significantly below provincial and federal standards.

The sampling and analysis of airborne dust in mines have been under investigation by CANMET staff for several years. In the past year alone, several thousand silica determinations were run for clients across Canada. Research efforts during 1979 focussed on determining the relationship between dust size distribution and thoron daughter content; development of a specific fibre instrument capable of determining asbestos concentrations in airborne dust samples; and statistical evaluation of quartz dust and total respirable dust data collected during sampling campaigns at two mines in the Elliot Lake area. CANMET's efforts in the development of the CAMPEDS personal dust sampling apparatus are being rewarded as the unit is gaining acceptance from provincial mine inspectorates and mining companies alike.

With the exception of noise, the best means of reducing underground health hazards is to provide adequate ventilation. To this end, CANMET is developing mathematical models of underground ventilation networks that will define the method, quantity and distribution of fresh air for every working area so that the average levels of airborne contaminants are reduced below existing standards. Models have been developed to calculate airway resistance and other ventilation parameters, and radon daughter growth in ventilated tunnels. Tests are continuing with SF_6 tracer gas to determine mine air residence times. In addition, a comprehensive study was completed on radiation, ventilation and dust variables in underground mines in the Elliot Lake and Agnew Lake regions. The final network ventilation model is being formulated to incorporate all these measured variables when defining underground ventilation system requirements.



A 3000-L radon gas box calibration facility now near completion for measuring the amount of radiation in mines

Last year, the Elliot Lake/Sudbury Ventilation Group identified a need for a training module for ventilation technicians to bridge the gap between theory and practice. Consequently, a manual was prepared demonstrating the proper methods of using, checking and maintaining instruments, the proper choice of locations for sampling, and the measurement of various ventilation parameters.

CANMET and the U.S. Bureau of Mines are conducting a cooperative study of radiation problems related to uranium mining. Instrumentation to accurately and quickly measure radon and radon daughters is being developed at CANMET. Underground technical evaluations of two alpha-particle personal dosimeters are in progress and the CANMET-designed and -developed Canalph-3 alpha-spectrometer has been contracted out for commercial production. A "flow-through" radon gas system has been designed for the purpose of making laboratory measurements of radon emanation from ores.

Using the CANMET developed "Noise Monitor Hat", noise exposure measurements of 650 operating per-

sonnel in two mines have been completed. A further 785 remain to be assessed. Analysis of the prodigious mass of data is currently under way with reports to be issued for each mine.

An apparatus for testing the hearing ability of mine workers has been fabricated and is currently being evaluated. The unit was invented and developed at CANMET.

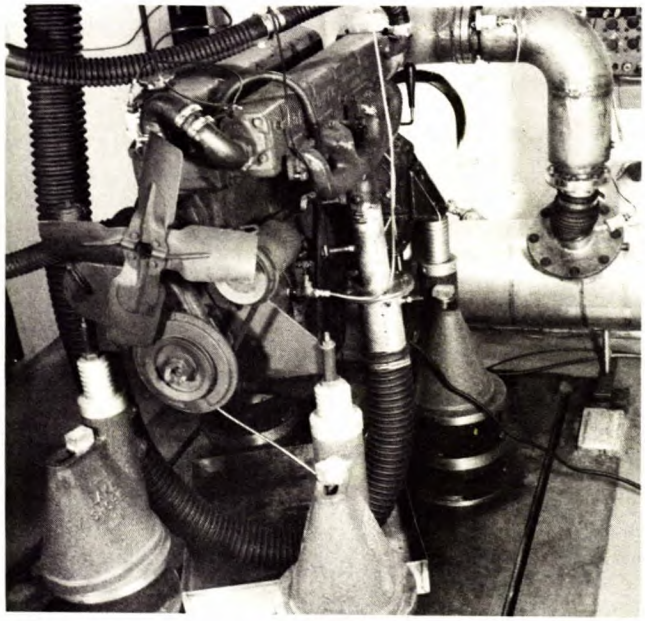
Work is continuing on certification of emission control systems for diesel engines underground. Exhaust treatment systems currently under investigation include venturi scrubbers, dry exhaust filters, a high efficiency water scrubber, and catalytic converters. Water/oil emulsions as fuels for diesel engines are also being studied to minimize exhaust emissions. The aim of this work is to reduce the toxicity of diesel engine exhaust by 70%.

Waste Management

Uranium Tailings - CANMET has been engaged since 1975 in a cooperative program with Rio Algom Ltd. to assess the effects of different surface treatments on the quantity and quality of seepage water from uranium tailings basins. Although considerable variation was recorded in effluent flows and analyses, the main conclusions were that vegetation of the test pits reduced effluent flow and lowered the levels of contamination. Data will be collected for several additional years to confirm these conclusions.

Direct seeding of tailings, a revegetation method developed by CANMET, is in its second year of a five-year demonstration program. This process circumvents the use of organic additives such as sawdust, sludge, plastic binders, etc., to build a stable layer of topsoil. Seed, fertilizer and limestone for pH control are added directly to untreated tailings. To date, approximately 40 acres of good vegetation have been established. Mining operators in the Elliot Lake region are planning the revegetation of between 500 and 600 acres of tailings by this method. CANMET is also investigating the composting of municipal wastes and their use as organic base for tailings revegetation.

Noise monitor gun used at the Elliot Lake Laboratory to measure exposure to noise



An instrumented diesel engine is employed by the Canadian Explosive Atmospheres Laboratory in efforts to minimize diesel exhaust pollution in underground mines

Hydrogeological studies on the movement and distribution of environmental contaminants - chemicals and isotopes - inside and outside an old abandoned uranium tailings basin in the Elliot Lake area are in progress. Radium, thorium, lead and uranium have been found to migrate downward and to concentrate along the interface plane between the tailings and black soil underneath. The University of Waterloo is conducting a contracted study on radium-226 mass transport in the seepage flowing from this tailings area and through the dam.

Effects of bacterial action by thiobacillus ferrooxidans on the leaching of environmental contaminants from Elliot Lake uranium tailings and a Saskatchewan uranium ore leach residue were investigated. Bacteria influenced the leaching of radium-226 and iron from Elliot Lake tailings through oxidation of the sulphide minerals. With the Saskatchewan uranium ore leach residue, bacterial action increased the leaching of uranium, thorium, nickel and iron while decreasing the leaching of radium-226 and arsenic.

In 1978 a joint project was initiated by representatives of the Canadian Government and the uranium mining industry to improve waste water treatment

An example of the vegetative growth obtained on stabilized mine tailings at Elliot Lake

processes, focussing on the isolation and removal of the radioactive contaminant radium-226, declared a public health hazard due to its gamma radiation. The objective of the joint venture was to develop physical-chemical treatment processes which would improve the removal and recovery of radium-226 and other contaminants from uranium ores, tailings and tailings decants prior to their discharge to the environment.

