CANMET REVIEW 1980-81

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FOREWORD

Since 1901, the Canada Centre for Mineral and Energy Technology (CANMET) has carried out research and development and the transfer of information and technology to meet the needs of government, industry and the public at large.

The breadth of research in CANMET is evidenced by the accomplishments documented in this review, e.g., in the development of the CANMET hydrocracking process whereby petroleum residues may be virtually completely converted into distillate fractions, and which culminates nearly twenty years of intensive chemical and engineering investigation; new methods developed for preparing thermal coals, and improved processes for uranium recovery; the progress made in the application of sophisticated instrumentation to study behaviour of minerals during processing; advances made in the science of mining in ground control, underground environment, waste disposal and electrical and explosive certification; the significant progress made on pressure vessels, X-ray stress diffractometry, energy conservation in the metal-casting industry, and degradable sand binders.

Advances were made in the ever-increasing important need to provide demonstration-scale projects to effect technology transfer, e.g., the transfer of CANMET's hydrocracking, fluidized-bed, and coal-oil mixture processes to meet urgent industrial needs, and the continuing impetus placed on technology transfer as a major component of branch objectives.

Under the National Energy Program introduced in Parliament in October 1980, further expansion of CANMET research and development is expected in three major areas: alternatives to gasoline, increased efficiency of energy use, and new energy sources.

The significant increase in work performed by outside agencies under contract required greater interaction between CANMET and industrial and university scientists - an important adjunct of contract research activities.

CANMET's long-standing reputation for being able to adapt to changes in economic conditions and research requirements is reflected in this year's review.

W.G. Jeffery,
Director-General

INTRODUCTION

The federal Department of Energy, Mines and Resources aims to ensure the effective use of Canada's energy and mineral resources by determining the country's natural resource potential, improving resource technology, evaluating economic and social factors, formulating and implementing policy, and transferring to governments, industry and the public new technology related to energy and mineral resources.

The 1980-81 review describes various contributions by the Canada Centre for Mineral and Energy Technology to the above objectives.

In energy research, emphasis was placed on: energy sources, conservation, petroleum supply technology - oil sands mining, bitumen and heavy oil recovery; coal technology; nuclear energy - processing, waste disposal; materials for heavy water plants; and renewable energy resources.

In the minerals sector CANMET scientists were involved in technical evaluation of mineral resources, technology development in mining, health and safety in mines, marginal mineral resources, mineral and metals processing, conservation of minerals and metals, environmental and materials development technologies, technology for the metal-casting industry, and administration of the Canada Explosives Act.

CANMET operates under a matrix management system whereby its Program Office interacts with line managers in planning, controlling and evaluating projects. Therefore, this review is organized according to program structure rather than functional units, thus bringing together related research activities of the branch's various laboratories: Energy Research Laboratories, Mining Research Laboratories, Mineral Sciences Laboratories and Physical Metallurgy Research Laboratories.

CANMET MANAGEMENT 1980-81

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Mining Research Laboratories ..... T.S. Cochrane
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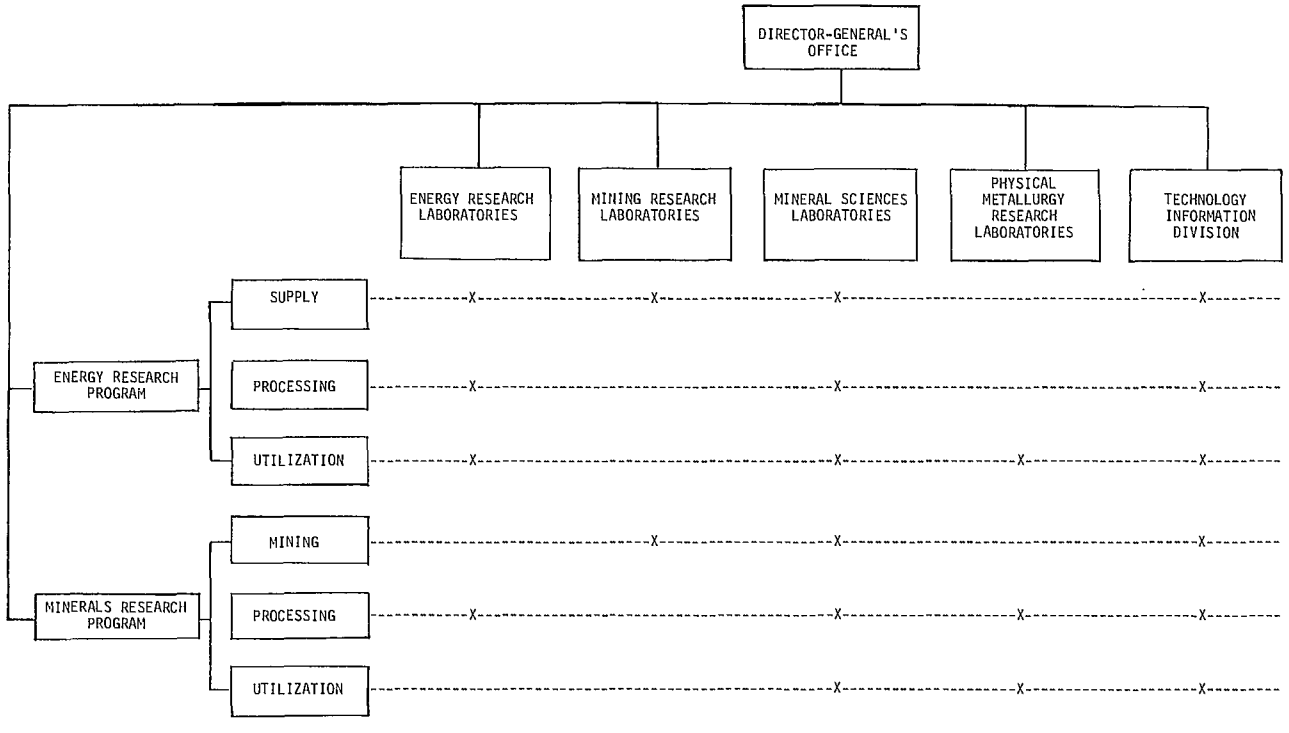
Technology Information Division ..... J.E. Kanasy



*See Appendix A

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ENERGY RESEARCH PROGRAM

Energy research and development at CANMET deals mainly with the abundant fossil and nuclear fuel resources available in Canada. The expertise CANMET has built through its many years of research in these areas is also being extended to new activities needed to reduce the national reliance on oil; wood combustion and materials for energy storage and conversion systems being just two examples.

Further expansion of CANMET Energy R & D is expected under the National Energy Program, which was introduced in Parliament in October 1980. Research and development is an important element of the program. Three priorities have been explicitly identified: alternatives to gasoline, increased efficiency of energy use, and new energy sources. Based on its expertise, CANMET has a role to play in all these areas by doing research, by sponsoring research, and by providing a technical advisory service. Of particular significance will be a general expansion of coal related R & D, a field that has been one of CANMET's great strengths.

The review that follows describes the activities and achievements of fiscal year 1980-81. The Research Program has operated under two departmental activities: Energy Sources (Supply, Demand and Substitution), and Energy Research and Technology Development. As CANMET is an applied research organization, by far the greater effort is directed at the latter. However, CANMET continues to provide essential information needed for accurate assessment of our resource base in uranium, coal, peat and low-grade petroleum.

A number of planning principles and trends will be evident from a reading of the review. In the framework of the Resources and Technical Surveys Act (RS 1970-72), it is assumed that government sponsored R & D should be accessible to all Canadians and be undertaken to ensure the widest possible dispersion of its benefits. Consistent with this assumption, CANMET adopts the stance of a public sector agency with a mission to provide R & D under circumstances where the private sector cannot be expected to perform the socially-required services. This principle is fundamental to energy R & D planning at CANMET.

One result of this approach is that work under the Energy Research and Technology Development Activity focuses on those specific technologies essential to Canada in maintaining long-term energy independence and thereby influencing, in a critical way, the economic well-being of the country. The research strategy is based on established notions of economic efficiency and environmental protection. It is recognized that public R & D should be conducted only where technology is an effective instrument in addressing a particular energy issue relative to non-technological policies. The essential relationship between private enterprise and public sector management should be maintained, and the least-cost principle should guide the selection of technologies to avoid waste and maximize net benefits.

The review describes research on a variety of scales and in a variety of settings. The projects are selected to be complementary and, in sum, to represent as comprehensive an effort as possible to meet the essential future energy needs of the nation. This includes non-discretionary elements or elements which help maintain a core science program. For example, a sophisticated capability for chemical analysis, while often in the background and providing benefits which may not be obvious to the casual observer, is an indispensable tool for applied research. It will become even more important in identifying processing problems and measuring product quality as we turn to alternative and lower-grade energy resources.

At the other end of the spectrum, the review indicates the increased importance of demonstration-scale projects in transferring technology and developing industrial capability to meet urgent needs. Major demonstration projects are under way in fluidized-bed and coal-oil mixture combustion. Petro-Canada, with R & D support from CANMET, is taking CANMET's hydrocracking process to the demonstration scale. Contracting-out programs in coal conversion have reached the stage where decisions can be made on moving selected technologies to the larger scale. CANMET experts also act as technical advisors on demonstration projects coordinated by other government agencies, such as those in conservation and renewable energy.

The importance of public and private sector co-operation through mechanisms such as contracting-out, cost sharing and joint projects is increasingly evident. Currently, 27% of the Energy Program expenditures are on contracts. CANMET is also playing a growing role in international activities such as those of the International Energy Agency.

ENERGY SOURCES: SUPPLY, DEMAND AND SUBSTITUTION

The energy resources of Canada are vast but making best use of these resources requires that their location, quantity and quality be accurately assessed. Beginning with resource data derived from geological surveys and exploration programs, CANMET participates in this interdisciplinary assessment effort by seeking answers to questions such as: What is the exact composition of the material? Can it be mined or otherwise recovered using proven technology? What are the characteristics of the material that influence its processing and marketing? Branch scientists then cooperate with departmental resource economists to estimate reserves, a subset of resources that takes into account detailed technical and economic criteria.

The main concern of CANMET, then, is with the quality of indigenous resources of low-grade petroleum materials, coal, peat and uranium. The information generated helps identify research directions for optimum extraction, processing and utilization of these resources, as well as guiding decision makers in the formulation of development policies. The emphasis is on low-grade resources, which could be our mainstay in the future, but which create special challenges for the technologist.

Resource Assessment of Petroleum-related Materials

The extensive oil-sand and heavy-oil deposits of Western Canada are major potential sources of supply for the most pressing energy supply problem - liquid transportation fuels. Assessments carried out by CANMET involve characterization of both fossil and matrix materials of feedstocks for liquid fuels extraction. Some of the work falls under the Canada/U.S.A. agreement on cooperative oil sands research.

The resource characterization work is linked to the CANMET hydrocracking process and is described more fully later in this review. Examples of the research are determination of the levels of aromatic hydrocarbons and other constituents in bitumen and heavy oils. Development of analytical procedures is a key element of the work. Scientists have also begun a study under contract to identify the potential of Canadian oil shales as sources of liquid fuels using hydroretorting technology.

The oil and gas analytical laboratory performed some 18 300 determinations on 3700 gaseous, liquid and solid samples, an increase of almost 15% in output over the previous year. Most of the analyses are on samples from CANMET's own research. However, the branch also provides a cost-recovery service to federal and provincial government agencies, crown corporations, and other organizations, as well as participating in the standardization programs of the Canadian General Standards Board.

Coal and Peat Resources and Reserves

Canada's coal and peat resources are extensive, but because they are such highly variable substances extensive studies are required to determine the quality of individual deposits. Growing domestic and export markets for coal are adding urgency to the need to know more about these resources.

With publication of the department's updated assessment of coal reserves and resources in 1979, CANMET's efforts to apply mineability criteria to resource data for establishing coal reserves was de-emphasized in 1980. However, the branch continued to gather data on reserve assessment criteria from major coal projects in Alberta and British Columbia. These criteria, as applied by coal-producing companies, were documented in a report. A similar report from the coal developers' viewpoint is being prepared.

Scientists also continued their active participation in efforts to assess resource quality in cooperation with other federal and provincial government agencies. Continued cooperation between the Ottawa and Sydney, Nova Scotia coal analysis laboratories and provincial resource departments under the federal-provincial mineral development agreements added further information to the growing national data base on coal quality. Under a program of commercial coal evaluation, scientists acquired and analyzed company samples and prepared an updated supplement to the Analysis Directory of Canadian Commercial Coals.

During the year progress was realized toward the use of Canada's huge peat resources through completion of a contract study on the technical and economic feasibility of a peat-fired steam-electric power station for New Brunswick. The positive results indicate a promising future for peat and the issue of the report excited local interest in development or continued assessment of this resource. A further contract was negotiated that will address the problem of dewatering peat, long a roadblock to wide use. Scientists also created a computerized file of basic peat resource data.

Resource evaluation work on coal also includes assessments of the suitability of coals for cokemaking, described later in this review.

Uranium Reserves and Production

Each year the Mine Evaluation Group within CANMET applies engineering and economic criteria to determine national reserves of uranium. The data are supplied to the department's Uranium Resource Appraisal Group (URAG) to be included in an annual assessment of uranium supply and demand which, in turn, helps form the basis for national policies on nuclear energy, including company-by-company export and supply quotas.

Mining and mineral engineers at CANMET are concerned mainly with mineability, productive capacity, and the viability of new operations. Staff

regularly visit company personnel at all operating and projected mines and mills to assemble and discuss representative data, and to review company plans. CANMET's own reserve calculations are compared with company estimates and both are included in the report to URAG. As essential input to such reserve and resource calculations, minimum economic or cut-off grades were established for each deposit. These were calculated after careful evaluation of mining and economic factors utilizing estimated mining costs and other projected mining parameters. An additional output was the estimated productive capacity of each relevant property over time, resulting in future projections of total uranium mining production in Canada. Related mineability studies involved analysis of possible alternative mining methods and equipment, with associated costs.

A major effort was made during the year to refine the methodology used to process data and calculate reserves. This included the development of sophisticated computer programs and the application of new geostatistical methods.

Mineral processing specialists coordinated a survey of Canadian uranium mills for the Nuclear Energy Agency (Paris) and the International Atomic Energy Agency (Vienna). The expansion of some existing mills and incremental process improvements at others has increased the overall productive capacity of Canadian uranium mills. Two new plants came on-stream during 1980, Amok in northern Saskatchewan and Earth Sciences in Calgary. The new orebodies being developed in Saskatchewan will demand more complex processing circuits in response to more complex mineralogy.

ENERGY RESEARCH AND TECHNOLOGY DEVELOPMENT

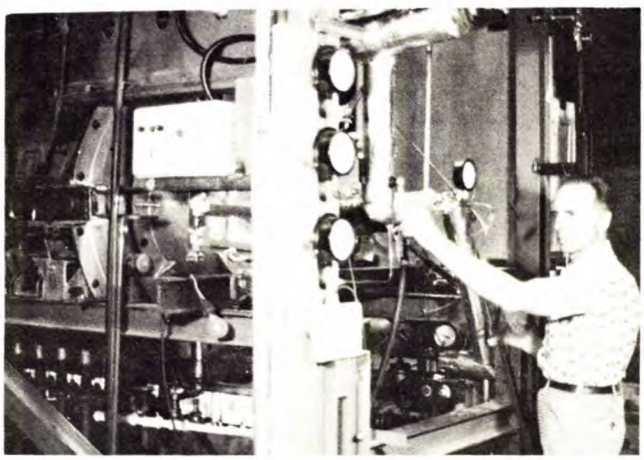
Under the National Energy Program, Canada's future energy requirements are to shift from traditional reliance on conventional crude oil to a more diverse and flexible supply mix. The transition will require more than just economic adjustments and initiatives. The ability of energy sources to meet the needs we have in mind will depend very heavily on the availability of suitable technology when and where it is needed, particularly if we wish to make optimum use of resources. In many cases new or extensively modified technology will be required to convert difficult or variable feed materials to products that meet Canadian specifications - with the long lead times that implies. Even where off-the-shelf technology is available we must ensure that it works efficiently with our feedstocks. Technology must be available to use the products efficiently and must meet our standards for resource conservation and environmental protection. These, along with the traditional policies of resource development in Canada, are the principles that guide energy R & D at CANMET.

Conservation Technology

Meeting national energy goals requires that we make the best possible use of the resources we are now consuming. For several years CANMET has been researching technological innovations that can improve the efficiency of fuel-burning equipment. This work is coordinated with the energy conservation efforts of many other public and private sector agencies.

Transportation - Results from CANMET's eight years of research on automobile fuel consumption in the Canadian climate have indicated that for engines with conventional technology, fuel economy degrades rapidly with decreases in ambient temperature. Engines with advanced combustion design, such as high-speed diesels, lean burn or stratified charge, degrade far less and produce lower atmospheric emissions. These findings led Chrysler Canada to submit an unsolicited proposal to improve automobile engine technology specifically to perform to Canadian winter conditions and designed to Canadian emissions standards. Modifications include a significant increase in compression ratio, improved fuel evaporation and preheat, optimized spark timings over the whole temperature range, and other devices to improve low temperature performance, while using energy efficient leaded gasoline. Modifications to the engines are being carried out by Chrysler using company funds, with testing being jointly sponsored by CANMET and Transport Canada.

Since 1978 CANMET has conducted road tests to determine the effectiveness of lead traps mounted on automobiles to collect solid particulates in the exhaust gases from automobiles fueled by leaded gasoline. These trials involved eight vehicles from the Department of National Defence operating under a range of Canadian climatic conditions from -25°C to +24°C. The following results were reported to the Air Pollution Control Association:



R. Fouhse, engineer makes adjustment to tunnel furnace operated in CANMET's combustion laboratory to evaluate the burning properties of a wide variety of conventional and novel fuels

- automotive exhaust lead traps can replace standard mufflers and portions of the exhaust system and reduce automotive lead emissions by 80%;

- there is no discernible deterioration of trapping efficiency with mileage accumulation;

- the traps are equally effective over the wide range of ambient temperatures encountered yearround in Canada;

- purging of previously collected lead which occurs with standard exhaust systems does not take place with well designed lead traps;

- the traps will not affect fuel consumption, vehicle driveability or exhaust muffling; they are relatively simple, have no moving parts, require no maintenance and can be designed to last the life of the car;

- if the use of leaded gasoline is increased in Canada to obtain better refinery efficiency and lower vehicle fuel consumption, lead traps offer a viable means to control lead emissions into the environment, if such control is considered necessary.

Domestic Oil Furnaces - For the past 10 years, CANMET has had a major program to improve the performance of oil-fired domestic heating systems. To do this, laboratory staff conducted extensive studies of a wide range of heating equipment for the Oil Heating Association of Canada, as well as for individual oil companies, manufacturers and users. As well, detailed studies were carried out over several winters in a large number of oil-heated houses in the Ottawa area, measuring such things as fuel consumption, number of cycles, and hours of operation for different technologies. The results were correlated with such parameters as outside temperature and weather conditions, thermostat settings and house insulation.

An efficiency manual on residential oil heating has been written to detail how the results can be translated into significant fuel savings. This book is a manual for servicemen, designers and builders on how existing oil heating systems function and various system and hardware modifications which can be applied to improve their seasonal efficiency by as much as 25%. In particular, proper sizing of the heating system is stressed, with decreasing firing rate and the use of chimney dampers improving off-load performance. Major efficiency gains can be realized by retrofitting a conventional burner with a retention head, increasing steady state efficiency by 10-15%. Detailed retrofit techniques are presented. Other improvements, such as reduction in sooting with a delayed action solenoid valve, improved heat distribution by duct insulation and ensuring an adequate supply of combustion air are also stressed.

This manual is the first Canadian book to clearly define the areas where efficiency is lost and presents easily applied techniques developed from R & D to reduce these losses significantly. During 1980, 1000 French copies and 7000 English copies of this manual were distributed to industries within Canada. It is used by all provinces as a training manual for licensing servicemen, and as the basis for upgrading efficiency courses to existing licensed servicemen.

Domestic Gas Furnaces - In conjunction with the federal government providing incentives for Canadian homeowners to convert from oil to gas or other fuel for space heating wherever possible, CANMET is applying its experience with oil furnaces to the possibilities for improving efficiency in gas furnaces. A conventional new gas furnace with a pilot light and naturally aspirating burner has a seasonal efficiency of 55 to 60% compared with 65 to 70% for an oil furnace with retention head burner. On the gas furnace, a continuously burning pilot light wastes about 5 to 7% of the total consumption over a year. Another 12% is lost in the steam which forms on combustion of the gas, and escapes up the chimney. The draft hood, constantly open, allows a significant loss of heated air up the chimney, both when the furnace is on and off.

Recently, gas furnace technology has undergone rapid development to improve efficiency. At least two types of new generation furnaces, similar in concept to models already available in the United States, are in the certification process through the Canadian Gas Association and provincial authorities.

These new models have features such as electric ignition, built-in vent damper, built-in induced draft fan and a heat exchanger to condense the combustion products and recover the latent heat they contain.

CANMET has entered into a contract with a manufacturer to produce a retrofit condensing flue heat exchanger for existing gas-fired furnaces. This unit uses a secondary finned-tube stainless steel heat exchanger located in the cold air return to condense the combustion products, gaining most of the potential savings of the new condensing furnace.

Low-calorific Industrial Gas Burner Development - Under Phase III of a contract with the Canadian Gas Research Institute a 300-kW burner for low-energy gas was designed and developed. In field trials at an operating wood gasifier, the burner was successfully fired at partial and full load on hot, dirty gases with heating values from 3 to 6 MJ/m^3.

One major problem was incomplete combustion of tarry liquids which were ejected from the flame at about 10 L/h. This problem will be studied and hopefully resolved during 1981 under Phase IV of this contract by incorporating a secondary burnout cell at the burner exit.

Energy Conversion and Storage Devices - Solid-state electrolytes used in electrical storage and conversion devices such as batteries, fuel cells, thermoelectric generators and electrolyzers must possess particular electrical, thermal and microstructural characteristics in order to function

efficiently. CANMET is applying its traditional expertise in materials science to the development of materials for these applications.

Extensive work has been done on the fabrication of durable sodium beta-alumina ceramic electrolytes. Recognizing the potential of this technology, a company has designed and built two prototype thermoelectric generators that incorporate CANMET-developed materials. The company using both flat plate and closed-ended tube configurations for the electrolyte have tested various design assumptions; in one case by operating one of the generators at low power for several days. CANMET scientists are now concentrating their efforts on measuring and improving the properties of these materials.

CANMET is also conducting or sponsoring research on other electrolyte materials. A group of materials referred to as sodium zirpsios, for example, compare favourably with the beta-aluminas in conductivity and durability, but are also three-dimensional conductors and can be produced at lower temperatures. CANMET succeeded in fabricating such materials in the laboratory attaining higher conductivities than other researchers have reported. Other groups of materials known as gasicons and yasicons have been produced at McMaster University using a conventional sintering process. These have advantages similar to zirpsios.

McMaster University is also working under contract to develop nondestructive procedures to detect flaws in electrolyte materials. Minor flaws could act as sources of major cracks that could lead to failure. Ultrasonics have been applied with some success. Thermophysical and nuclear magnetic resonance properties are also being investigated in other studies to characterize electrolyte materials.

Hydrogen by Photoelectrolysis - The aim of this work is to develop efficient and stable oxide and sulphide semiconducting materials in polycrystalline and film form to convert solar energy to hydrogen by the photoelectrolysis of water. During the year a number of electrode specimens composed of layer-type, transition-metal sulphides were tested by surface and photoelectrochemical means to determine conductivity and corrosion resistance. Film-type oxides were tested for photoelectrochemical response. In cooperation with the Electrochemistry Society, CANMET sponsored a symposium entitled "Photoelectrochemical Cells for Solar Energy Conversion", which brought together scientists from across Canada and the U.S.A. Part of the CANMET research constitutes the Canadian contribution to the International Energy Agency's effort on photoelectrolysis of water for hydrogen production using solar energy.

Petroleum Supply Technology

The federal government's involvement in petroleum-related R & D has traditionally been concentrated on those subjects or research avenues that are of a long-term nature and for which the returns have been too distant to attract serious industrial interest. Of particular interest to CANMET scientists for many years has been the challenge of tapping the potential of Western Canada's huge resources of oil sands and heavy oils. These low-grade petroleum materials are complex and difficult to process: understanding their chemistry with a view to developing process technologies that provide better oil yields and generate less waste has been the main thrust of the research. The principal product of this effort is the CANMET hydrocracking process.

Oil Sands Mining - While the two subjects, mining technology and oil sands development, are both of great interest to CANMET and consistent with its expertise, heavy activity by other organizations in oil sands mining has led CANMET to restrict its role to maintaining an awareness of mining development on behalf of the federal government. Each year engineers produce a review of the technology.

This year short-term work was also undertaken to meet the information needs of external agencies. In conjunction with the Gulf/AOSTRA project at Surmont, core samples were obtained and the quantity and quality of gas emitted was determined. A second study examined the quality of gas emitted from exploration holes drilled by one of the operating companies.

The cuttability of frozen oil sand material was investigated in cooperation with a group planning new oil sand mines. CANMET's interest in this is to establish a basis for extrapolating the performance of bucketwheel excavators from oil sands to coal overburden.

Bitumen and Heavy Oil Recovery - In situ recovery of oil using steam injection yields relatively stable oil/water emulsions. For environmental, economic and technical reasons the oil and water phases must then be separated as cleanly as possible. In a study done in cooperation with Texaco Canada Inc., CANMET has evaluated demulsifiers and identified optimum conditions for their use. Quantitative methods for emulsion analysis were developed.

Upgrading: The CANMET Hydrocracking Process - Typical bitumen or heavy oil contains about 50% pitch (non-distillable fraction), as well as materials such as sulphur, nitrogen, nickel and vanadium that would cause serious operating difficulties in a conventional refinery. The feedstock must therefore be upgraded to meet refinery requirements.

By taking a hydrogen-addition approach, rather than rejecting carbon as coke, CANMET hydrocracking produces more oil and less waste than existing commercial methods. It is also adaptable to refinery residuals and possibly coal liquids.

In the CANMET process, the feedstock is mixed with hydrogen under pressure and the mixture pumped up a long tubular reactor where hydrocracking takes place at high temperatures. The high-boiling pitch fraction is converted to lighter distillate oil fractions that can be processed to produce synthetic crude oil.

The following facilities have been used by CANMET to develop the process:

- two 159-L/d pilot plants with a modern data acquisition system; the first was completed in 1965, the second in 1979;
- catalyst development facilities: four bench-scale high-pressure flow reactors and a 1-L hydrotreating unit;
- one 1200-L/d continuous vacuum distillation column for preparing feed and distillates and a Podbielniak flash vacuum distillation unit;
- analytical facilities.

A comprehensive data bank has been developed using both bench-scale equipment and pilot plants. The pilot-plant data base contains information on the effect of process variables such as pressure, feed rate, temperature, gas rate and additives. More than 100 reports on the process have been published. Nine patents have been issued so far, and seven additional patent applications are pending. Ultimately, the process will be patented in eight countries. A cost study carried out by independent consultants has shown that the capital and operating costs for the CANMET process compare favourably with existing and competing commercial processes.

Industry-wide, the CANMET process has been recognized as an attractive alternative to currently used technology for upgrading heavy oil and refinery residuals. At year end, Petro-Canada and Lavalin Inc., a fully owned Canadian company, had completed negotiations and were ready to sign an agreement to jointly develop and commercialize the process. An aggressive plan to locate a demonstration plant was undertaken.

During 1980-81, the joint CANMET/Petro-Canada efforts to commercialize the process continued. More than 7000 operating hours were logged in the two pilot plants. The program comprised further feedstock characterization runs as well as runs at very high pitch conversion (up to 100%), with recycle, with different reactor geometries, with fast start-up and runs of long trouble-free duration to demonstrate reliability. Optimization runs showed that pitch conversions well in excess of 95 wt % can be routinely achieved. New feedstocks were successfully tested. Work was also initiated on gamma scanning techniques to study bed behaviour and three-phase flow, and on mathematical process modelling. In-house research was supported by seven contract studies.

Catalyst Development - Successes achieved in the CANMET hydrocracking pilot plant program in recent years were based in part on preliminary experiments in bench-scale equipment by catalysis experts. These specialists have attempted to cope with the catalyst deactivation problems presented by heavy feedstocks. Various types of catalyst materials have been made in the laboratory and tested. The specialists have also studied the fundamental structural aspects of catalysts in an attempt to better understand the effects of structural differences and devise catalysts that will better cope with the heavy feeds.

Experimental evidence obtained in the laboratory shows that the rate of reaction of large molecules (in petroleum residuals and heavy gas oils) is limited by the rate at which they diffuse through the pores in a conventional catalyst. In the past year a catalyst support having both large pore diameters and high catalyst surface area has been developed. This new support structure is expected to enhance reaction rates substantially.

M. Fulton, technologist takes readings during an experimental run in CANMET's bench-scale catalytic hydroprocessing laboratory

Processed Product Characterization and End-Use Assessment - Because the feedstocks used in CANMET hydrocracking are complex, it is important to understand their chemical make-up and effects on reactions before processing strategies can be developed. Moreover, as with any new process, the products are likely to differ from those produced by other technologies, and these differences must be understood with further processing or marketing in mind. CANMET maintains sophisticated laboratories to do these characterization studies.

Nitrogenous components, for example, are important because they cause catalyst deactivation during upgrading. Scientists are patenting a technique for removing most of these undesirable components by using inexpensive sorbent materials. To determine the chemical characteristics of polynuclear aromatic compounds (potential carcinogens)

in feedstocks and products, scientists have developed a high-performance liquid chromatographic method and applied it to five different materials. The effects of hydrocracking conditions on sulphur compounds in the naphtha product have also been studied.

The work necessarily involves the development of new analytical methods and procedures for these difficult materials. A highly specific approach for chemical identification of olefinic hydrocarbons in petroleum distillates and synthetic processing products was successfully investigated this year. Work on improving the compound-type analysis of synthetic fuels focused on high performance liquid chromatography. A method was described for rapid analysis of hydrocarbon types in naphtha using this technique with an adsorbent mobile phase system previously developed at CANMET. Methodology development for rapid determination of asphaltene content in bitumens, heavy oils and their synthetic products using thin layer chromatography (TLC) was also initiated.

Materials for Oil Sands Tailings Pipelines - CANMET metallurgists are studying the problem of transporting slurries of oil sands tailings to disposal areas in pipelines. Because these slurries can be highly abrasive and corrosive, frequent pipe replacement can be a problem.