Bench and pilot-scale experiments have resulted in the development of two processing alternatives for the treatment of uranium mine effluent streams containing radium-226. Both processes employ barium-radium co-precipitation, but differ in mode of sludge recovery. Based on these processes, cost estimates were prepared for various plant configurations treating 4550 or 18200 L/min (1000 or 4000 Ig/min) of effluent. The estimated installed fixed capital costs varied from $552,000 to $2,580,000 whereas annual operating costs were estimated to vary between $0.09 to $0.20/1000 L ($0.41 to $0.93/1000 Ig) treated. Both these processes produce a contaminated $BaSO_4/RaSO_4$ sludge that must be isolated from the environment. Work is continuing on developing technology for the removal, dewatering and disposal of these sludges.

Other investigations of radium removal technology currently under study at CANMET involve: radium leaching from uranium tailings by salt (KCl) washing; hydrochloric acid leaching of radium from a pyrite-radioactive mineral concentrate produced from uranium tailings; and removal of radium from chloride leach liquors by ion-exchange.

One method of isolating the environmental contaminants present in uranium ores from the final mill tailings is by preconcentration prior to uranium extraction. CANMET is currently investigating various processing strategies whereby uranium, thorium, pyrite and radium can be recovered from uranium ores in a preconcentrate. The preconcentrate, roughly one-third the mass of the original uranium ore, is then subjected to uranium extraction processing. Consequently, only the uranium processsing effluent requires treatment versus the much larger quantities discharged from the tailings basin. Batch and continuous testing of a number of uranium ores, incorporating a variety of flowsheets, produced preconcentrates with high uranium recoveries and environmentally acceptable tailings low in pyrite and radioactive contaminants. Further testwork is being conducted to demonstrate the feasibility and benefits of the preconcentration process.

Sulphide Tailings - The formation of polythionates during grinding and flotation of sulphide ores results in a particularly troublesome environmental problem due to their tendency to slowly oxidize. This creates acid conditions in the receiving stream several kilometres downstream from the tailings pond.

During the past four years CANMET has been investigating the storage and analysis of thiosalt effluents, the generation of thiosalts during milling and the destruction or containment of the offending thiosalt pollutants.

In the area of analytical methodology, the effects of various metals on the accuracy of polythionate determinations were investigated. The presence of copper and iron were found to cause significant errors in these determinations and procedures were modified to remove these interfering elements

A physical scientist with the environmental technology group specializing in monitoring ground movement from mine sites, examines level of radium 226 contamination using multi-level piezometer

where necessary. Employing a titrimetric method, CANMET recently developed a procedure for the direct determination of sulphate in the presence of thiosalts.

Studies continued on the generation of thiosalts during the milling of sulphide ores. Testing of Brunswick Mining and Smelting Corporation (BMS) ore in CANMET's continuous process development unit (CPDU) indicated that approximately 1000 g thiosalt per ton of ore were generated during milling. Thiosulphate was generated primarily during grinding and conditioning and trithionate during scavenging. A comparison of the rates of generation of thiosalts by BMS ore versus the rates for individual mineral components of the ore, indicated that pyrite was the largest contributor to thiosalt generation.

Destruction of thiosalts in mill solutions through oxidation with SO_2 plus air, charcoal plus air, and chlorine was examined. Only the chlorination process proved technically successful, but had a major economic drawback due to operating costs, estimated at $6 million per year for the BMS operation. A similar economic drawback was encountered for the electro-oxidation process.

Bacterial oxidation is one of the few processes that appears to be economically and technically feasible for treating mill effluent containing thiosalt. At optimum conditions, the bacteria thiobacillus thiooxidans can consume or oxidize 38 mg/h thiosulphate in a solution containing 2000 mg thiosulphate. Testwork is continuing on the development of mixed cultures of these microorganisms and selection of optimum conditions for the efficient oxidation of all thiosalt species present in mill effluents.

Pyrometallurgical Emissions - The emission of undesirable elements during the pyrometallurgical processing of ores, concentrates and metals is of concern to federal and provincial health and environmental authorities, private industry, and the public. Sulphur oxides, arsenic, mercury, lead, selenium and tellurium are just some examples of toxic elements emitted in the off-gases of roasting and smelting operations. Sulphur dioxide has recently gained notoriety for its link to acid rain formation. CANMET's objectives are to provide fundamental data on the form and distribution of the major toxic elements encountered in Canadian non-ferrous pyrometallurgical processes, and to develop and evaluate economically attractive methods for controlling these gaseous and particulate emissions.

Analytical methods are being developed to rapidly and accurately determine trace quantities of these toxic metals in various sediments, sulphide ores, concentrates, dusts and solutions. A study is under way to characterize mercury sources in ores and concentrates according to mineral origin. The development of a fluidized bed-type scrubber for the removal of mercury from gaseous emissions is continuing. Compilations of process flowsheets and mass balances for mercury and arsenic in Canadian non-ferrous metal processing plants are in progress.

As a result of CANMET's participation in the Non-Ferrous Smelting Industry Task Force, input is being provided for reports and regulations relating to emissions in the smelting industry.

Plant Environment - To alleviate health and safety problems associated with asbestos fibre dusts generated during dry processing of asbestos ores, work is being carried out to develop the basic unit operations required for wet asbestos processing, and to evaluate these techniques on the basis of their technical and economic viability.

Testing of the CANMET developed cone-type classifier for primary wet fibre separation is continuing. Results indicate that the recovery of liberated fibre from the wet asbestos separator is somewhat better than that from a laboratory dry separation technique. Some entrapment of dust and short fibre in the long fibre was encountered, and was attributed to possible opening of long fibre by water. Further work is planned on the entrapment aspect as well as overall cone-classifier performance to gain better understanding of the water/solids system.

Transportation

To develop and promote new and improved materials for Canadian transportation systems - both public and private - is the major goal of CANMET's efforts in transportation R & D.

Materials for Transportation - The continuing growth of bulk commodity traffic on railroads is causing increased rail wear, especially on curved track. One approach to this problem is the use of improved premium rail. The objective of this CANMET project is to contribute to the development of a better rail. In particular, the aim is to develop technology to produce an economical, weldable premium rail that can be manufactured in Canadian rail mills with minimum modifications to existing facilities.

There are several aspects to this project. They range from the characterization of existing premium rails and their failure modes to the development of alloy compositions, processing technology and welding procedures for improved premium quality rail.

During the past year, considerable progress was made towards winding up work on the evaluation of existing premium rails. The objective of this work has been to provide base-line data against which progress in developing an improved premium rail could be assessed. In the course of this phase of the project, the metallurgical and mechanical properties of a number of quenched and tempered alloy rails, including rail from the Soviet Union, were determined.

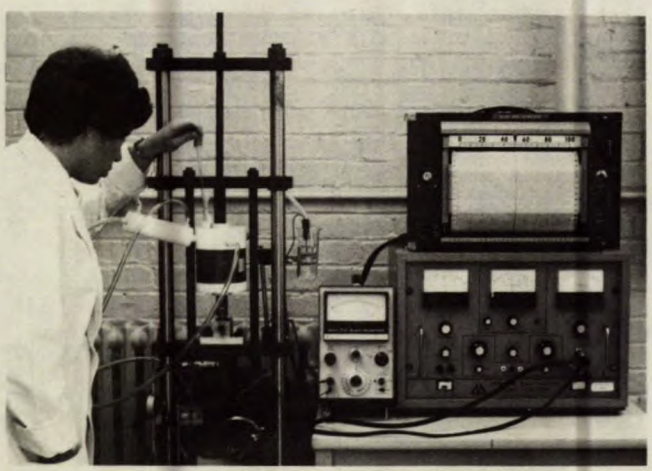
In the welding procedures developed in earlier work for simulating, with the thermal cycle simulator (Gleeble), the microstructures resulting from electric flash welding have been refined and extended to several premium rail steels. As a result, it is now possible to translate the experimental parameters determined on the Gleeble into guidelines for controlling electric flash welding of rails.