Results from tests with synthesized tailings and with tailings from the Syncrude Canada plant show that the small quantities of oil remaining in the Syncrude tailings act as a lubricant and reduce abrasive wear. This reduction, however, is offset by the highly corrosive nature of the Syncrude tailings.

Materials for Oil and Gas Pipelines - There are more than 175 000 km of oil and gas pipelines in Canada. Over the next several years many more lengths of pipe will be laid to bring energy from frontier areas to reach new markets. With these delivery systems being so crucial to our energy supply system, the steels from which the lines are made must be of the highest quality available within economic limits.

In 1979, research by CANMET's metallurgists on pipeline steels was resolved into two projects, reflecting the shift in emphasis from the evaluation of the properties of newly developed commercial X-70 pipe, towards investigation of the mechanisms responsible for failures of X-52 pipe occurring in service. During 1980-81, the spread continued with the formation of a third project aimed at developing base line data on the separate and synergistic effects of microalloying elements added to high strength line-pipe steels. The purpose of this work is to point the way to an economically optimum composition of X-70 grade line pipe and to prepare for the next quantum jump in strength.

When it became apparent in the early seventies that pipelines in Canada's North would be constructed from an emerging class of steels with mechanical properties superior to line pipe installed in Southern Canada, work was begun at CANMET to assess the properties of the new steels. Essentially, the purpose of this work has been to set up a knowledge base in the public sector to provide impartial answers to questions touching on matters of industrial and public interest and, in particular, to provide advice on the establishment of technically sound criteria for line-pipe acceptance. Ten years later, the task is almost complete and resources devoted to pipeline R & D are being redirected within the project.

One of the critical subjects being studied is welding. During the past year, the notch toughness of mill seam welds and the field weldability of selected pipe specimens have been determined. Field weldability has been evaluated by determining the heat-affected-zone (HAZ) notch toughness and the resistance to hydrogen-assisted cracking. However, mechanical properties in a HAZ are difficult to determine reproducibly because they and the microstructure vary abruptly over very short distances. Scientists have therefore had to rely on inferential assessment using correlations with bulk specimens of known microstructure.

The image-analyzing microscope has also been used to characterize microstructure. A method of measuring grain-size distributions for certain types of ferrite has been developed. Grain size has been found to affect impact toughness and cleavage patterns. In a long-term program to evaluate the properties of selected lengths of pipe, a specimen of grade 483 (X-70) was subjected to a comprehensive series of tests for uniformity. In another study, X-ray diffraction was used to determine the nature and distribution of residual stresses that are "frozen" into the pipe during fabrication.

A number of pipeline failures in Western Canada have resulted from stepwise cracking caused by corrosive hydrogen sulphide in sour oil and gas. In response to an industrial request, CANMET has begun a series of investigations to learn more about this phenomenon.

Mechanical and electrochemical hazards that are external to the pipeline can also lead to failure. For example, stress-corrosion cracking can occur in the presence of certain ions and an electrochemical potential in the soil if a change of strain is induced by changing operating conditions. CANMET is carrying out laboratory experiments to identify the metallurgical and environmental factors that cause this problem.

Mechanical damage such as dents, scrapes and gouges caused by earth-moving equipment can reduce the operational life of pipe by introducing localized highly strained areas which may act as sites for crack nucleation. To quantify these effects, pipes dented up to 6% of their diameter were tested in fatigue. Failure did not occur within 3000 cycles of loading to within 80% of yield strength.

A contractor has written a complex computer program that optimizes the frequency and timing of pipeline inspections to maximize pipeline lifetime while taking account of attendant costs and cost

M. Fichera, technologist adjusts apparatus to test stress corrosion of line-pipe steels

savings. In another contract, an ultra-sonic scanning device was designed and built to detect and monitor the growth of fatigue cracks originating at a welding defect.

CANMET is also beginning to apply on-going work on high-strength low-alloy (HSLA) steels to the requirements of the pipeline industry. Using unique laboratory facilities for working steel and rolling plate, the work will be aimed at a more systematic understanding of the separate and synergistic effects of alloying elements and thermo-mechanical variables. The work is linked to industrial efforts to reduce dependence on molybdenum as a major alloying element.

Coal Technology

CANMET is Canada's major centre for R & D on coal science and technology. Building on expertise developed throughout this century, and maintained in the national interest during coal's period of decline in the 1950's and early 1960's, CANMET now has a comprehensive, expanding program in the many aspects of coal mining, processing and utilization.

Coal Mining Technology - The steep, thick coal seams located in mountainous terrain in Western Canada comprise some of Canada's richest and largest coal deposits. These seams are of variable thickness and the behaviour of the surrounding strata is difficult to predict and control. In cooperation with coal companies, research engineers working out of CANMET's Western Office in Calgary are investigating the behaviour of these strata during mining. Much of the work is connected with hydraulic mining at a major mine. A contract to monitor ground subsidence has reached the field evaluation stage. A subsidiary contract was let to evaluate aerial photogrammetry as a method of subsidence measurement.

In underground coal mining, a study of a mining method to work the highwall of a surface mine by an underground method was carried out jointly with Calgary Power Ltd. The contract was completed and a seminar held. The concept of "punch mining" was elaborated and two operators are presently in the process of introducing the concept in one form or another. An overview of mining methods applicable to particular geotechnical settings in various coal regions in Canada is in the final stages of preparation.

Data on reserve assessment criteria were gathered on major coal projects in Alberta and British Columbia. A report on criteria used for coal reserve assessment by coal companies was prepared and a similar report from the perspective of the coal developer is being prepared.

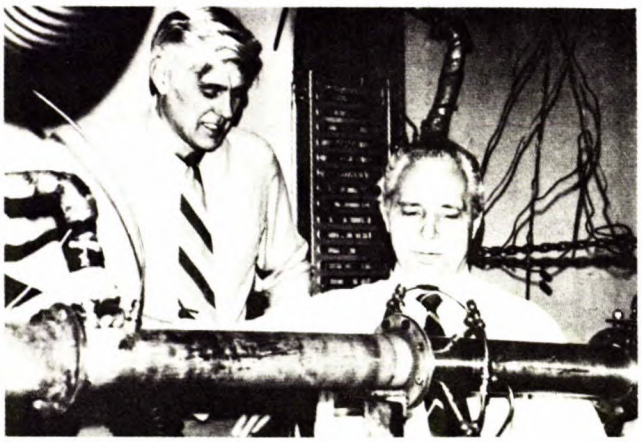
A research contract on bucketwheel selection criteria for surface coal mining has been carried out including some geotechnical testing of overburden formations to assess their cuttability. A report on selection of bucketwheel excavators is in the final stages of preparation.

Coal Mining Equipment Safety - In 1953, as a result of the unanimous desire of the provincial inspectors in the coal mining provinces, the federal government established a laboratory for the certification, on a cost recovery basis, of coal mining electrical equipment as safe for use in explosive underground environments. An Order-in-Council empowers the "Federal Certification Officer" to undertake this work. This original mandate has evolved slowly over the years to include numerous fire resistant materials and fluids, diesel machinery and explosive gas detection equipment in both underground and industrial hazardous locations. Other agencies such as Canadian Standards Association (CSA), Underwriters' Laboratories of Canada (ULC) and Canadian Gas Association (CGA) send such equipment to CANMET for specialized testing.

The main activity of the laboratory is to test and certify equipment that is destined to be used in coal mines where explosive mixtures of methane and air occur. Laboratory staff also perform supplementary research and development and help write national and international standards.

The laboratory issued 46 equipment safety certificates during the year. Officials also certified the first repair facility for explosion-proof equipment at a coal mine. The company has shown the capability to repair equipment in accordance with established standards without re-examination by the Certification Officer. Laboratory staff also held their first formal seminar for the industry on principles of safety related to the types of equipment CANMET tests. Staff also published documents describing the certification services and listing the equipment certified to date.

In research and development, a contract resulted in the construction of a high-efficiency, venturi-type water scrubbing system suitable for use in coal mining diesels. The device can remove more than 70% of particulate emissions from exhaust. It will be installed on load-haul-dump machinery and tested underground in 1983.



P. Mogan (L) and D. Dainty (R), scientists observe high-efficiency, venturi-type diesel exhaust scrubber capable of removing more than 70% of particulate matter from exhaust emissions

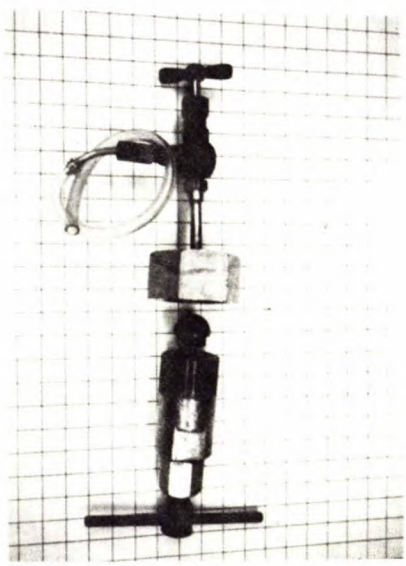
Underground Environment - The process of coal formation over geologic time has resulted in the presence of adsorbed methane within the coal seam. When the coal is mined, this methane is released. Together with the dust produced during mining and the combustibility of the coal itself, methane creates an underground mining environment where explosion and fire are serious hazards.

The monitoring of Canadian coals for methane desorption has regained its importance as a result of the recent resurgence of interest in underground mining and with the realizaton that even small amounts of methane may affect the dust explosibility index. Research in this field has been carried out for many years but a closer look is now being given to spontaneous combustion, methane and environmental monitoring. CANMET provides advice to various organizations in these fields.

On the basis of literature search and visits to U.S. research laboratories, CANMET has decided to field test the Conspec system for underground environmental monitoring. A U.K. instrumentation system for air velocity and methane monitoring has been obtained and a proposal to examine existing coal mine ventilation systems by research contract has been developed.

Coal Preparation - Coal preparation is a general term referring to the upgrading of the mine product to meet the specifications of a particular end use. The objectives are to remove impurities such as free mineral matter and sulphur, to adjust the moisture content, and to consistently produce a product that is uniform in size and quality. In addition to reducing the technical problems encountered in end uses, preparation can reduce environmental emissions and transportation costs. In today's economic and regulatory environment, these are important considerations for coal producer and user alike. They have been especially important in developing the export market for Western metallurgical coals.

CANMET's research in coal preparation extends back many years. It is an inter-disciplinary effort, as coal is both an energy and mineral commodity. Scientists have recorded a number of advances, such as the compound water cyclone, on which much of the work in the Edmonton laboratory has been based. In addition to doing R & D on improved processing methods, scientists have worked with



Coal crushing apparatus - laboratory equipment for methane desorption

Laboratory ball mill is used in the final stage of methane desorption tests

the coal industry to study the characteristics and preparation requirements of commercial coals.

In this work the pilot plant has been, and will continue to be, an essential tool. In the past, reliance on imported technology and flowsheet concepts has led to inefficiencies and high costs in Canadian plants. Having a sophisticated pilot plant available will enable engineers to study more fully the techniques best suited to their particular circumstances.

At Edmonton, CANMET operates a 150-kg/h miniplant and a 10-t/h pilot plant. Both were modified this year to expand their capabilities. Tests in the miniplant provided further information on the effect of very fine material on the sharpness of separation of coal from mineral matter. This is critical to plant design and water treatment because mined Western Canadian coals often contain a high proportion of very fine material. The treatment of fine coals is a major focus of current research.

Certain Western coals also tend to be highly oxidized, and this decreases the efficiency of surface-chemistry-dependent equipment such as froth flotation cells. Two research contracts were initiated this year to determine the feasibility of and to explore methods for chemical and physical changes in the bulk and surface properties which accompany oxidation. A large resource company continued participation on a cost-sharing basis in the first phase of a study involving development of methodology and instrumentation, characterization of oxidized coals, micro-flotation testing and scale-up over a five-year period. Feasibility of a procedure for contact angle measurement for fine particles is being carried out through a research contract at the University of Toronto.

Results from research contracts on the analysis of product samples obtained for washing, sizing and other processes from ten Canadian washeries during the previous two years provided valuable data that were used for modelling and flowsheet development. The data also showed that of the total losses in product recovery for all washeries in Canada, more than 80% occurred in fine coal processes such as flotation and water cyclones. Since these processes represent on the average 33% of the total installed capacity of all Canadian washeries, the need for a concerted R & D effort in fine coal cleaning is apparent.

Tailings from several Canadian coal mines were investigated for coal recovery by progressive grinding and processing. After size reduction to minus 300 μm, concentration of most of the coal by flotation at a good thermal grade (15 to 23% ash depending on the coals) was possible. With further grinding to minus 25 μm coal concentrates grading 10% ash were produced by both flotation and spherical agglomeration.

A comparative study was made of wet and dry magnetic separation for cleaning Nova Scotia pyritic coals. The two methods gave equally good results for both de-ashing and desulphurization. When compared with dense liquid separation, coal recovery efficiency by the high-gradient magnetic separator averaged 83% for the sulphur removal and 91% for the ash reduction. High-gradient magnetic separation is being compared with flotation for the beneficiation of the highly pyritic Western coals.

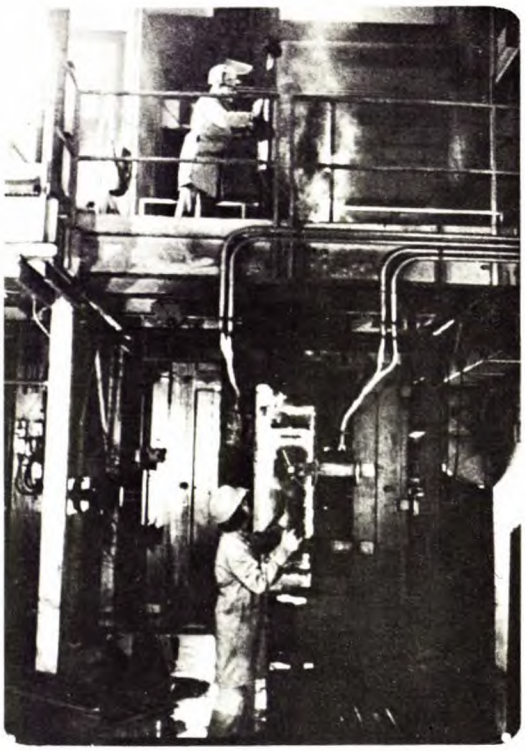
Two contractors also completed work on chemical comminution and its effect on subsequent cleaning of coal. Using gaseous ammonia at 758 kPa and 22°C, significant size reduction was obtained with both Prince and Lingan coals from DEVCO. However, the washability curves on chemically comminuted coals were similar to those obtained from comparable mechanical size reduction. Furthermore, ammonia consumption was high unless prolonged vacuum pumping of this chemical was carried out on the comminuted coal.

Coal washeries produce large amounts of liquid effluent containing finely-divided solids. To reduce environmental impact and the demand for fresh water, plant operators attempt to remove the solids for disposal and recycle the water. However, this is not easy to do efficiently and there is room for much research of the fundamental principles involved.

A highlight of the year was field testing of CANMET's new mobile water treatment plant at a coal mine. The plant can be hooked up to a commercial plant to study the company's treatment needs and research new concepts, without interrupting operations. The heart of the mobile plant is flocculation, a technique whereby reagents are added to cause the solids to bind together and become easier to separate. Oil-agglomeration equipment is also included to recover fine coal if desired. The work in the plant is complemented by laboratory studies in which several commercially available flocculants were evaluated this year.

Carbonization - Coking coals are an important Canadian export. In 1980, Canada exported 15.2 x 10^6 t, for a total value of $700 million. The Canadian steel industry, on the other hand, imports most of its coal - 9 x 10^6 t in 1980. Thus both the coal producers, who are looking at markets, and the steelmaker (domestic and foreign), who is looking at secure sources of supply, are interested in the quality of Canadian coals when used as coking blend components, and in coke-making innovations. Steelmakers are also keen to identify ways of reducing the coke rate - the amount of coal needed to produce a tonne of iron.

Commercially, coke is made in batteries of slot-shaped coke ovens. CANMET operates four scaled-down versions: two at its Ottawa laboratories and two in Edmonton. Although much smaller than industrial ovens they are of similar width, and are therefore referred to as "technical scale". A recent detailed comparison verified that all CANMET ovens simulate industrial practice and produce a comparable product. This year CANMET initiated the testing of an apparatus to measure internal gas pressure in its ovens. Gas pressures are believed to be related to oven wall pressures, which



Operators Z. Tazbir (top) and R. Bell (bottom) charging crushed coal to technical-scale coke oven

are of concern to industrial personnel because they can cause damage to oven batteries.

The ovens at CANMET are used both to perform R & D and to evaluate the coking behaviour of selected coals. The programs are planned in cooperation with the Canadian Carbonization Research Association (CCRA), an organization comprising the major coal and steel companies and CANMET.

CANMET investigations have shown that partial briquetting of coke oven charges, used extensively in Japan, can improve coke quality for coal blends used by the Canadian steel industry. Coke quality can be maintained by adding considerable amounts of poor and non-coking coals to the briquetted portion of the blends. An investigation of the effect of process variables on charges containing non-coking coals indicated that coke quality improved with increased pulverization of the briquetted coal portion and increased amounts of binder in the briquets. Results of trials with the relatively fluid coal blends used by Canadian coke producers were presented to a joint technical meeting of the CCRA and Japanese steelmakers. Demonstration trials using the Canadian blend are to take place in Japan.

Previous CANMET investigations have shown that coke quality from a poor-coking, medium-volatile coal could be improved prior to carbonization. Recently, microscopic and tumbler testing of cokes made on a smaller scale by carbonizing poor-coking, low-volatile Western Canadian coals with additions of experimental pitches also indicated that the additions improved coke quality. However, cokes made in technical scale ovens by adding commercially available pitch materials to a good coking industrial blend and to an industrial blend containing good coking but highly inert Western Canadian coal showed little improvement to coke quality.

The ultimate test of coke quality is its strength and resistance to abrasion under blast furnace conditions. The reaction of carbon dioxide (CO_2) with coke in the blast furnace can weaken coke and cause operating difficulties. CANMET has been testing the strength of coke after reaction with CO_2 at 1100°C, to determine the effects of additives such as pitches and of coal ash content on coke strength. Results indicate both coke reactivity to CO_2 and its strength after reaction are improved by decreased coke ash. A contract awarded to McMaster University has shown that alkali vapour originating from coke ash diffuses into the coke structure at elevated temperatures and weakens it. This was confirmed by experiments in CANMET's counter-current reactor, which simulates blast furnace reaction conditions.

The effect of ash removal by coal preparation was measured in another study. In oven tests, reduced ash content substantially improved the quality of some cokes made with non-blended coals. When blends were used, improvements were more modest.

Pilot plant carbonization work is supported by a variety of laboratory tests and analyses. All coals in the program undergo petrographic and rheological examination and chemical analysis. In addition, the R & D studies are backed up by fundamental research on coal and coke constitution. For example, microscopic analyses have been initiated to characterize the optical anisotropy of carbon forms in different cokes.

A successful procedure was developed wherein both high and low fluidity coals can be tested in the same apparatus to obtain their high-temperature (500-1000°C) contraction coefficients during coking. Results can be compared directly and the effects of blending different coals on contraction (and therefore on fissuring) characteristics relevant to carbonization are being investigated.

Carbon-13 nuclear magnetic resonance was used to measure the extent of oxidation of metallurgical coals both before and after treatment with pitch additives. The effect of the additives on the carbonization characteristics of the coal has been determined on small samples using the "moving sample" carbonization oven recently commissioned in the laboratory. Continued studies of functional group distribution using solid infra-red evaluation procedures have identified group changes due to maturation of Western Canadian coals.

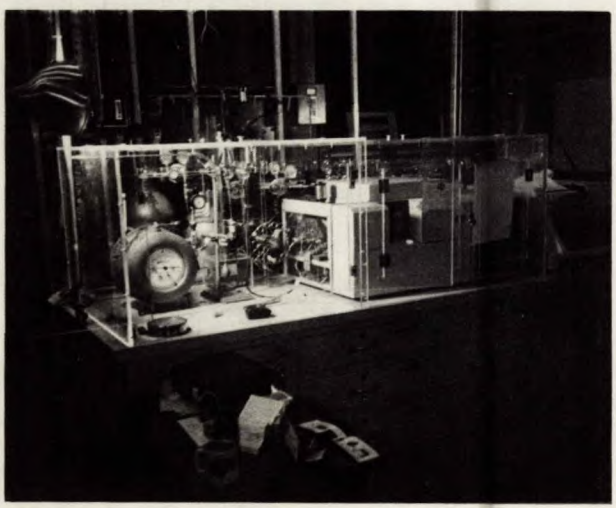
Coal Gasification - Coal gasification, the reaction of coal with oxygen and steam, presents an important technical option for Canada in both electric power production and alternative liquid fuel supply. Electricity production via the gasification-combined cycle route is a way to overcome the limiting 40% efficiency of the steam

cycle and to remove the sulphur prior to combustion. Gasification combined with catalysis is the only commercially demonstrated route to liquid fuel production (gasoline or methanol) from coal.

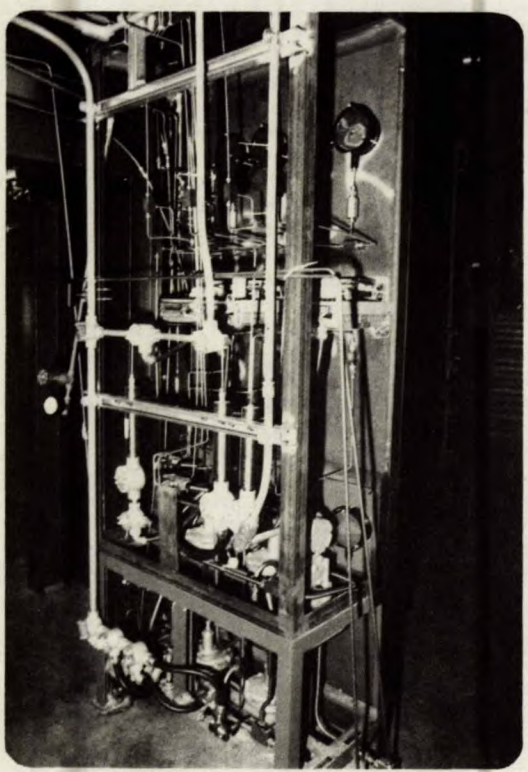
Gasification research is being carried out intramurally and through contracts. The main objective of the in-house program is to develop information on the gasification characteristics of various Canadian coals. This information provides the basis for assessing advanced gasification technologies for the conversion of Canadian coal to gas, electricity or methanol in various regions of Canada using local feedstocks. The contracting-out program is designed to introduce the technology to Canada, to encourage some technical development, and to build Canadian expertise.

Experimental facilities at CANMET include a batch-mode, atmospheric-pressure, fixed-bed gasifier and a high-pressure thermobalance reactor. The gasifier is suitable for initial assessment of the gasification performance of various coals. Characterization of significant Canadian coals according to their gasification parameters at atmospheric pressure has almost been completed and the emphasis is turning to obtaining data at higher pressures. A high-pressure, fixed-bed continuous gasifier to simulate the Lurgi-type configuration is being built.

A significant technical development during the past year has been the commissioning of a multiple sampling and analysis system which allows the high discrimination of gas chromatography to be applied to the rapidly changing gas compositions that occur during the early stages of coal devolatilization. The use of this technique in atmospheric pressure gasification has allowed the ranking of various coals according to their rate of carbon conversion.



Multiple sampling and analysis system based on gas chromatography for analyzing rapidly changing gas compositions during coal gasification

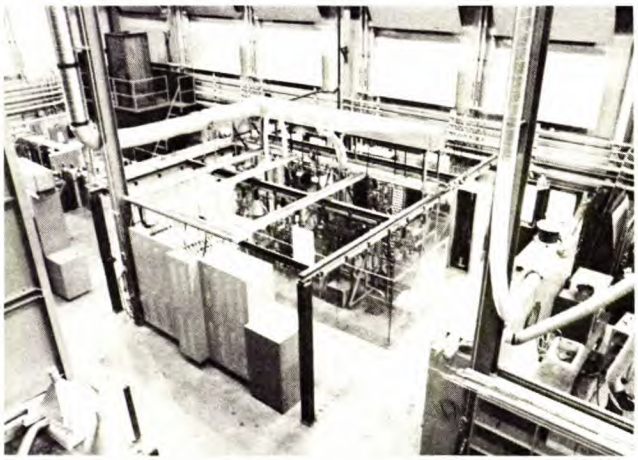


High pressure, high temperature thermobalance reactor for kinetic study of gasification reaction

The national response and achievements in the first five years of the external contract program on the R & D of coal gasification technology have been very encouraging. For example, the Shaunavon coal utilization project is a major joint undertaking of a public utility and CANMET to demonstrate the feasibility of the gasification/combined-cycle process for electricity generation, which is more efficient and less polluting than the conventional pulverized fuel process with flue gas desulphurization. It is hoped that this technology will be introduced commercially. The spouted-bed technique being developed at the University of British Columbia is a promising technology for caking coals.

Coal Liquefaction - Liquefaction research is also split into contract and in-house research. Three projects constitute the in-house program: the continuous liquefaction unit, the continuous hydrogenation unit and coal liquefaction chemistry. By the end of the year, construction of the continuous-flow liquefaction unit was completed, and commissioning was 90% complete. As a first priority, this unit will be used to investigate the co-processing of coal with bitumen or heavy oil as a unique Canadian option.

A contract was awarded to Catalytic Enterprises Ltd., for detailed design and construction of a bench-scale hydrogenation unit. This unit will be used to prepare solvents for coal liquefaction



Overview of recently-installed continuous-flow coal liquefaction unit

experiments and to hydrotreat coal-derived liquid fractions generated with the liquefaction unit. Batch liquefaction facilities are being established to study a variety of problems in support of the continuous units.

The major achievements in coal liquefaction have been in the contract program, which has been operating for five years. Several companies now have working coal liquefaction teams, and two continuous experimental units have been built outside CANMET. University research has also expanded. This year, four shared-cost and ten 100%-funded contracts were awarded for a dollar value of about $900 000.

Conventional Coal Combustion - Current conventional combustion activities at CANMET reflect the increasingly important contribution that coal is expected to make in meeting our future energy requirements and reducing our dependence on foreign oil. Canadian thermal coal production, which increased from about 10×10^6 t in 1974 to about 20×10^6 t in 1980, will likely reach 50 to 60×10^6 t by 1990. This escalating demand for coal will, however, be heavily dependent on the ability of conventional and emerging combustion systems to cope with disruptive conflicts caused by variations in fuel quality, on requirements for better equipment availability and on implementation of progressively more stringent environmental constraints.

Through a series of pilot-scale studies, CANMET attempts to evaluate the performance of coals in pulverized-fired equipment, to improve the combustion technique when feasible and to conserve fuel oil use by modifying industrial combustion systems. The work extends to other solid fuels that can be burned in pulverized-fired equipment, such as wood wastes.

During the year, combustion scientists conducted test burns on several coals of varying ranks. The tests, carried out in CANMET's pilot-scale research boiler, were all done on behalf of, or jointly with, utilities or coal companies. A number of variables were studied, including ignition, combustion stability, burn-out, slagging, fouling and emissions. Optimizing combustion conditions to get the best performance is one goal of the work.

CANMET is also involved in three studies of coal burners that produce low nitrogen oxide emissions. In a cooperative International Energy Agency project being done in California, seven Canadian coals have been evaluated in a technical-scale rig to reveal the role of fuel nitrogen in oxide formation. The other two projects involve retrofitting of existing equipment at a utility power station and a Canadian Forces heating plant.

Trace element emissions from coal-fired power stations are becoming a major environmental concern. At CANMET, samples of coal and fireside residues are being analyzed for elements including actinides for a number of Canadian coals of different ranks that have been evaluated in the pilot-scale boiler. In another study, the Canadian Electrical Association, with EMR and Environment Canada participation, is negotiating a contract with Battelle Northwest to study the flow of trace element emissions from four Canadian thermal generating stations to their eventual receptors. The study is expected to be completed in late 1982.

Plume Dispersion - In 1980, consolidation of the plume rise data generated during six years of research in the CANMET/industry plume dispersion program, resulted in a paper to the annual Air Pollution Control Association meeting.

The plume rise data were compared with two forms of the relationship derived by Briggs which is a standard predictive relationship in the literature. In all, ten sources in stable and unstable conditions, five geographic regions and three seasons were represented by the data. It has been shown that the data can be presented by the Briggs form of equation, particularly for stable conditions.

Combustion of Coal-Oil Mixtures - One way to reduce reliance on oil for energy supply is to convert thermal electric generating stations to coal firing. However, this measure is constrained by the high cost of changing over the equipment. By substituting coal for part of the oil - that is, by mixing the two as a slurry and burning it as a liquid - dependence on oil can be reduced without major expense.

This is the objective of a demonstration project being carried out by CANMET and the New Brunswick Electric Power Commission in the 10-MW(e) No. 1 unit at Chatham. Phase III of this project, which began in 1977, was undertaken this year with two goals: to make more effective the oil agglomeration process being used to beneficiate the coal, and to test two burners for long-term performance. Equipment wear caused by the highly abrasive slurry continued to be a problem inhibiting commercial introduction of the technology. Moreover,

measuring the effects of wear was complicated by the variations in coal content of the slurry and ash content of the coal, both of which were needed to meet other project objectives.

The project has provided much useful information on the wear phenomenon. The main difficulty is in the burners, where wear leads to progressive flame deterioration. Pumps, valves and secondary grinding equipment are also susceptible. Component design, materials selection and slurry characteristics have been pinpointed as the main factors affecting wear.

The work at Chatham had been expected to lead to a 100-MW(e) demonstration project at Dalhousie, N.B., but the present economic analysis shows that it is more reasonable to convert all units above 100-MW(e) in the province to full coal firing.

CANMET, along with four other organizations, has jointly sponsored a smaller-scale coal-oil mixture project at the Ontario Research Foundation. Completed in 1980, it was designed to study coal beneficiation, slurry preparation, combustion performance, slagging, fouling and emissions, using three coals, one each from Pennsylvania, Eastern and Western Canada.

The research team attempted to use a vortex mixing device to mix the slurry and pass it to the burner without contacting a pump. This would avoid the pump wear problem. However, the mass throughput in the mixer was too low for effective mixing. Combustion evaluations were therefore carried out by using a simple shear-mixing tank. The vortex mixer was used to make an emulsion containing micro-dispersed water, and this was tested.