Work on premium rail development has two aims. The first is to produce a premium rail from a lean alloy steel with a microstructure and hardness comparable to the best premium rails in the current generation. To achieve this objective, techniques are being investigated for inducing mildly accelerated cooling rates in the hot bed of a rail mill. The second aim is to produce a premium rail of superior quality to the current generation of rails. To this end, alloy compositions are being evaluated for the hardness and other mechanical properties they exhibit in response to a controlled, interrupted cooling procedure.

In response to the energy crisis, increasingly stringent regulations have been established for automobile gasoline consumption. One major method of achieving these objectives is by reducing the mass of automobiles. In addition to reducing the size of automobiles, mass can be saved by substituting higher strength steels and aluminum alloys for the traditional low-carbon steels.

The objective of the CANMET automotive materials project is to contribute to the technological development of more formable, higher strength materials and, at the same time, to mitigate corrosion caused by road salt de-icers.

CANMET continued investigations on the potential use of high-strength low-alloy steels (HSLA) in automobile construction. During the year mechanical and metallurgical properties of these dual-phase (HSLA) steels were evaluated. The steels have been made to compositional limits characteristic of hot rolled dual-phase steels responsive to batch annealing - the least capital intensive means of producing dual-phase steels in existing steel plants. Good properties are attainable by this route if certain narrow compositional limits and annealing conditions are observed. Industrially, these limits are undesirably restrictive. Further work is required to overcome these technological hurdles and to develop a viable dual-phase sheet steel necessary to maintain Canada's competitive position in the North American automotive market.



Equipment for assessing susceptibility of dual-phase and line-pipe steels to stress-corrosion cracking

The corrosion resistance of a number of sheet materials were compared in under-car and accelerated laboratory testing. After exposure to one Ottawa winter in under-car tests, sheet coupons of aluminum and galvanized steel showed markedly superior corrosion resistance compared with those for low-carbon and HSLA steels. Good correlation was obtained for HSLA steels between the results of under-car tests and the CANMET developed laboratory "dip-and-dry" accelerated corrosion test. In addition, laboratory simulative testwork was initiated to determine the effects of polyphosphate corrosion inhibitors on the corrosion rates of various steels.

The increasing importance of mineral and energy resources of the off-shore and Arctic regions of Canada raises questions about fabrication and in-service performance of materials to be used in the transportation systems that will be required to deliver such resources to southern Canada and the rest of the world. CANMET's objective in the marine materials project is to contribute to the development of technology required for the production and fabrication in Canada of materials resistant to brittle fracture and bare hull corrosion under conditions encountered in Arctic marine service.

In this first year of the project, work commenced on the weld-related corrosion of hulls in icebreakers and on characterzation of ship-plate materials for Arctic use. Two distinct forms of corrosion have been identified - loss of weld metal and loss of metal from the heat-affected zone. Studies of the factors contributing to corrosion in these regions are currently under way. The mechanical properties of fractured hull plate from two older icebreakers and of undamaged plate from the new Dome Petroleum icebreaker are being investigated. Preliminary results indicate that grade EH-36 plate used in the new Dome ship, has significantly superior toughness properties than the hull plate of the two older Coast Guard icebreakers. Work on this phase is continuing.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

Authorization and Testing

Under the Canada Explosives Act, the Canadian Explosives Research Laboratory (CERL) carries out authorization tests and provides technical advice to the Chief Inspector of explosives. These re-

sponsibilities have continued to increase because of technical advances in formulation, Canada's international responsibilities as a major explosives producer, and critical reactions of the public to accidental explosions.

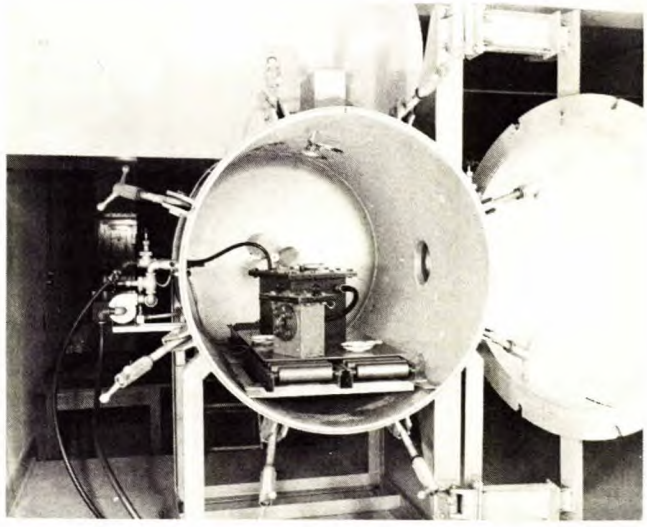
During 1978, approximately 238 samples of new explosives were tested and reports written covering chemical analysis, hazard sensitivity tests such as friction and impact, performance sensitivity tests such as velocity of detonation, and power and chemical stability. Samples submitted ranged from family and display fireworks to high explosives used in mining and civil engineering. The dramatic decrease in the number of new explosives tested (238 versus 425 in 1978) is attributed mainly to the fact that in the domestic market Canadian explosives are now competitive with those of American origin resulting in only Canadian explosives being offered for authorization.

There were no major accidents in explosives manufacturing during the year. Investigations continued into the cause of a fatal explosion in a pyrotechnic factory in 1977. Some 100 pyrotechnic compositions were examined but none was found to be unduly hazardous in manufacturing or handling. A viable cause for the explosion was narrowed to ignition of dust clouds. To minimize the potential recurrence of similar accidents, new mixing machines have been developed that drastically reduce dust production during blending. These machines are currently undergoing testing.

As the third largest producer of commercial explosives in the world, Canada is playing a correspondingly significant role in the establishment of a new uniform international explosives classification system sponsored by the United Nations Group of Experts on Explosives. A delegate from CERL participated in the informal working group in London that recently negotiated a concensus on a new classification system based on hazard ratings rather than on chemical similarities. The choice of tests is a matter of prime importance, consequently Canada's delegation has been increased from two to five, made-up of three members from EMR and two from industry. One result of this involvement is expected to be CERL's participation in international cooperative tests to assign specifications for the new UN classification. This will be a major addition to CERL's workload for some years.

Research and Development

Ammonium nitrate, used in large quantities as a fertilizer, is known to possess explosive properties. Since World War I, some six large-scale disasters have occurred involving ammonium nitrate with little so far known of the way in which they were initiated. The tendency has been to assume that ammonium nitrate's explosion hazard is associated with its shock sensitivity. These assumptions could hinder Canada's competitiveness in the international fertilizer market as Canada produces large quantities of the shock sensitive form.