In the combustion evaluation, the three coals were mixed to form a 30 wt % slurry and also a 30% mix containing 20% water. Tests were conducted at two firing rates, 7 GJ/h and 3.25 to 4 GJ/h and two different types of burners, a high intensity burner developed at ORF with Gulf Oil and known as the Vortometric burner, and a standard Peabody burner. Both burners performed well in the tunnel furnace arrangement of the test facility despite the fact that the Vortometric produces a highly rotating flame resulting in some wall flame impingement.

Traditionally, coal-oil mixtures have been prepared by grinding coal in a dry or semi-dry state and then dispersing the finely ground coal in oil to form a slurry. Significant advantages, such as eliminating surface oxidation of the coal, eliminating the need for dust control equipment and enhancing the dispersion of coal in oil, can be envisaged when the coal is ground in an oil suspension. General Comminution Incorporated has developed a laboratory size "Szego" mill with a maximum throughput capacity of 0.5 t/h of coal for grinding coal-oil mixtures. Preliminary experiments in this mill indicate that a coal/water (60/40) slurry containing minus 19-mm coal feed can be ground to 85% minus 74 µm mesh size in a single pass, at a coal feed rate of 400 kg/h. A particle mean size of 12 to 20 µm can be obtained in 2 to 4 passes. Since this mill is not in sustained commercial operation, information on wear, maintenance and related operational details is minimal. Accordingly, CANMET is co-sponsoring a program to design and construct a prototype Szego mill capable of grinding 1 to 3 t/h of coal. This unit will then be used to obtain sufficient performance and scale-up data to prepare a functional design of a commercial size mill capable of producing 10-30 t/h of coal as a slurry.

Fluidized-Bed Combustion - Fluidized-bed combustion (FBC) is of potentially great benefit to Canada because it offers the following advantages:

- the ability to burn high-sulphur coal such as those in Eastern Canada with convenient control of SO_2 emissions through use of limestone beds;

- the ability to burn coals having combinations of high moisture content, high ash content and low reactivity. This is important for some Western Canadian coals, and coke byproducts of oil sands extraction;

- a solid fuel-burning technology which is economic in small as well as large sizes, and thus might provide a means for utilizing coal or wood waste to replace oil and natural gas in the commercial and industrial markets;

- when pressurized, a means to more efficient coal-to-electricity cycles.

However, while FBC technology is available on a normal commercial basis for incineration of waste materials such as sewage sludge and wood waste, its application to coal-fired steam generation is still under development, with only a few commercial-scale demonstrations in the western world. The CANMET energy program has accordingly given a high priority to encouraging the rapid application of FBC technology to Canadian needs, both through pilot-scale research and development, and the support of full-scale demonstration projects.

A major demonstration project on this technology was launched in 1977 when EMR and Defence Canada (DND) agreed to co-sponsor the demonstration of an atmospheric FBC boiler in the heating plant at CFB Summerside, P.E.I. DND defined its needs as a new heating plant containing two steam boilers, each having a capacity of 18 000 kg/h. The design coal would be from Cape Breton's Prince mine having a sulphur content of about 5%. Emissions of SO_2 would be controlled by means of a limestone bed. The boilers would be designed for supplementary firing of wood chips, up to 30% heat input of any load.

Since in 1977 no Canadian boiler manufacturers were in a position to offer fluidized bed boilers, it was found necessary to transfer foreign technology to Canadian suppliers. Two engineering firms submitted competing designs, one based on American technology, the other on British. Both submissions were technically acceptable, but the American design prepared by Foster-Wheeler Ltd. was selected because of its lower price. However, the competitive design process has made both firms

capable of supplying FBC boilers in Canada.

Current estimated cost of the project is $13.1 million. Foster-Wheeler was awarded the construction contract. The boilers should be ready for commissioning in December 1982.

CANMET is also participating as a technical authority in a proposed scheme to install fluidized-bed technology in a thermal power plant operated by the Nova Scotia Power Corporation. The most promising site identified is the Point Tupper generating station, where a 150-MW(e) unit could replace an existing oil-fired boiler. The Trenton station is also a possibility. An engineering firm has been engaged to conduct a detailed technical review of the potential sites, to prepare detailed specifications and to do a risk analysis. The project is funded under the federal-provincial oil substitution agreement.

In another project, CANMET invited expressions of interest in March 1980 in a joint industry-government project to demonstrate an industrial-scale FBC boiler, having approximately 100 t/h of steam capacity, to burn coal, preferably with up to 50% co-firing of wood waste. Of the seven responses received, four met the guidelines of combining design capability, fabricating capability in Canada, and identification of a Canadian end user willing to provide part of the capital cost.

A fourth project involves the possible burning of coal washery rejects in a fluidized bed to dry the clean coal product of a Western mine. A pilot-scale study in 1976 showed the scheme to be feasible. CANMET has co-funded a study for a conceptual commercial-scale design and economic analysis. Further pilot-scale tests carried out by an engineering firm showed that the rejects can be burned at high efficiency but an elaborate gas clean-up system is needed. Estimated total cost is $20 million, but less costly alternative designs are being explored.

Two other contracts on FBC are also under way. A Finnish firm is investigating the feasibility of burning high-sulphur coke from the Syncrude oil sands plant in a recirculating fluidized bed. A Canadian company is supervising tests on the coal applications of a proprietary feeder designed in Canada to feed hardwood chips into a high-pressure steam cooler. The device has potential for use in pressurized fluidizided bed combustors and coal gasifiers.

The contract work described above is complemented by experiments in two pilot-scale FBC rigs - one at CANMET and one at Queen's University. Performance characteristics of specific fuels, neutralizaton characteristics of specific limestones, metallurgical aspects of erosion and corrosion, effects of bed depth, fluidizing velocity and bed temperature on combustion, sulphur neutralization and heat transfer are all areas where pilot-scale research can contribute essential knowledge.

Since 1978 CANMET has operated a 20-cm combustor to test a variety of coals and other solid fuels. Experience with that unit was used in designing a 0.38-m rig, most of which has now been installed. An identical facility is being built at Queen's mainly to study sulphur capture by limestone or dolomite.

Transportation of Coal Slurries - The cost of transportation is a major obstacle to coal development, especially in remote areas or where the distances to be covered are great. Both these conditions are common in Canada. Coal is now moved by unit trains but where rail facilities are inadequate or non-existent, pipelines could become an attractive alternative.

This year CANMET did a comparative study of the economic and technical feasibility of transportation by the alternative carrier fluids oil, methanol and water. Preliminary results indicate that oil is the most likely carrier over long distance. If the distance is less than 1000 km, methanol has certain advantages; it is therefore a serious candidate for moving Western coal to Pacific coast ports.

For some years researchers have been concerned that pipeline transport could alter the properties of the coal. This suspicion was confirmed in coking tests on two metallurgical coals before and after pipelining. The reasons for the changes will be investigated in further research.

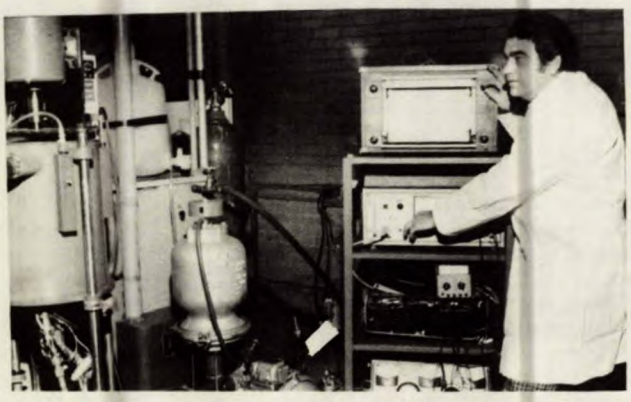
CANMET has accepted responsibility of lead agency for the Coarse Solids Water Slurry Transport and Concentration Sensor Evaluation tasks of the International Energy Agency's Mining Technology Clearing House. In this role, CANMET prepared a status report on research in several countries. The primary interest is in coarse coal transport in a water carrier over distances of 80-500 km.

Materials Requirements for Coal Technologies - One of the engineering challenges in increasing the production and use of coal is to select or develop materials that can cope with the abrasive and corrosive properties of coal ash. CANMET is using its knowledge of metallurgy to help meet this challenge.

A study of erosion and corrosion problems in washery equipment processing fine coal revealed that corrosion resistance is more important than hardness to a material's performance.

CANMET was also called upon in connection with a mine disaster investigation to assess the sparking tendency of materials used in the cutting heads of coal mining equipment. Cutter tip inserts of tungsten carbide were found to be far less prone to sparking than the hardened steels in the other components of the cutter heads. A literature survey indicated that regular sharpening of cutter tips and low cutting speeds play the most important role in suppressing sparking propensity.

Coal Analysis - The success of research programs related to energy resources hinges on the reliability of analytical data. CANMET has for many years maintained well-equipped analytical facilities to support its coal research, but with coal



J. Bednar, technologist operates laboratory installation to test erosion/corrosion of various metals and alloys for use in coal washing plants

growing in importance it is imperative that high levels of analytical expertise be more readily available in laboratories across the country. To achieve this, CANMET has created the Canadian Inter-laboratory Coal Analysis Exchange Program.

Thirty-six laboratories currently active in coal and coke analysis now participate in the program. CANMET staff prepare and distribute the samples. The laboratories then do routine analytical determinations (proximate analysis, sulphur, calorific value and free swelling index) on successive days according to ASTM standards and send the data to CANMET for statistical analysis. In three exchanges done in 1980, the analyses met high standards.

Nuclear Technology

Since the early days of Canada's nuclear program, CANMET has been active in assessing the nuclear fuel resources available in this country. As described earlier in this review, the branch joins other branches of the department in measuring resources and reserves. Under the Minerals Research Program, work on uranium mining and tailings disposal is outlined. The effort to improve the recovery of uranium and byproducts from ores, while protecting the environment, is described below.

Uranium Extraction - CANMET's current research on uranium extraction involves both conventional and new alternative technologies. Conventional technology involves sulphuric acid leaching of the ore followed by ion exchange or soluent extraction purification of the leach solution. Research on this existing technology is aimed at maximizing the recovery of uranium from low-grade and complex ores, recovering all valuable byproducts such as thorium and rare earths and producing tailings with minimum environmental impact. With respect to the latter, isolation of radionuclides such as radium-226 and thorium-230 is of prime importance in order that tailings from uranium processing operations can be disposed of safely.

CANMET scientists have initiated or completed investigations into several aspects of conventional sulphuric acid leaching. One project dealt with improved uranium recoveries and decreased costs that are associated with the choice of oxidant during the leaching of various ores. The most common oxidant is sodium chlorate, however it is expensive, often corrosive and not always the most efficient. A number of alternative oxidants were tested on various ores indicating that sodium chlorate was not always the best choice.

During the processing of sulphuric leach solutions the ion exchangers become contaminated with tetrathionate and rejuvenating them, usually with sodium hydroxide is a costly operation for mill operators. An investigation has shown that sodium carbonate and calcium hydroxide were found to perform as effectively as sodium hydroxide at costs that were approximately 20 and 10% respectively of costs involved in using sodium hydroxide.

In a cooperative project with Eldorado Nuclear Ltd., continuous ion exchange is being investigated to remove uranium from minewater of the Beaverlodge mine in Saskatchewan using the single stage, deep fluidized bed, continuous ion exchange column developed at CANMET. A continuous pilot plant run resulted in a reduction of uranium in the minewater from 9 to 0.5 µg/g thus improving the quality of the water as well as uranium recovery.

Researchers have also been looking at the reason for the formation of unwanted stable emulsions, commonly referred to as crud, in solvent extraction circuits. Current evidence indicates that a combination of the dissolved and suspended solids, together with the relatively high shear produced by the mixer contribute to the formation of crud, particularly in the extraction circuit. In the stripping circuit poor control of the ammonia addition together with shear produces the stable crud.

In many uranium circuits, precipitation and drying contribute significantly to the operating costs. A problem encountered by one Canadian plant with its uranium precipitate is the formation of a stable emulsion due to excessive amounts of silica in the precipitate when it is dissolved in nitric acid at the refinery. CANMET is investigating methods to eliminate this silica from the ion exchange-precipitation circuit at the plant. A process employing solvent extraction of the chloride eluate has successfully eliminated silica from the circuit. The process was proved on a continuous basis and product purity met refinery specifications. An alternative method involving direct precipitation of the chloride eluate by peroxide is under investigation. Development of new technology involves leaching in chloride media to solubilize all the radionuclides in the milling process and to reduce to a minimum the amount of sulphide reporting to the tailings. These new processes are also aimed at improving the recovery of byproducts such as thorium and rare earths as well as the removal of undesirable compounds such as arsenic from complex uranium ores for safe disposal.

In this search for new technology to replace sulphuric acid leaching a number of options are being

investigated. Continuous high-temperature chlorination in a vertical shaft furnace has given high recoveries of uranium, iron and radium-226 using an Elliot Lake ore as feed. Based on results obtained from bench scale tests the pilot scale furnace will be used on high-grade, complex ores containing arsenic and nickel.

Hydrochloric acid leaching of Agnew Lake ore produced tailings that were essentially free from radionuclides. Chlorine-assisted leaching was applied to several different Canadian ores with varying results.

As with coal and other energy resources, good facilities for chemical analysis are essential to the success of research programs. One of the tasks is to develop analytical methods to make the necessary measurements for the components of ore and process streams. New methods for a variety of components including isodecanol, radium and thorium were developed this year. Laboratory staff are also developing statistical sampling methods for the nuclear materials inventory in connection with a Canadian Standards Association task force. A computerized data management and evaluation system to handle radon daughter exposure data of mine workers was turned over to the Atomic Energy Control Board for production use.

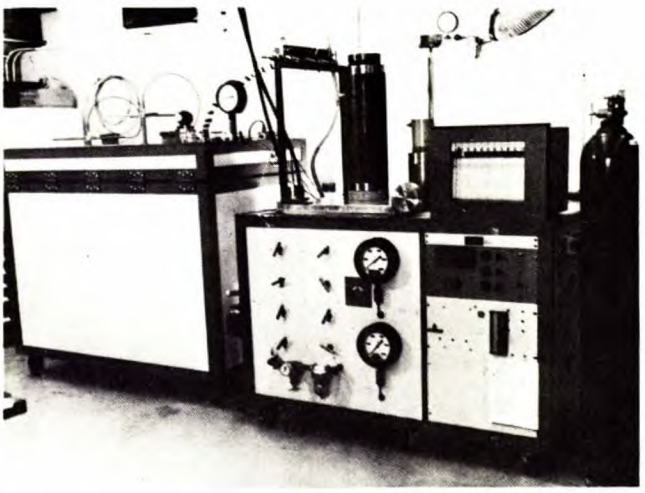
Nuclear Waste Disposal - CANMET participates in the Canadian fuel cycle waste management program by applying its expertise in rock properties, rock mechanics and underground engineering to the development of disposal sites. Potential sites at Chalk River and Atikokan, Ontario and Pinawa, Manitoba are under investigation.

CANMET is measuring the mechanical and thermal properties of rock specimens to help select a suitable site and design the repository. The thermal measurements include elongation, diffusivity and conductivity and thermomechanical stability. The factors affecting these variables are also being studied, and experimental methods are being developed to cope with varying conditions.

A cooperative study with the Lawrence Livermore Laboratory was started to develop an experimental method of studying the effect of triaxial strain on thermal diffusivity. The unit has been used to measure variation in deformational and strength properties at Pinawa.

CANMET researchers are also studying mechanical properties such as composition, texture, fracture state and porosity. A high-pressure porosimeter was used to measure porosity of Pinawa granite specimens.

Development of a repository will mean that the host formation will be pierced by a number of shafts and exploration holes, and be crossed at depth by a network of roadways and disposal galleries. CANMET scientists are working to ensure that technology is available to effectively seal off the repository and completely isolate the wastes from the surrounding environment. Shaft grouting has been investigated as a sealing technique, with emphasis on the long-term stability of emplaced grouts.



Instrumentation to measure porosity of rock specimens

Materials for Heavy Water Plants - CANMET completed a four-year project on the integrity of pressure-containing structures in heavy water plants. The impetus for this work was provided by the requirement that heavy water towers at La Prade, Quebec be able to operate at a pressure representing one-third of the ultimate tensile strength (UTS) of the structural plate rather than at a pressure representing one quarter UTS as normally required. CANMET and the Atomic Energy Control Board wished to know whether the changed design code was acceptable in view of the potential consequences. Laboratory experiments have shown that hydrogen-related damage can occur under the operating conditions in the towers but that steel is unlikely to be sufficiently affected by the change in the code to cause concern.

Renewable Energy Resources

Wood and wood wastes are alternative, renewable energy sources that are available in large quantities in Canada. By burning these fuels or converting them to other fuel forms such as gases and liquids, the energy requirements of communities and industries can be augmented, thereby reducing reliance on traditional non-renewable sources. CANMET has used its experience in solid fuel combustion to study the technical aspects of wood combustion.

Wood is growing rapidly in popularity for residential space heating. At the same time, there is increasing concern over the emissions from domestic wood-fired appliances. Incompletely burned gases and condensed liquids cause environmental concern downstream from the source, as well as posing safety hazards for the occupants of the dwelling itself, in the form of toxic carbon monoxide from combustible "creosote". These products of incomplete combustion also represent an efficiency loss, thus reducing these emissions can contribute to more efficient use of wood energy.

CANMET has developed a continuous heat loss test procedure to measure solid fuel-fired appliance performance and has carried out an R & D program to determine the effects of design on performance, considering both efficiency and emissions. Tests showed that emissions tend to decrease with increased firing rate, and are also related to appliance design. The most efficient units, with the lowest emissions were the well-designed sidedraft units. Freestanding fireplaces perform very poorly.

As well as being tested in the laboratory, stoves, furnaces and fireplace inserts are being tested in instrumented homes in the Ottawa area. Results have shown that a well-designed sidedraft or horizontal baffle stove, properly located, can be an effective complement to a conventional central heating system, and may even operate at a higher efficiency than that of the central system.

Scientists also tested synthetic fireplace logs in response to an industrial request. The information was needed in connection with the certification of these logs as a fireplace fuel. The logs are 90% paraffin and 7% sawdust. The study showed that single synthetic logs can be burned in non-airtight fireplaces or stoves without risk of overheating or excessive pollution, compared with dry maple. Heat output was 25% less than that of dry maple.

At the industrial scale, CANMET conducted a series of test burns with milled planer shavings from a forestry operation. Done in a refractory-lined tunnel furnace in the pilot plant, the trials showed that the shavings can be a feasible substitute for fuel oil in a lime-calcining kiln if milled fine enough to produce a stable flame.

CANMET also operates an advisory service for other government-sponsored projects dealing with the combustion of renewable and waste solid fuels. For example, CANMET scientists acted as technical consultants on a proposed district heating scheme using wood waste or prepared garbage. Advice on fuel selection and project management was provided.

MINERALS RESEARCH PROGRAM

The CANMET Minerals Research Program (MRP) contributed during 1980-81 to three activities of the department's Minerals Program:

MINERAL RESOURCE DETERMINATION
  Sub-activity - Technical Evaluation
MINERAL TECHNOLOGY DEVELOPMENT
  Sub-activities - Mining
  - Health and Safety
  - Marginal Mineral Resources
  - Mineral Processing
  - Conservation of Minerals and Metals
  - Environmental Technology
  - Materials Development
  - Metals Processing
  - Standards and Specifications

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT
  Sub-activity - Authorization and Testing

The main objectives of the three 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.

MINERAL RESOURCE DETERMINATION

Technical Evaluation

A strong technological base is essential for establishing the exploitability of mineral resources. CANMET is developing that base for complex base metal sulphides, for platinum-group minerals and for precious metals such as gold and silver.

Complex Sulphide Ores - The provision of technological data related to the mining and processing of known New Brunswick deposits of zinc-lead-copper-silver sulphide minerals is continuing. Mineralogical studies on the Caribou deposit were completed and results will facilitate rational planning of its development.

D.R. Owens, technologist examines mineral specimens using microprobe analyzer

Studies on the behaviour of minerals during flotation and grinding included measuring the distribution of elements and minerals in mill products from the concentrators of Brunswick Mining and Smelting (BMS), and Heath Steele Mines Ltd. Concentrator performance was evaluated by determining the recovery of free mineral grains. The possible metal recoveries that can be obtained from the ores were interpreted by determining quantities and sizes of unliberated mineral grains in the concentrator tailings.

The main loss of free sphalerite was to the Pb and bulk concentrates where the zinc is recovered. The free chalcopyrite was lost to the tailings and the free galena to all products. The tailings from both concentrators contained some coarse-grained middling chalcopyrite and sphalerite that could be liberated and recovered by regrinding. The galena is so fine grained that regrinding would not significantly improve recovery. It was interpreted that at optimum grind and mill performance the maximum recoveries that could be obtained from the BMS ores in selective concentrates would be 3-5% more Zn, 5-10% more Cu, and 1-3% more Pb with slightly better improvement possible for Heath Steele ores.

The host minerals for Ag, Sb, Bi, In, Hg and As were determined and the reasons for their occurrence in certain concentrates or tailings evaluated. In the BMS ore about 65 wt % of the silver occurred in a silver-bearing tetrahedrite, about 35 wt % in galena with a trace being found in pyrargyrite. In the Heath Steele ore, about

Pilot-scale flotation studies

35 wt % of the silver was in a tetrahedrite, about 25 wt % in galena and 39 wt % in a variety of sulpho-salts.

Studies to determine mineral liberations in various mills are currently being conducted.

A new mineral stibivanite (Sb_2VO_5), an antimony-vanadium oxide, was found at the Consolidated Durham Mines and Resources Ltd. antimony deposit, Lake George, N.B.

Platinum-Group Minerals and Precious Metals - Mineralogical research on platinum-group elements consisted of: studies on new, poorly known or unusual samples of minerals; studies on samples from mineral processing plants to determine reasons for poor recovery; and the writing and coordinating of a book to be published by the Canadian Institute of Mining and Metallurgy entitled "The platinum-group elements: mineralogy, geology, recovery". Some of the chapters were prepared in collaboration with the universities of Toronto, Ottawa, McMaster and Yale.

Although some 140 x 10^6 g of silver is contained in the annual Canadian production of zinc concentrates, little or no payment is received for this from custom zinc smelters, many of which are located in other countries. An investigation was undertaken to determine the feasibility of selectively floating a lead-silver concentrate from these concentrates. Not only would value be obtained from the sale of this lead-silver concentrate to a lead smelter but the resultant zinc concentrate would be of higher grade and therefore of greater value.

Investigations were made on zinc concentrates from the Nanisivik and Texasgulf operations treating lead-zinc-silver ores. No discrete silver-bearing minerals were found in the Nanisivik concentrate and lead-zinc-silver flotation separation was thus not attempted. All the silver appeared to be present as a constituent of sphalerite crystals. It was, however, possible to separate the zinc concentrate into high- and medium-silver portions by passing it through a high-intensity magnetic separator.

For the Texasgulf concentrate a selective flotation separation technique was developed but recoveries were too low to be economically viable. The low silver recovery was attributed to close association with sphalerite of the major portion of the silver content.

The optical emission spectrographic method for determining trace elements in sulphide ores and process products was extended to include germanium.

MINERAL TECHNOLOGY DEVELOPMENT

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

Mining Technology Development

The objective of this sub-activity is to advance the technology necessary for increasing the efficiency of both underground and open pit operating mines other than coal. Another concern is promoting technology development for diamond drilling.

Open Pit Mining - CANMET's Pit Slope Manual was completed in 1978 and to date more than 26 000 copies of individual chapters and supplements have been sold. An external committee expressed the industry's appreciation for this manual and recommended modifications and expansion of some chapters with continued research on specific topics. Audio visual packages on slope design were supplied on request. Supplement 2-1, a user's manual for DISCODAT, the geological data processing computer program was rewritten and a draft for the update of the monitoring chapter was received. An update of the blasting chapter is also in progress. Some of the reports had to be reprinted because of heavy demand and depletion of stock.

Underground Mining - The Elliot Lake rock mechanics group, initiated in 1979 by CANMET, Rio Algom Ltd. and Denison Mines Ltd. continued their investigation into regional stability. Guidelines were established on mining layouts and sequence of extraction near property boundaries so that operations of one company do not interfere with those of another. Studies were also done on a pillar removal trial at the Nordic mine and on proposed pillar recovery operations at both the Denison and Quirke mines.

To facilitate mine design, an interpretation of ground stress determination was carried out for the Canadian Shield which identified spots of high ground stress in rock masses near geological discontinuities and changes of material properties in various mines. A borehole TV inspection system was received for geological data collection in boreholes larger than 32 mm in diameter; this unit

is undergoing field trials. Studies were conducted to improve the success rate of ground stress determinations and an additive for strain gauge cement was found which improved bond quality under water. Laboratory trials with friction gauges to obtain elastic strain recovery during ground stress determinations were encouraging.

A cost-shared contract with Falconbridge Nickel Mines Ltd., for the design of a bulk mining trial at depths of 1200 to 1700 m at the Onaping mine was completed. Several mining methods were evaluated and it was concluded that sub-level longitudinal blasthole stoping was feasible provided certain problems could be overcome. These included design of a suitable support system for a relatively weak hanging-wall and a drilling and blasting pattern for a 45° dipping orebody to ensure free flow of the broken ore. It is intended to test these concepts in a trial stope.

Further research on regional stability was delayed following a fatal cave-in at the Denison mine in June 1980. A joint research project was set up between Denison and Rio Algom Ltd., to determine which monitoring system would give adequate warning of impending roof collapse. Test stopes will be instrumented with convergence meters, borehole extensometers, roof bolt load cells, rock permeability equipment and microseismic devices, after which controlled roof failure will be initiated by blasting the heads off existing rock bolts. The first test was scheduled for the spring of 1981.

A contract was awarded to investigate the potential of radar to detect dangerous roof conditions in underground mines. Field work is planned in cooperation with Elliot Lake mines.

Diamond Drilling Research - Following presentations by the Canadian Diamond Drilling Association to the federal government regarding the low level of technical innovation in diamond drilling tools, about $50 000 was made available annually for this purpose. At present four pieces of equipment are in various stages of development - a water heater, a data logger, a drill carrier, and a quiet diamond drill.

Field tests with an improved waterline heater were carried out at a test site near North Bay, Ontario. These proved the unit capable of providing the heat energy necessary for diamond drilling operations during Canadian winters. Some modifications, however, will be required for it to become a viable field unit. Further efforts were made to calibrate the data logger, using in-house facilities. The revolution-sensing unit still did not function satisfactorily and for this reason planned field tests were not carried out. Work is continuing under contract on the development of noise suppression enclosures for diamond drill equipment.

Health and Safety in Mining

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 for these environmentally related issues seldom provide a return on investment, industry tends to minimize such expenditures and to develop short-term remedies. Long-term technology development to ensure proper resolution of environment, health and safety issues is therefore dependent on government initiatives. CANMET, in cooperation with other federal and provincial agencies, is a major contributor to these developments.

Underground Environment - The objective of this project is to develop control methods capable of reducing levels of dust, radiation, noxious fumes and noise in underground mines so that average levels of exposure are below standards set by regulatory agencies.

The compressibility of air in deep mine ventilation networks requires that conventional ventilation network computer programs be modified to take this into account. A computer model is thus being generated through a contract and will be enhanced by adding plotting routines to provide a visual representation of the airflow circuits.

The quantitative determination of quartz in mine air by analyzing deposits of dust on membranes using infra-red spectroscopy is under continuing investigation.

A one-year combined dust, occupational, environmental and medical study of the iron ore mines in western Labrador commenced under the sponsorship of Memorial University. CANMET staff members are analyzing the airborne dust samples for quartz and other minerals and are acting as consultants on the occupational sampling program. A sample head designed for measuring asbestos levels has been tested and appears to work satisfactorily; however, tests cannot proceed because of difficulty in producing a controlled asbestos dust cloud.

A radon gas/meteorological continuous monitoring system under development by EDA Instruments was scheduled to be operational by June 1981. A radon/thoron calibration facility was built. A technical evaluation of several personal α-dosimeters including the USBM, alpha-NUCLEAR, H & H, Track Etch, and TLD/CAMPED was initiated at Rio Algom. A complete series of laboratory and underground flow rate measurements was carried out to determine the reliability of the CEA Track Etch personal α-dosimeter. An automatic spark counter was designed and built to count track etch films. Up to 5000 tracks can be counted in less than one second. The prototype is to be used to build a commercial instrument under contract.

The Canalph-3 portable α-spectrometer was built by Pylon Instruments during the current year and should be marketed shortly.

Theoretical work, including the writing of computer programs predicting the levels of radon and thoron gases and their decay products was completed. Calculations were made for several mine models in which the following variables were taken into consideration: diffusion and transport

mechanisms of radon/thoron gas in mine walls, attachment of decay products to mine walls, and air flow in the ventilation network system. A comparison between theoretical and experimental values was also made. Noise exposure index measurements were taken underground and on surface on 500 employees at Denison mines.

Contract work on vibration characteristics of mining equipment and its effects on workers has been completed. A specification was proposed for diesel fuel for underground use having special provisions to reduce the negative impact on the health of miners that normally available surface transport fuel would produce because of deteriorating fuel quality. Emission performance of a truck equipped with a turbo-charged engine and venturi-type water scrubber was studied. The bare engine exhaust toxicity was reduced by a significant 38% by means of equipment designed to limit emissions. Six prototype filters were designed and built under contract during 1980-81. Preliminary underground testing is to take place in 1981-82. Diesel-soot monitoring results were obtained simultaneously with gravimetrically-obtained data for a six-cylinder water-cooled engine using a smokemeter developed by CANMET's Canadian Explosive Atmospheres Laboratory (CEAL). This quick soot determination method may lead to discontinuation of the time-consuming gravimetric method. A compact exhaust cooler 250 mm OD x 500 mm in length, designed to reduce exhaust temperature at maximum load to less than 290°C, was designed and built under contract. Such coolers would permit reduced water scrubber capacity or extend the operating life of contemporary scrubbers while putting less moisture into the air thus reducing environmental fogging.

Four health effect contracts were pursued:

- USA studies were monitored with particular attention to data suggesting modifications to the form of the Health Effects Index which assesses the toxicity of multi-component diesel emissions. This study did not suggest changes in the index, but indicated the action of nitrogen-based compounds may be more responsible than diesel soot for the Ames activity and therefore for health effects.

- The Ames bioassay technique development was completed and applied to determining the Ames activity of catalytically purified exhaust samples. This work will continue in 1982-83.