An explosion chamber at the Canadian Explosive Atmospheres Laboratory is employed to certify equipment for use in potentially explosive mine atmospheres

A three-year contract investigation was recently completed on the explosion hazards of ammonium nitrate, the work being sponsored jointly by the Canadian fertilizer industry and the Canadian government, and performed by Queen's University. This study indicated that virtually all ammonium nitrate disasters occurred during accidental fires. Such fires burning for a considerable period in bulk materials are known to produce large pools of molten substance. These molten pools could then be detonated by rapid decomposition or by impact. This detonation mechanism is currently under investigation. Thus, the production of a pool of ammonium nitrate is a prerequisite for an explosion, and whether or not nitrate was of high or low shock sensitivity has no bearing on the hazards arising from the pool. As a result, the sensitive brands of Canadian ammonium nitrate are no more hazardous than other brands.

A new and important step in explosives technology has been the development of explosives which are liquids or, as in the case of slurry explosives, have a continuous liquid phase. The explosion of a slurry manufacturing plant in 1975 and of a tank car containing a slurry sensitizing solution in 1974 provided evidence that too little was known about explosion initiation in bulk quantities of liquid explosives. For the foreseeable future, the main thrust of R & D work at CERL will be to provide a better understanding of the processes as from ignition to explosion and particularly in liquid, gel and slurry explosives.

MINERAL AND ENERGY TECHNOLOGY INFORMATION

Through research publication, seminars, technical advice to policy makers, assistance to industry with technological problems in extracting, processing and utilizing mineral and energy resources, through assessing and creating significant information resources, and making them readily available to the Canadian public, CANMET in 1979/80 continued to make important contributions to the economic well-being of Canada. The Technology Information Division, (TID) in collaboration with the research staff contributed to this objective specifically by:

(1) selecting, acquiring and organizing relevant information resources required to support in-house research, and by acting as the national resource centre for world-wide literature in mineral and energy technology;

(2) preparing machine-readable abstracts and indexes on various aspects of mineral and energy technology to supplement existing commercial abstracting and indexing services;

(3) disseminating technical information through editing, transcribing, publishing and distributing research reports by CANMET scientists or private sector researchers working on CANMET-sponsored projects;

(4) disseminating technical information and providing technical advice to policy makers, scientists and engineers in government, industry and the universities on mineral and energy technology through its inquiry response and referral service.

Information Resources Development

As part of the national science-technology information network, CANMET has a special responsibility to maintain an information resource collection in mineral and energy technology, not only to meet the demands of CANMET's research scientists, but also to respond to the information needs of scientists, technologists and decision makers throughout Canada.

Towards this goal, the library acquired 2226 new monographs, conference proceedings, technical reports, etc., and more than 7500 research reports on microfiche. Thirty-seven new periodicals were added to the subscription list for a total of 2136 technical journals providing world-wide coverage of research and development in mining, mineral processing, metallurgy and fossil-fuel energy technology. Current inventory of the technology information base stands at 177 406 items.

Information Processing

The library's Cataloguing and Classification Unit processed and entered 1292 new items. Plans are well advanced to introduce computer-assisted cataloguing in 1980/81 with an expected increase in productivity through sharing of common data with other libraries using the same UTLAS system.

The Mining Technology Information File (MINTEC), publicly accessible through QL Systems since July 1979, was augmented by 1631 items. Significant inroads were made to convert to machine readable form components of this file created prior to 1973. These records, numbering about 6000 will be added to the on-line file during 1980/81.

Public reaction to the on-line availability of MINTEC has been most favourable. Use of the file by researchers throughout Canada has been increasing every month and several data base vendors outside Canada have shown interest in acquiring it for distribution on their systems.

Conversion preparation for on-line implementation of the Mineral Processing Technology File (MINPROC) received considerable attention during the year and despite some unforeseen difficulties, it is expected to become accessible to the public in 1980/81, commencing with approximately 3000 records.

Contributions of Canadian material to the International Energy Agency's (IEA) Coal Technology Data Base were maintained at the target level; 325 new records of Canadian origin were added. Preliminary work on this database containing about 25 000 items on recent world coal research and development is complete and on-line implementation in Canada is expected before the end of 1980.

A joint study with CISTI has been undertaken to determine feasibility of a cooperative Canadian Energy Data Base. Discussions were held with potential contributors from across the country and results indicate good potential and considerable interest. Further study and discussions are planned for 1980/81 and a final report to senior management is expected late in 1980.

Information Dissemination

Reports describing CANMET research and development in 1979/80 numbered 515, including 15 contract reports. A large number of contract reports were received too late for processing before the end of the year but will be reported in 1980/81. Details on the type of reports produced are provided in Table 1.

To deal with the heavy demand for CANMET publications resulting from wider publicity, arrangements were made with a private company to distribute copies of all new CANMET publications not normally handled by Supply and Services Canada. The company offers CANMET publications in traditional print or microfiche formats, providing speedy response and distribution services that would be difficult to match with available in-house resources. The service is proving popular with the public, and provides a greater awareness of CANMET contributions to technology far beyond that possible through CANMET's distribution facilities.

Substantial progress was made in gathering some 6000 pre-1975 CANMET publications for microfilming. Target for public access to microfilm sets and a printed index to these older but useful publications is late 1981.

The Technical Inquiries Section serviced a total of 106 current awareness profiles; 65 of these were based on databases provided by commercial vendors and 41 on CANMET's own MINTEC file. As part of this service, the library circulated more than 47 000 copies of current issues of scientific and technical journals to CANMET staff.

Over-the-counter loans from the library to EMR staff continued at close to 24 000; loans to other government departments and to industry, and academic libraries totalled 4968.

The technical information service provided by CANMET through its Technology Information Division handled 2443 major inquiries relating to CANMET's areas of expertise. A break-down by field and source of inquiry is provided in Table 2. The more than 25 per cent increase in inquiries over the previous year clearly indicates the need, wide acceptance and growing awareness of this service.

In addition to the more formal information dissemination activities of TID, CANMET scientists and engineers provided advice and technical information relating to their own fields of expertise to various personnel in 495 companies, of which 411 were Canadian-based and 84 in other countries around the world. Information and advice was requested from and supplied to 181 government departments and agencies, and 60 educational institutions, bringing the total techical inquiries responded to by CANMET staff in 1979-80 to well over 5000.

In other activities designed to exchange and disseminate technology information, CANMET research staff participated in more than 85 conferences, and contributed to mineral and energy technology development through participation in national and international technical committees.

Exchange of publications with international agencies, is a significant means of providing knowledge of Canadian expertise and development abroad, as well as an important source of difficult-to-obtain information. The practice has been continued and slightly expanded by the addition of new exchange partners from Mexico, South Korea and Poland.

In addition to the coal documentation already mentioned, TID, as the Canadian operating agents of IEA's Coal Technology Information Service (CTIS) and the Mining Technology Clearing House (MTCH) continued to gather information on coal research and development in Canada, distribute IEA publications on coal science and technology to interested parties in Canada, and to act as the intermediary between suppliers and users of coal information.