- Polynuclear aromatic hydrocarbon (PNA) levels were established in some Ontario mines where diesels operate and comparisons were made with four urban centres. On average, mine exposures were 2.9 times higher than the highest ambient levels in the urban centres.

- Sampling of PNA material in mine air continued to broaden the data base of the previous year. This data included samples of diesel emissions generated with and without the action of catalytic purifiers.

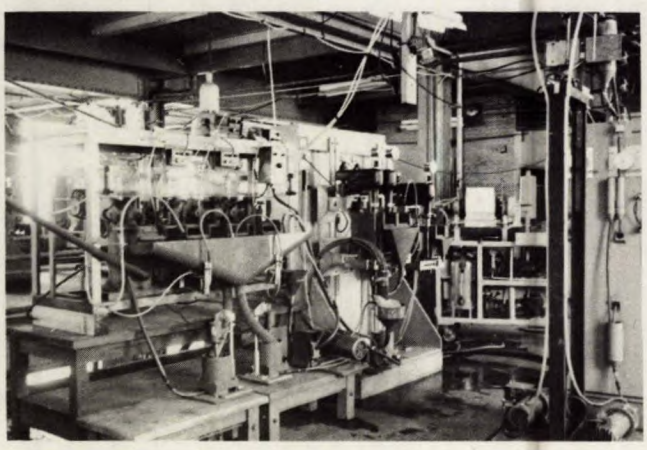
Marginal Mineral Resources Technology

Comminution and Beneficiation of Complex Sulphide Ores - The objective is to evaluate the applicability of the comminution/beneficiation techniques developed on Brunswick Mining and Smelting Corp. Ltd. (BMS) ore, to similar but lower grade and higher copper content complex sulphide ores and to determine the technical and economic merits of producing selective and bulk concentrate combinations, maintaining overall recoveries of at least 90%.

Satisfactory results were obtained for five flotation investigations using the continuous process development unit (CPDU) on complex, fine-grained sulphide ores at various feed rates.

To achieve greater efficiency at a high surface area to volume ratio a new type of cleaner flotation cell was designed, fabricated and tested. Initial results have been encouraging.

J. Vallières examines cloth of diesel exhaust filter for removing soot from engine emissions



CPDU flotation circuit

Batch and continuous tests were carried out on Heath Steele ore using the same bulk flotation technique developed for BMS ore. This was lower-grade material containing only half the zinc and lead but more copper with results on a par with those obtained for BMS ore. The results of some selective flotation tests in which lead, copper and zinc concentrates were produced, are being evaluated.

Alumina from Non-Bauxite Sources - Laboratory scale studies relating to the energy efficiency, environmental acceptability, and technical and economic viability of processes for the recovery of alumina from Hat Creek, British Columbia coaly wastes and from selected anorthosites are now essentially complete.

Because of difficulty in producing pure alumina from fluidized-bed coaly waste ash by the hydrochloric acid-gas sparge process, an alternative hydrochloric acid leach-caustic purification process was developed by CANMET. A flowsheet was devised for the recovery of alumina within specifications for all impurities.

A modified lime-sinter process was developed in which anorthosites containing differing amounts of alkali oxides were fortified with added soda increasing alumina extraction up to 27%.

For this lime-sinter process the carbon level was found to be of minor importance, whereas the molar ratio of $Na_2O:Al_2O_3$ was confirmed as one of the prime variables. The concentration of magnesia was also confirmed as a variable in this lime-sinter process and must be taken into consideration.

In a detailed study using an anorthosite and coaly waste, the complete modified lime-sinter process was examined on a laboratory scale. An ignited alumina product was obtained which was close to meeting specifications required for electrolytic reduction.

A review of potential Canadian sources for alumina is being compiled. Capital and operating cost estimates for producing alumina from Hat Creek coaly wastes by the soda-lime sinter process were prepared. Operating cost per tonne of alumina was estimated at $242 compared with the Bayer process at $211.

Extraction and Refining Complex Sulphide Ores - The economic exploitability of many of the large deposits of zinc, lead and silver in New Brunswick can only be achieved by producing bulk concentrates which are not amenable to conventional extraction and refining. CANMET is evaluating three processes to produce high value refined products. One is a chloride extraction process being investigated in-house at CANMET. Two sulphate extraction processes are also being investigated primarily at Sherritt Gordon Mines and the New Brunswick Research and Productivity Council (RPC) by means of Department of Regional Economic Expansion (DREE) contracts under the federal/provincial "General Development Agreement" for resource development, with CANMET as scientific authority.

Sulphation Roast Leach (SRL) Process - A government/industry consortium was formed to advise on the further development of the process. Economic evaluations using the CANMET system were prepared for cost/benefit comparisons of the pressure sulphuric acid (PSA) and SRL processes. High intensity magnetic separation tests on SRL process residues produced a lead-silver concentrate containing 31.5% Pb and 600 µg/g Ag with recoveries of 81 and 77%; recommendations were made for further work.

Pressure Sulphuric Acid (PSA) Leach Process - Sherritt Gordon is developing and evaluating a modified PSA process to facilitate recoveries of lead and silver from a high-grade concentrate. Estimated material and heat balances were produced for process streams in the leaching, solids/liquid separation, iron and sulphur removal and energy sensitive steps. Recommendations were made to implement new techniques to generate more accurate data in future testwork.

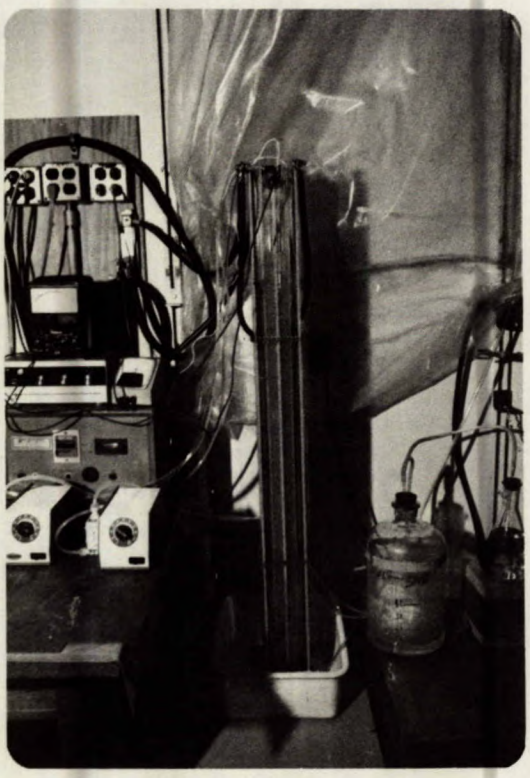
Chloride Extraction-Ferric Chloride Leach (FCL) Process - To determine to what extent nitrate ion affects leaching rates, tests were carried out in both sulphate and chloride media under percolation and vessel leaching conditions. In the ferric sulphate system, no significant catalytic effect was observed; in chloride media, high concentrations caused the rate to increase. Initial findings suggested that the accelerated leaching was due to the formation of aqua regia and that real nitrate catalysis did not occur. New experimental work on ferric ion leaching of chalcopyrite was undertaken to resolve leaching parameters still in dispute.

Studies on factors influencing the formation of alkali jarosites were initiated. Control of pH is the most important factor affecting either the yield of jarosite or its settling properties. Work is progressing on the incorporation of impurities and on factors affecting silver jarosite precipitation. Selenium is commonly associated with sulphur in sulphide ore deposits and its behaviour during jarosite precipitation has been the subject of study.

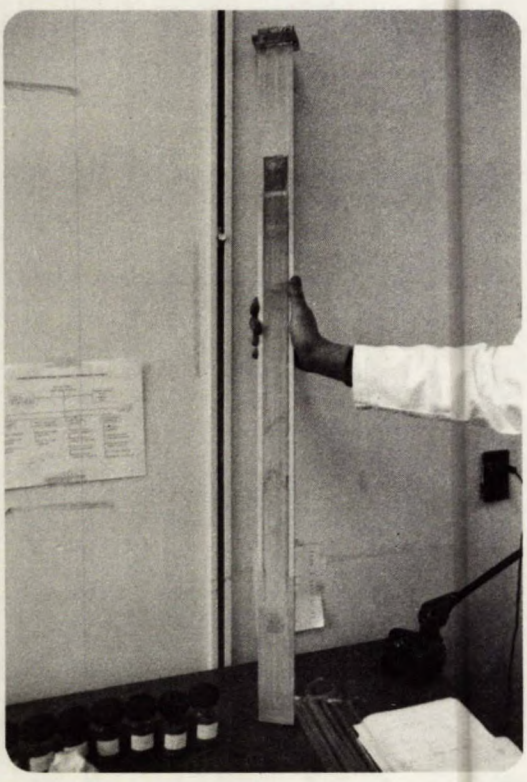
Application was filed in Canada in February 1980, to patent a new process developed at CANMET for the electrowinning of zinc from aqueous chloride electrolyte. The method, which produces smooth, compact dendrite-free 24-h zinc deposits, is considered to have long-term industrial potential for recovering zinc from low grade and complex sulphide ores. Various organic levelling agents for producing smooth zinc deposits in this system were evaluated and the effects of various impurities on the deposit were determined.

Current joint work with Cominco on zinc electrowinning from acid sulphate electrolyte is focusing on the effect of cobalt.

Conditions were established for electrowinning smooth, compact copper deposits from acid sulphate electrolytes produced by solvent extraction of copper from synthetic chloride leach solutions.



Bench-scale apparatus for electrowinning zinc from chloride solutions



Bench-scale cathode showing zinc electrowon from chloride solutions

The results of a study to determine the electrochemical parameters for the dissolution of chalcopyrite will be correlated with those obtained from the chemical leaching of this mineral in ferric ion media. The objective is to develop a model for the oxidation process to account for the electrochemical behaviour of these sulphide minerals under various conditions.

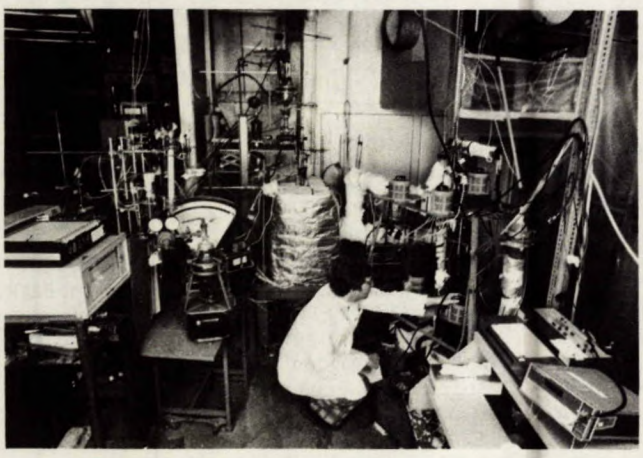
A method for the determination of small amounts of chloride and fluoride in sulphide ores, involving separation of the halides by pyrohydrolysis, has been modified.

Dry-Way Chlorination-Oxidation Process - Laboratory and mini-mini pilot scale investigations continued to optimize the operating conditions for chlorination of Brunswick concentrate at 500 to 700°C employing submerged lance chlorine injection. The chemical results were encouraging and a conceptual reactor was designed incorporating chlorination and iron removal (deferrination) steps into one continuous reactor. Heat and mass balances showed that the sulphide chlorination stage is autogenous and that no external heat input is required in the total reactor.

The first stage of development and testing of the sulphide-chlorine burner was completed under contract with the Ontario Research Foundation. In less than 0.5 s the conversion of sulphides to chlorides has normally been greater than 70% and in some cases as high as 98%.

Further work on low-temperature chlorination was terminated due to difficulties in eliminating elemental sulphur at 300°C.

As an alternative to oxidation, iron removal from chlorinated calcine by second stage chlorination to produce volatile $FeCl_3$ has been shown viable for melts without NaCl. Iron concentrations as low as 0.8% have been obtained.



G. Carter, technologist adjusts temperature on dry-way chlorination reactor

A detailed study of the kinetics of chlorination of galena was conducted using thermo-gravimetry. The results indicated that, due to the highly exothermic nature of the reaction, parameters such as particle size, container design and heat transfer had a substantial influence.

Lead chloride was found to promote completion of the oxidation of anhydrous ferrous chloride at a lower temperature with the formation of ferric chloride and iron oxychloride. The latter was found to decompose around 420°C to the chloride and oxide. There was no indication of compound formation between the chlorides.

A new atomic-absorption spectrophotometer equipped with a background corrector and improved capacity for using the standard additions technique was tested for determining silver, copper, lead, zinc and iron in sample materials from chlorination studies.

Mineral Processing Technology

The objective of this sub-activity is to develop and promote technology to increase recovery and upgrade marketable products from Canadian mineral deposits. This is achieved by generating and advancing new and improved processing techniques and equipment with particular attention to minimizing adverse effects on public health and safety, and on the environment.

Hydrometallurgical Lead Process - The objective is to provide background information and experimental data to develop a hydrometallurgical process based on chloride leaching and fused salt electrolysis for the recovery of lead, silver and other valuable components from typical Canadian lead sulphide concentrates and residues generated in the extraction and refining processes being developed for complex bulk zinc-lead-copper concentrates.

Conventional lead smelting may be unable to meet hygiene specifications for lead and cannot readily handle the lead residues. Chloride processes would give a $PbCl_2$ product which might be amenable to fused salt electrolysis or aqueous $PbCl_2$ electrolysis to recover the lead and regenerate the chlorine. Sulphate processes would result in a $PbSO_4$ product which could readily be converted to $PbCl_2$ by brine leaching. There is an incentive, therefore, to develop and evaluate leaching, purification and electrolysis techniques for recovering lead from $PbCl_2$ 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.

Studies on the leaching of tetrahedrite in ferric ion media were initiated to enhance the recovery of silver during the ferric chloride leaching of lead concentrates. Leaching rates with both natural and synthetic tetrahedrite were very low, tetrahedrite being at least as refractory as chalcopyrite.

In the hydrometallurgical lead process, the most critical factors affecting jarosite precipitation were sulphate concentration, initial pH and concentration of HCl. Initial work has shown that both silver and copper losses into the jarosite can be greatly reduced by forming strong chlorocomplexes of these metals.

Solubility experiments at temperatures ranging from 22 to 100°C in $FeCl_3$-HCl and in $FeCl_2$-Cl media showed that at constant acid concentration, the solubility of AgCl increased with increasing temperature and $FeCl_3$ concentration. At constant $FeCl_3$ concentration, the AgCl solubility increased with increasing HCl concentration. Other chlorides such as $FeCl_2$ or $CuCl_2$ enhanced the AgCl solubility whereas the addition of NaCl to the leaching solution greatly increased the solubility in $FeCl_3$-HCl media.

The solubility of $CaSO_4$ in $FeCl_3$ leaching solutions increased with temperatures from zero to 80° and dropped sharply from 80 to 100°C.

Solubility data for $PbCl_2$ in water were fitted to multiparameter equations resulting in expressions of solubility versus temperature. A compilation of $PbCl_2$ solubilities in ternary systems was made and solubility equations for the general systems MCl-$PbCl_2$-H_2O were evaluated. Preliminary tests were done to estimate $PbCl_2$ solubilities in $FeCl_3$-HCl-H_2O or $FeCl_2$-HCl-H_2O systems.

Studies on the purification of $PbCl_2$ solutions by cementation of copper and silver on lead dust showed that stirring speed was not a major variable and that temperature had little effect. Final solutions containing as little as 0.1 mg/L Ag were obtained by selective cementation of silver on copper.