Table 1 - CANMET publications by category and source, 1979-80

Category	MSL	ERL	MRL	PMRL	RPO	MRP	ERP	ADM	TID	Total
CANMET Reports	22	8	5	3	2				4	44
Presentations and journal submissions	44	9	21	21					9	104
Unclassified, limited external distribution	72	20	74	29					8	203
Unclassified, internal distribution	29	-	15	19					4	67
Confidential	8	27	10	37						82
Contract reports					15					15
Total	175	64	125	109	17				25	515

Number of confidential reports declassified - 95

Table 2 - Inquiries processed by TID staff by subject and origin, 1979-80

	Within Canada						Outside Canada				Total	
	CANMET	Other EMR	Other Government	Educational Institutions	Industry	Other	Government	Educational Institutions	Industry	Other	No.	%
Mining	142	39	153	103	265	72	8	14	54	29	879	35
Min Proc	176	16	38	34	141	36	14	13	26	9	503	21
Metallurgy	175	7	30	11	106	15	3	5	11	5	368	15
Energy	71	17	61	36	32	75	4	2	7	7	312	13
Coal	58	22	62	21	63	27	14	9	10	8	295	12
General	45	7	13	2	11	5	-	2	1	-	86	4
Totals: No.	667	108	357	207	618	230	43	45	109	58	2442	
%	28	4	15	8	26	9	2	2	4	2		100
Total within Canada											2187	90
Total outside Canada											254	10

APPENDIX A

CANMET PROFESSIONAL STAFF

DIRECTOR-GENERAL'S OFFICE

D.F. Coates; B.Eng., M.Eng., Ph.D. (McGill), B.A., M.A. (Oxford); D.Sc. (h.c.) (Carleton); F.R.S.C.; Director-General
V.A. Haw; B.Sc., M.Sc. (Queen's); Deputy Director-General

RESEARCH PROGRAM OFFICE

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LIBRARY

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J. Ho; B.A., B.L.S. (Ottawa); Librarian
K. Nagy; B.Sc., B.L.S. (McGill); Librarian
I. Weniger; B.A., M.L.S. (Western); Librarian

TECHNICAL INQUIRIES

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L.G. Hicks; B.Sc. (Memorial), B.Sc. (Queen's); Min. Info. Off.
A.A. Ignatow; B.Sc., M.Sc. (McGill); Min. Proc. Info. Off.
A.L. Job; A.C.S.M. (Eng.), C.Eng.; Min. Info. Off.
B.E. Lawton; B.Sc. (Queen's), P.Eng.; Coal Info. Off.
R.J.C. MacDonald; B.Sc. (St. Francis Xavier); Min. Proc. Info. Off.
I. Slowikowski; M.A. (Ottawa), D.D.S. (Beirut); Eastern European Tech. Spec.
G.W. Taylor; B.Sc. (Queen's); Energy Info. Off.

PUBLICATIONS

C. Mamen; B.Eng. (McGill), Eng.; Section Head, Editor
J. Collins-Decotret; B.A. (Ottawa); Ed. Asst. (French)

TECHNICAL SERVICES DIVISION

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ENERGY CONSERVATION

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ENGINEERING DESIGN AND PROJECT MONITORING

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QUALITY ASSURANCE

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ANALYTICAL AND EVALUATION SERVICES

Solid Fuels Analyses and Standardization

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Coal Treatment

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Petrology

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COAL AND PEAT RESOURCES

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Coal and Coke Constitution

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Metallurgical Processes

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Gasification

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SPECTROCHEMISTRY

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SPECIAL ANALYSES

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PHYSICAL CHEMISTRY

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V.H. Rolko; B.Sc. (Manitoba); Chemist

INDUSTRIAL MINERALS LABORATORY

G.W. Riley; A.C.S.M. (Camborne School of Mines), P.Eng.; Manager

CONSTRUCTION MATERIALS

V.M. Malhotra; B.Sc., B.E. (W. Australia); Res. Sci.
H.S. Wilson; B.E. (Sask.); Res. Sci.
E.E. Berry; C.Chem., MRIC, Ph.D. (Surrey); Res. Sci.
G.G. Carette; B.Sc. (Laval); Engineer

NON-METALLIC AND WASTE MINERALS

R.K. Collings; Eng. Dipl., B.E. (N.S.T.C.), P.Eng.; Res. Sci.
A.A. Winer; B.A.Sc. (Toronto), P.Eng.; Res. Sci.
S.S. Wang; B.Sc. (Hong Kong Baptist), M.Sc. (U. of California), Ph.D. (Toronto); Phys. Sci.

ORE MINERALOGY

R.M. Buchanan; B.A., M.A. (Toronto); Phys. Sci.
J.A. Soles; B.A.Sc., M.A.Sc., Ph.D. (McGill), P. Eng.; Res. Sci.
R.S. Dean; B.Sc., M.Sc., Ph.D. (McGill), P.Eng.; Res. Sci.

*Retired 12/27/79

CERAMICS

K.E. Bell; B.E. (Sask.), P.Eng.; Res. Sci.
T.A. Wheat; Ph.D. (Leeds); Res. Sci.
D.H.H. Quon; B.Sc. (National Sun Yat Sen U.), M.Sc. (Ohio U.), Ph.D. (Michigan U.); Res. Sci.
D.J. Green; B.Sc. (Liverpool), M.Sc., Ph.D. (McMaster); Res. Sci.
V.V. Mirkovich; Dipl. Eng. (Zagreb); Ph.D. (Toronto); Res. Sci.
T.B. Weston*; B.A. (Toronto); Res. Sci.

PHYSICAL METALLURGY RESEARCH LABORATORIES

W.H. Erickson; B.Sc. (Mich. Tech.), Ph.D. (Durham), P.Eng.; Chief of Laboratories

METAL PROCESSING LABORATORY

J.T. Jubb; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Manager

FOUNDRY

R.K. Buhr; B.Eng. (McGill); Res. Sci.
K.G. Davis; B.Sc., M.A.Sc., Ph.D. (UBC); Res. Sci.
B. Lagowski; B.Sc., M.Sc. (Polish Univ. London); Res. Sci.
E.I. Szabo; M.Sc., Ph.D. (Nottingham); Res. Sci.
R.D. Warda; B.A. Sc. (UBC), Ph.D. (Cambridge); Res. Sci.
L. Whiting; B.Sc., M.Sc., Ph.D. (McGill), MBA (Ottawa); Res. Sci.
J.L. Dion, B.A.Sc. (Montreal) P. Eng.; Phy. Sci.

METAL FORMING

A.F. Crawley; B.Sc., Ph.D. (Glasgow); Res. Sci.
W.A. Pollard; B.Sc., A.R.S.M. (London) P. Eng.; Res. Sci.
G.E. Ruddle; B.A.Sc., M.Sc. (Waterloo), D.Sc. (Virginia) P.Eng.; Res. Sci.
H.M. Skelly; B.Sc., Ph.D. (Glasgow), F.R.I.C., F.I.M.; Res. Sci.

NONDESTRUCTIVE TESTING

V.L. Caron; B.A.Sc. (Laval), M.Eng. (Paris); Phys. Sci.
J. Gordine; B.Sc., Ph.D. (Leeds); Res. Sci.

WELDING

J.T. McGrath; B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.; Res. Sci.
Z. Paley; B.Sc., M.Sc. (Haifa), Ph.D. (McGill); Res. Sci.

METAL DEVELOPMENT LABORATORY

D.W.G. White; S.M., Sc.D. (M.I.T.); Manager

*Retired 12/17/79

CORROSION SCIENCE

R.J. Brigham; B.Sc., Ph.D. (McGill); Res. Sci.
G.J. Biefer; B.Sc., Ph.D. (McGill); Res. Sci.
J.B. Gilmour; B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.; Res. Sci.
G.R. Hoey; Sc., M.Sc., Ph.D. (Toronto); Res. Sci.
A.W. Lui; B.Sc., M.A.Sc., Ph.D. (Windsor); Res. Sci.
R.D. McDonald; B.Sc., (Queen's); Res. Sci.
W.R. Revie; B.Eng. (McGill), M.Eng. (R.P.I.), Ph.D. (M.I.T.); Res. Sci.
J.C. Saiddington; Chem. Eng., M.A.Sc. (Toronto); Res. Sci.
V.S. Sastri; B.Sc., M.A., Ph.D. (New York); Res. Sci.

ENGINEERING AND METAL PHYSICS

A.J. Williams; B.Sc., M.Sc., Ph.D. (Birmingham), P.Eng.; Res. Sci.
L.P. Trudeau; B.A.Sc., M.A. (Toronto); Res. Sci.
O. Vosikovsky; B.A.Sc., Ph.D. (Prague); Res. Sci.
K.C. Wang; B.A. Sc., Ph.D. (Rensselaer); Res. Sci
P.J. Todkill; B.A.Sc. (Toronto); Engineer
J. Harbec; B.Eng. (McGill), P.Eng.; Phys. Sci.
E.J. Cousineau; B.Sc. (Carleton); Phys. Sci.
K.S. Milliken; B.Sc. (Queen's); Res. Sci.
C.M. Mitchell; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
J. Ng-Yelim; B.A. (Carleton), B.Sc. (Ottawa); Phys. Sci.
R.H. Packwood; B.Sc., Ph.D. (Birmingham); Res. Sci.
E. Smith; M.A., Ph.D. (Cambridge); Res. Sci.
W.R. Tyson; B.A.Sc. (Toronto), Ph.D. (Cambridge); Res. Sci.

METALLURGY

J.D. Boyd; B.A.Sc. (Toronto), Ph.D. (Cambridge); Res. Sci.
D.R. Bell; B.Eng. (McGill); Res. Sci.
D.M. Fegredo; B.Sc., M.Sc., Dipl., I.I.Sc., Ph.D. (Sheffield), A.I.M.; Res. Sci.
M.J. Godden; B.Met., Ph.D. (Sheffield); Res. Sci.
R.F. Knight; B.Sc., M.Sc. (Queen's); Res. Sci.
D.C. Briggs; B.Eng., M.Eng. (McGill) Ph.D. (Queen's); Res. Sci.
A. Couture; B.A., B.A.Sc. (Laval), P.Eng.; Res. Sci.
I. Ogle; B.Sc., Ph.D. (British Columbia); Res. Sci.
M. Sahoo; B.Sc., B.E. (I.I.Sc., Bangalore) Ph.D. (British Columbia), P.Eng.; Res. Sci.
M.J. Lavigne; B.A., B.A.Sc., Ph.D. (Laval); Res. Sci.
D.E. Parsons; B.A.Sc. (Toronto); Res. Sci.
W.R. Tyson; B.A.Sc. (Toronto), Ph.D. (Cambridge); Res. Sci.
L.N. Pussegoda; B.Sc. (Eng.), (Ceylon), Ph.D. (Canterbury, N.Z.); PDF
M.T. Shehata; B.Eng. (Cairo), Ph.D. (McMaster); Res. Sci.

CANMET STAFF AS OF MARCH 31, 1980

Division	Professionals	Non-professionals	Total
Administration and Central Services	4	84	88
Research Program Office	9	3	12
Energy Research Laboratories	61	77	138
Mining Research Laboratories	44	39	83
Mineral Sciences Laboratories	88	99	187
Physical Metallurgy Research Laboratories	45	75	120
Technology Information Division	14	19	33
Totals	265	396	661

APPENDIX B

CANMET REPRESENTATION ON TECHNICAL COMMITTEES 1978-79

INTERNATIONAL

BRITISH FLAME RESEARCH COMMITTEE (member)	G.K. Lee (ERL)
CANADA/SOVIET MIXED COMMISSION FOR COOPERATION IN THE INDUSTRIAL APPLICATION OF SCIENCE AND TECHNOLOGY	
Non-Ferrous Metals Industry Working Group (chairman)	V.A. Haw (DGO)
EXTEST (regional representative)	J.A. Darling (MRL)
INSTITUTE OF BRIQUETTING AND AGGLOMERATION	
Executive Committee (member)	T.E. Tibbetts (ERL)
Proceedings Committee (member)	T.E. Tibbetts (ERL)
Program and Papers Committee (member)	T.E. Tibbetts (ERL)
INTERNATIONAL ATOMIC ENERGY AGENCY	
Advisory Group Division of Nuclear Safety and Environmental Protection (member)	M. Gyenge (MRL)
INTERNATIONAL COMMITTEE ON COAL PETROGRAPHY	
Petrography (working member)	B.N. Nandi (ERL)
Petrography of Organic Sediments (member)	B.N. Nandi (ERL)
Subcommittee on Industrial Applications of Coal Petrology (member)	B.N. Nandi (ERL)
INTERNATIONAL COMMITTEE FOR COAL RESEARCH (member)	D.A. Reeve (RPO)
INTERNATIONAL COMMITTEE FOR SOLVENT EXTRACTION TECHNOLOGY (member)	G.M. Ritcey (MSL)
INTERNATIONAL CONFERENCE ON THERMAL CONDUCTIVITY CONFERENCES	
(director)	V.V. Mirkovich (MSL)
INTERNATIONAL ELECTROTECHNICAL COMMISSION	
Committee 31, Electrical Apparatus for Explosive Atmospheres (chairman)	J.A. Bossert (MRL)
Subcommittee 31A, Flameproof Enclosures (chairman)	J.A. Bossert (MRL)
INTERNATIONAL ENERGY AGENCY	
Coal Services	
Mining Technology Clearing House	
Executive Committee (member)	D.A. Reeve (RPO)
Hydrotransport Subcommittee	L. Geller (MRL)

AFFILIATION KEY:

DGO	Director-General's Office	MSL	Mineral Sciences Laboratories
ERL	Energy Research Laboratories	PMRL	Physical Metallurgy Research Laboratories
MRL	Mining Research Laboratories	RPO	Research Program Office
		TID	Technology Information Division

Technical Information Service
Executive Committee (member) ..... D.A. Reeve (RPO)
Technical Committee (member) ..... J.E. Kanasy (TID)

Annex VI (Photocatalytic Water Electrolysis) of the Implementing Agreement for a Program of Research and Development on the Production of Hydrogen from Water
(Canadian Technical Contact Person) ..... S.M. Ahmed (MSL)

INTERNATIONAL FLAME RESEARCH FOUNDATION

Aerodynamics Panel (member) ..... H. Whaley (ERL)
Flame Chemistry Panel (member) ..... E.J. Anthony (ERL)

INTERNATIONAL INSTITUTE OF WELDING

Canadian Council (member) ..... J.T. McGrath (PMRL)
Commission X, Residual Stress, Stress Relieving Brittle Fracture (chairman) ..... J.T. McGrath (PMRL)

INTERNATIONAL JOURNAL OF HYDROMETALLURGY (editor) ..... G.M. Ritcey (MSL)
Editorial Board (members) ..... D.J. MacKinnon (MSL)
..... G.M. Ritcey (MSL)
International Solvent Extraction 80 Committee (member) ..... G.M. Ritcey (MSL)

INTERNATIONAL JOURNAL OF PRESSURE VESSEL AND PIPING
Editorial Board (member) ..... J.T. McGrath (PMRL)

INTERNATIONAL MINERAL PROCESSING CONGRESS

International Scientific Committee (member) ..... L.L. Sirois (MSL)
Organizing committee (member) ..... M.C. Campbell (MSL)

INTERNATIONAL MINE VENTILATION CONGRESS (member) ..... G. Knight (MRL)

INTERNATIONAL MINERALOGICAL ASSOCIATION

Commission on New Minerals and Mineral Names
(Canadian representative) ..... D.C. Harris (MSL)
Commission of Ore Microscopy (Canadian representative) ..... L.J. Cabri (MSL)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

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CERTICO, Certification (member) ..... J.A. Bossert (MRL)
REMCO, Reference Materials (chairman) ..... R.L. Cunningham (MSL)
(member) ..... G.H. Faye (MSL)
TC17/SC1, Analysis of Steel and Cast Iron (member) ..... R.G. Sabourin (MSL)
SC4, Heat Treated Alloy and Free-Cutting Steels (members) ..... R.K. Buhr (PMRL)
..... D.E. Parsons (PMRL)
SC6, Methods of Mechanical Testing (chairman) ..... D.E. Parsons (PMRL)
SC7, Test Methods other than Mechanical (member) ..... D.E. Parsons (PMRL)
SC11, Steel Castings (secretary) ..... D.E. Parsons (PMRL)
SC15, Rail Steels (member) ..... D.E. Parsons (PMRL)
TC18/SC1, Zinc and Zinc Alloys (member) ..... C.H. McMaster (MSL)
TC24, Sieves, Sieving and other Sizing Methods (member) ..... G.W. Riley (MSL)
TC25, Cast Iron (member) ..... R.K. Buhr (PMRL)
TC26, Copper and Copper Alloys (chairman) ..... J.O. Edwards (PMRL)
SC1, Analysis of Copper and Copper Alloys (members) ..... C.H. McMaster (MSL)
..... R.G. Sabourin (MSL)
SC3, Cast Copper Alloys (member) ..... J.O. Edwards (PMRL)
WG5, Terminology ..... J.O. Edwards (PMRL)
TC27, Solid Mineral Fuels (chairman) ..... W.J. Montgomery (ERL)
SC1, Coal Preparation ..... J.L. Picard (ERL)
SC2, Brown Coals & Lignites (member) ..... W.J. Montgomery (ERL)
SC3, Coke (member) ..... J.C. Botham (ERL)
WG6, Evaluation of Flocculants for use in Coal Preparation (convenor) ..... H.A. Hamza (ERL)

WG9, Grindability (member)	W.J. Montgomery (ERL)
WG12, Plasticity (member)	J.C. Botham (ERL)
WG13, Ash Analysis (secretariat)	W.J. Montgomery (ERL)
TC33/WG3, Refractories (member)	K.E. Bell (MSL)
TC47, Chemistry (member)	C.H. McMaster (MSL)
TC56, Mica (chairman)	G.W. Riley (MSL)
TC69, Application of Statistics (member)	R. Sutarno (MSL)
TC71, Concrete (chairman)	V.M. Malhotra (MSL)
TC77, Asbestos (member)	A.A. Winer (MSL)
TC79, Light Metals and their Alloys (member)	P.J. Todkill (PMRL)
SC1, Light Metals and their Alloys (member)	C.H. McMaster (MSL)
TC82, Mining (chairman)	R. Welwood (MRL)
(member)	A.L. Job (TID)
TC102, Iron Ores (member)	R. Sutarno (MSL)
SC1, Sampling (chairman)	R. Sutarno (MSL)
SC2, Chemical Analysis (chairman)	R. Sutarno (MSL)
WG7, Statistics (chairman)	R. Sutarno (MSL)
SC3, Physical Testing of Iron Ores (chairman)	J.T. Price (ERL)
SC4, Size Determination, Iron Ores (chairman)	G.W. Riley (MSL)
TC107/SC6, Metallic and other Non-organic Coatings (member)	K.E. Bell (MSL)
TC111/SC1, Chain (member)	R.K. Buhr (PMRL)
SC4, Materials for Chain (chairman)	R.K. Buhr (PMRL)
TC119, Testing of Powder Metallurgical Materials and Products (member)	H.M. Skelly (PMRL)
TC129/SC2, Aluminum Ores (member)	C.H. McMaster (MSL)
TC155, Nickel and Nickel Alloys (member)	M.J. Lavigne (PMRL)
SC3, Refined Nickel (member)	C.H. McMaster (MSL)
SC4, Analysis of Nickel Alloys (member)	C.H. McMaster (MSL)
TC156/WG1 Corrosion of Metals and Alloys (member)	G.J. Biefer (PMRL)
TC163/SC3, 4, Insulation (member)	A.A. Winer (MSL)
TC164, Mechanical Testing of Metals (chairman)	P.J. Todkill (PMRL)
(members)	J.T. Jubb (PMRL)
	O. Vosikovsky (PMRL)
TC166, Ceramic Ware in Contact with Food (member)	K.E. Bell (MSL)
TC175, Fluorspar Ore (member)	R.M. Buchanan (MSL)
INTERNATIONAL PEAT SOCIETY (vice-president)	T.E. Tibbetts (ERL)
Canadian National Committee (secretary-treasurer)	T.E. Tibbetts (ERL)
INTERNATIONAL SCIENTIFIC COMMITTEE OF THE INTERNATIONAL MINERAL PROCESSING CONGRESS (member)	L.L. Sirois (MSL)
Organizing Committee of the International Federation of Automation in Mining, Mineral and Metal Processing (member)	L.L. Sirois (MSL)
INTERNATIONAL SOCIETY FOR ROCK MECHANICS	
(member of Council)	D.F. Coates (DGO)
Commission on Standardization of Laboratory and Field Tests (member)	G. Herget (MRL)
INTERNATIONAL SOLVENT EXTRACTION CONFERENCE	
International Journal of Hydrometallurgy (editor)	G.M. Ritcey (MSL)
(proceedings editor)	B.H. Lucas (MSL)
Editorial Board (member)	D.J. MacKinnon (MSL)
INTERNATIONAL STANDARDS ORGANIZATION - CANADIAN ADVISORY COMMITTEE	
Committee on Certification (member)	J.A. Bossert (MRL)
Technical Committee 82-Mining (chairman)	R.J. Welwood (MRL)
INTERNATIONAL STRATA CONTROL CONFERENCE (7th) (1978)	
International Organizing Committee (members)	T.S. Cochrane (MRL)
INTERNATIONAL THERMAL CONDUCTIVITY CONFERENCE (director)	V.V. Mirkovich

INTERNATIONAL TUNNELLING ASSOCIATION

Tunnelling Office of Canada (members)	L. Geller (MRL)

INTERNATIONAL UNION OF CRYSTALLOGRAPHY

Executive Committee XIIth Congress and General Assembly (member)	K.S. Millken (MSL)

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY 28TH CONGRESS

(session chairman)	J.E. Dutrizac (MSL)

INTERNATIONAL UNION OF TESTING AND RESEARCH LABORATORIES FOR MATERIALS AND STRUCTURES

Committee 42 CEA, Early Strength Development of Concrete (member)	V.M. Malhotra (MSL)

NUCLEAR ENERGY AGENCY/INTERNATIONAL ATOMIC ENERGY AGENCY

Working Group on Uranium Extraction (vice-chairman)	M.C. Campbell (MSL)
Working Group on Uranium Mill Tailings (member)	E.G. Joe (MSL)

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT

International Group of Experts on Unstable Substances (member)	J.A. Darling (MRL)
Ammonium Nitrate Subcommittee (member)	J.A. Darling (MRL)
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WORLD MINING CONGRESS

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Organizing Committee (member)	D.F. Coates (DGO)

UNITED STATES OF AMERICA

AMERICAN CONCRETE INSTITUTE

Committee 214, Strength Evaluation (chairman)	V.M. Malhotra (MSL)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS - AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

Aerosol Technology Committee	G. Knight (MRL)

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Ductile Iron Division Research Committee (member)	R.K. Buhr (PMRL)
Editorial Board, International Cast Metals Journal (member)	R.K. Buhr (PMRL)

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Hydrometallurgy Committee (member)	G.M. Ritcey (MSL)
Hydrometallurgical Session, Denver (chairman)	G.M. Ritcey (MSL)
Metal. Trans. (key reader)	J.E. Dutrizac (MSL)

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Fuels Division Research Committee (member)	G.K. Lee (ERL)

Research Committee on Corrosion and Deposits from Combustion Gases (member)	G.K. Lee (ERL)
Task Force on Energy Conversion Research (member)	G.K. Lee (ERL)

AMERICAN SOCIETY FOR METALS

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AMERICAN SOCIETY FOR TESTING AND MATERIALS

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Task Group on Asbestos Materials (chairman)	A.A. Winer (MSL)
B-2, Non-Ferrous Metals and Alloys (member)	J.O. Edwards (PMRL)
B-5, Copper and Copper Alloys, Cast and Wrought (member)	J.O. Edwards (PMRL)
B-6, Die Cast Metals and Alloys (member)	J.O. Edwards (PMRL)
B-7, Light Metals and Alloys, Cast and Wrought (member)	J.O. Edwards (PMRL)
C-9, Concrete (secretary)	V.M. Malhotra (MSL)
C-9-02-05, Nondestructive Testing of Concrete (chairman)	V.M. Malhotra (MSL)
C-9-02-11, Accelerated Strength Testing (member)	V.M. Malhotra (MSL)
D-5, Coal and Coke (chairman)	W.J. Montgomery (ERL)
D-5-02, Nomenclature and Definitions (member)	W.J. Montgomery (ERL)
D-5-07, Physical Properties of Coal (member)	T.A. Lloyd (ERL)
D-5-15, Plasticity and Swelling (member)	J.C. Botham (ERL)
D-5-21, Methods of Analysis (member)	W.J. Montgomery (ERL)
D-5-22, Physical Testing of Coke (member)	J.C. Botham (ERL)
D-5-27, American Group ISO/TC-27 (member)	W.J. Montgomery (ERL)
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	J.G. Jorgensen (ERL)
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E-2-E-3, Merger Committee (member)	G.L. Mason (MSL)
E-2-11, Ores, Slags and Miscellaneous Materials (chairman)	G.L. Mason (MSL)
E-9, Fatigue (member)	O. Vosikovsky (PMRL)
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E-24, Fracture Testing of Metals (member)	O. Vosikovsky (PMRL)
E24-04-05, Fatigue crack growth rate testing in aqueous environments (member)	O. Vosikovsky (PMRL)
E-28, Mechanical Testing (member)	P.J. Todkill (PMRL)
E-34, Toxic and Hazardous Materials (member)	A.A. Winer (MSL)
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E-155, Magnesium Alloys (chairman)	B. Lagowski (PMRL)

INSTRUMENT SOCIETY OF AMERICA

Committee SP-12, Instruments for Use in Hazardous Locations (member)	J.A. Bossert (MRL)
Subcommittee SP-12.13, Combustible Gas Detectors (member)	G. Lobay (MRL)

MINERALOGICAL SOCIETY OF AMERICA

Nominating Committee for Fellows (chairman)	J.L. Jambor (MSL)

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Unit Committee on Inhibitors (member)	G.R. Hoey (MSL)
Unit Committee T-1F, Metallurgy of Oil Field Equipment (member)	R.W. Revie (PMRL)
Task Group T-1F-9, Metals Testing Techniques for Sulphide Corrosion Cracking (member)	G.J. Biefer (PMRL)

Task Group T-1F-20, Stepwise Cracking of Pipeline Steels (member)	R.W. Revie (PMRL)
Unit Committee T-3N, Corrosion by De-icing Salts (member)	R.D. McDonald (PMRL)

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SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS

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U.S./CANADA RESEARCH COMMITTEE ON THE LONG TRANSPORT OF AIR POLLUTANTS (member)	H. Whaley (ERL)
U.S./CANADA STEERING COMMITTEE ON ALUMINA (representative)	C. Hamer (MSL)

WELDING RESEARCH COUNCIL

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Subcommittee on Corrosion Resistance (member)	M.J. Lavigne (PMRL)
Subcommittee on Heat Resistant Alloys (member)	M.J. Lavigne (PMRL)
Weldability Committee (member)	Z. Paley (PMRL)

CANADA—FEDERAL

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CANADIAN ARMED FORCES CORROSION PREVENTION COMMITTEE

Ottawa Subcommittee (member)	J.B. Gilmour (PMRL)

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Test Methods Subcommittee (member)	E. Furimsky (ERL)
Middle Distillate Fuels Subcommittee (member)	A.C.S. Hayden (ERL)
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10-GP, Refractories (member)	K.E. Bell (MSL)
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(member)	T.E. Tibbetts (ERL)
34-GP, Asbestos Cement (member)	A.A. Winer (MSL)
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	A.C.S. Hayden (ERL)
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53-GP, Shears (member)	D.E. Parsons (PMRL)
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Cast Steel Propeller Specifications Committee (member)	D.E. Parsons (PMRL)

CANMET

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	J. Metz (TID)
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.....	P.J. Todkill (PMRL)
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