Studies to determine the distribution of impurities during the electrowinning of Pb from fused salt electrolytes containing 0.6 M $PbCl_2$-0.2 M KCl - 0.2 M NaCl at various cell operating conditions are being investigated. The electrowinning of lead from aqueous chloride solutions, which is an alternative approach to obtain Pb metal from $PbCl_2$, is being done under an EMR research agreement awarded to the University of Ottawa.

Mineral Insulation - Because of the need to conserve energy and to reduce heating costs, CANMET is investigating the development of electrical melting technology for the production of thermal insulation from mineral and mineral-based indigenous resources.

Indigenous materials such as blast furnace slag-quartz, asbestos tailings-sand and basalt-limestone mixtures, were successfully melted in CANMET's electric furnace and fiberized into mineral wool. Viscosity and electrical conductivity of the melt are two of the more important factors in the mineral wool process. A technique was developed for measuring fibre diameter in mineral wool by image analysis.

Iron Ore Processing - Although Canada is well endowed with iron ore resources there is a need to improve production efficiency, reduce energy input and improve product quality and recovery if the industry is to remain competitive. High labour and energy costs have made pellets less attractive than sinter feed for blast furnaces.

The integrity of iron ore pellets produced from Iron Ore Company of Canada concentrates was studied. Apparently slag bonding is not a major factor contributing to pellet strength. Strengths of sintered pellets are highly variable and no correlation with physical parameters was found except with density, indicating that green pellet density and sintering time/temperature are probably the determining factors.

Studies are in progress to determine optimum sintering conditions; strengths are found to vary with temperature and sintering rate, indicating lack of uniformity in the bed temperature of the commercial sintering machine. Too rapid heating or cooling also adversely affects the integrity of the pellets. Microstructural changes during sintering are being examined by optical and scanning electron microscopy.

In conjunction with Environmental Protection Service a study was commenced of colloidal iron in water effluents noting zeta-potential, electrophoretic mobility, particle characterization and size distribution.

Ironmaking Technology - An ironmaking process being developed at CANMET is a possible alternative to blast-furnace smelting which requires expensive coke made from premium grades of coal. This is a coal-based direct-reduction process that can use lower grades of coal to produce liquid iron directly and will have no need for coke. Iron ore and coal are mixed and formed into composite briquettes, which when reacted at high temperatures within a body of foaming slag, produce liquid iron. Oxidation of the pellet off-gases, carbon monoxide and hydrogen provides thermal energy needed for the reduction reactors. Theoretical and bench-scale studies were completed and operational procedures for briquetting and hardening of ore-coal pellets were developed. In February 1981, pilot-plant ironmaking trials were started using a 100-kg capacity hot model basic oxygen furnace.

CANMET is studying means of reducing coke consumption in blast furnaces by regulating the quality of the iron ore feed. Recent effort has centred on determining the required degree of precision for free swelling and low-temperature disintegration testing.

Hydrometallurgical Process for Nickel-Copper - The objective of this project by 1984 is to develop and demonstrate on a laboratory scale hydrometallurgical technology for treating nickel/copper sulphide ores to recover 95% of the nonferrous metals, including precious metals and to yield elemental sulphur and an iron product. This project was initiated in response to the environmental concern over acid rain which is expected to result in the enforcement of more stringent regulations on SO_2 emissions. Although reductions in emissions can be achieved by conversion to sulphuric acid in an acid plant, marketing and storage constraints on the acid make alternative long-term solutions for SO_2 control desirable.

Niccolite is a common arsenic-bearing impurity in many nickel and copper ores which might be treated by ferric ion leaching. Studies on its dissolution in ferric chloride-hydrochloric acid media were initiated to evaluate the kinetics and stoichiometry of the oxidation reaction. One important discovery is that the arsenic liberated into solution is arsenic (III), the form most difficult to stabilize.

Studies on the electrowinning of smooth, compact, dendrite-free copper deposits from aqueous chloride electrolyte were initiated. The difficulty is that the copper prefers to deposit as crystals. The development of an electrolysis cell comprised of diaphragms and featuring electrolyte agitation by vibrating the cathode, and the use of an organic additive have overcome this problem. Compact, smooth, 24-h copper deposits have been electrowon at current density of 323 A/m^2 and at a current efficiency >90% on a consistent basis. Developmental work is continuing and will likely be extended to include an evaluation of the effect of impurities.

Simulated Processing for Ore and Coal (SPOC) - The objective of this work is to produce an expandable computer simulator of mineral dressing plants as a teaching and analytical tool for mill operators and equipment manufacturers and to contribute to the optimization of equipment design and operation. To analyze a complete mill circuit, a master program with sub-routines for each unit operation is required. CANMET's aim is to develop the master simulator and its subroutines for a modest circuit. It is estimated it will take five years to transfer the concepts and methods of process simulation to industry with consolidation of methodology being Phase 1, transfer Phase 2, and its application Phase 3.

Phase 1 was addressed by awarding five contracts to expert groups for writing chapters of an engineering manual covering key topics of process evaluation and modelling, sampling, material balance computation, modelling method, and available mineral and coal process unit models. A flexible executive FORTRAN program for plant simulation called SPOC 81 was developed in-house. Simultaneously, various aspects of methodology transfer were successfully tested. The year's effort has resulted in gathering at CANMET of state-of-the-art methods and programs in a standardized format which will be invaluable in Phase 2. A model for a balling drum was normalized for inclusion in the manuals and one of a rotary vacuum filter was completed. A material balance workshop was held at Laval University with industrial, academic and government participation. Some programs in the utility library produced by the SPOC project were documented in a format similar to that of most commercial libraries.

Conservation of Minerals and Metals

Identification, Characterization, Evaluation of Primary Mineral Wastes - The objective is to encourage further research and development on re-use of mineral wastes from waste rock, mill tailings, metallurgical slags and dusts and chemical residues. Increased utilization of these wastes would aid conservation of mineral and energy resources and could contribute to environmental improvement.

Results from studies on waste rock and mill tailing samples from the Atlantic Provinces were completed and published. Studies were started on mining and mineral processing wastes from the Prairie Provinces. Ferrous slag and dust samples were processed and examined, and technical information from ferrous metallurgical plants in Canada was compiled. Studies were initiated on non-ferrous metallurgical wastes. Morphological characterization and phase identification of inorganic wastes or manufactured materials from working environments were made to permit assessment of their health hazards.

Gold/Silver Recovery from Mill Tailings - Sharply rising prices of gold and silver stimulated interest in their recovery. The objective of this project is to prepare an inventory of both active and abandoned mill tailings that appear to have economic potential and to determine the technical and economic feasibility of such recovery.

An initial set of criteria was established to aid in identifying tailings of potential interest followed by a literature review to locate those that met the necessary criteria. Results to date indicate that: very few tailing deposits meet the established criteria; cyanide tailings usually do not contain significant amounts of gold; gravity tailings probably are more attractive from the standpoint of gold/silver recovery.

Environmental Technology

Containment or Disposal of Mine/Mill Tailings - Objectives were to reduce the detrimental effects of inactive tailings piles with regard to volume and quality of seepage and wind and water erosion. Support was given Rio Algom Mines Ltd. to conduct maintenance fertilization of a section of its tailings area. The company also implemented the direct seeding method on their tailings. Detailed identification and development of a recognizable soil profile is being done; a microbial assessment has already been conducted, and samples are being prepared for chemical and physical analysis.

A field investigation is in progress to determine the general directions of groundwater flow within tailings, to provide a basis for calculating the underground flux into and out of the tailings, and to provide a groundwater sampling network that will serve later investigations into the chemical composition of groundwater within the tailings. To achieve this, a groundwater monitor network was installed. A hydrogeochemical investigation and plume study was conducted in conjunction with the University of Waterloo. The required instrumentation in the form of nests of piezometers was installed. Core sampling was conducted to assist with the hydrogeochemistry and mass balance of contaminants. A major portion of this analysis will be done on contract. An improved method for the rapid analysis of radium-226 in water samples was developed.

The optimum composition of a mixture of shredded municipal waste, sewage sludge, wood waste and recycled compost for a windrow-composting process was determined to develop a ground cover that would facilitate revegetation of uranium tailings in areas remote from topsoil. The effects of low ambient temperatures on this mixture were estimated from laboratory experiments and showed that difficulties could be expected if the windrow process is continued during winter. This problem may be overcome by storing the mix as hydraulically-compacted briquettes which degrade without producing foul odours.

Preparation of tailings for revegetation

Same as above, showing established grass legume cover over tailings

As part of a project to measure the movement of environmental contaminants in the tailings basin of Nordic mine, drill core samples are being analyzed for various elements and radionuclides in order to determine the extent of tailings weathering.

Removal of Contaminants from Uranium Mill Effluents - The objective is to develop technology for removing environmental contaminants from uranium ores, tailings and tailing decants prior to discharge and to evaluate methods for segregating them from the environment.

The elution of radium-226 and the generation of acidic ferric sulphate solutions by the oxidation of pyrite was studied in a series of Lysimeter tests designed to simulate the effect of weathering on tailings.

Aerobic and anaerobic heterotopic bacteria were enumerated in various samples of vegetated and unvegetated tailings to establish a relationship between the bacteria count and the extent of pyrite oxidation.

Statistical analysis of data on enumerated heterotopic bacteria in Rio Algom uranium tailings test pits indicated that for the first 10 cm of pit depth, the differences in both aerobic and anaerobic bacteria counts were highly significant among the pits, but became less so with depth.

A process outline was developed for the removal, dewatering and disposal of the $Ba/RaSO_4$ sludges produced as an environmental protection measure from the tailing dam decants at uranium milling operations in Canada. The proposed process involves pond decantation and dredging, screening, cycloning, aeration, press-filtration and underground disposal of the sludge.

Preconcentration studies directed towards producing uranium and pyrite concentrates and tailings low in radium-226 content by means of flotation techniques were conducted on laboratory and continuous scales with Elliot Lake ores (0.08% and 0.1% U) and Agnew Lake ores (0.25% and 0.5% U) as feeds. Results showed that 95-98% of the uranium, 90-95% of the radium, 92-95% of the thorium and about 98% of the pyrite in the ores were recovered in the pyrite and radioactive concentrates comprising between 25 and 38% of the ore by mass. The preconcentration tailings produced from these ores contained 0.002-0.004% U, 24 pCi/g radium-226, 0.002-0.01% thorium and 0.03-0.06% S as pyrite. A contract was awarded to a private consultant to assess the economic and technical viability of this work.

Simulation of weathering of uranium tailings

Treatment of Thiosalt Effluents - The objective is to develop economically attractive processes for treating thiosalt-bearing effluents from the milling and processing of sulphide ores, and to assist industries and other external organizations in the evaluation and commercial development of the most promising alternatives.

The effects of copper, lead, zinc, iron, cadmium and silver on the determination of thiosulphate and tetrathionate by the mercuric chloride acidimetric titration method were studied. The removal of interfering elements by ion exchange was investigated.

The rate expressions for the alkaline decomposition of the three major thiosalt anions - thiosulphate, trithionate and tetrathionate were determined.

The effects of temperature, initial pH and the concentrations of ammonium, phosphate and heavy metals on the oxidation of thiosalts by an authentic strain of thiobacillus thiooxidans (ATCC 8085) and by a mixed culture isolated from a base metal processing mill effluent pond were studied. The optimum temperature was 30°C and the optimum initial pH 3.75 for both cultures using thiosulphate and for mixed culture using tetrathionate. Thiobacillus thiooxidons ATCC 8085 did not oxidize tetrathionate.

In order to determine the physical and chemical characteristics of these sulphur oxyanions which are most evident in the effluents of pyritic Zn-Pb-Cu sulphide flotation units, ultraviolet spectra were measured for aqueous solutions of pure thiosalts and related compounds and infra-red spectra were determined for the corresponding solids.

Capture-Fixation of SO_2 from Dilute Smelter Gas - The objective of this project was to conduct a technical and economic evaluation of processes suitable for treating dilute SO_2 gas streams in pyrometallurgical operations to produce a saleable or readily disposable product.

Desulphurization of dilute smelter gases is not well documented. The usual strategy in smelters is to change the process so as to produce streams having higher concentrations of SO_2 for which technology is available. A contract was awarded to evaluate a lime/limestone adsorption process to produce a potentially marketable gypsum; this work is still under way.

Control of Toxic Pyrometallurgical Emissions - The objective is to provide data on the form and distribution of the major potentially harmful elements encountered in Canadian non-ferrous processes and to develop and evaluate economically attractive methods for controlling them.

Infra-red spectroscopy, X-ray powder patterns and electron microprobe studies were conducted as a means of identifying mercury and arsenic components in feeds to non-ferrous pyrometallurgical processing plants as well as in the process streams within the plants. It was apparent during processing of the sulphide concentrates from two companies that mercury was volatilized and could thus be readily controlled. Wet scrubbing techniques to remove mercury are available, but these can add significantly to the production cost. The development of a fluidized-bed dry scrubber for removing mercury from gaseous emissions is continuing. Compilation of flowsheets and mass balances for sulphur, mercury and arsenic in nonferrous processing circuits is in progress.

Materials Development Technology

CANMET's efforts to improve the quality of metal and mineral materials embrace a wide variety of products and the processes to produce them. Projects during 1980-81 included studies to reduce the effects of corrosion and abrasion of metals and to improve their weldability and on the preparation of concretes and ceramics for special purposes.

Corrosion of Metals in the Arctic - Mild steel wire-on-bolt atmospheric corrosivity specimens, exposed at various Canadian Arctic locations for two years, provided results consistent with those obtained previously using specimens exposed for one year. Average rates of penetration by corrosion were from 2-4 μm/a at five sites in the Arctic Islands and on the northwest mainland. However, at Cape Parry, a relatively high rate of 22 μm/a was observed 1 km from the Beaufort Sea.

Commercial and laboratory carbon and weathering steels, in plate and sheet form, have been given 7 to 10 years of atmospheric corrosion tests in Ottawa and at an Arctic-marine location at Tuktoyaktuk, Northwest Territories. In Ottawa, weathering steels showed lower mass losses and shallower corrosion pit depths than carbon steels, but at Tuktoyaktuk they showed similar behaviour and generally lower corrosion rates.

Abrasion/Corrosion-Resistant Cast-on Coatings - Abrasion-resistant materials are required for many applications in the mining, construction and transportation industries. A process was developed at CANMET in which an abrasion-resistant coating can be applied during casting in a sand mould. During 1980-81, twelve dragger shoe castings of ductile iron coated with chromium carbide were made by a Canadian foundry using the process, indicating that it is readily adaptable to industrial practice. An Atlantic Coast fishing company is testing experimental dragger shoe castings with evaluations to be completed in 1981-82.

Development of High-Strength Line-Pipe Steel - In anticipation of a requirement for line pipe with higher mechanical properties than the X-70 grades now in use, CANMET established the feasibility of producing X-100 grade plate in the experimental rolling mill and quenching directly off the mill.

Abrasion-Resistant Plate Steels - In 1980-81, work continued on direct-quenched Mn-Mo-Nb steels produced in-house. The steels were harder and presumably more abrasion-resistant in the direct-quenched condition than in the conventional hardened condition. Although the experimental direct-quenched steels had the same carbon content as commercial abrasion-resistant steels, they were harder at the surface than at the centre of the plates although they contained less alloying elements.

Corrosion of Steels in Soils - Because of the economic significance of the corrosion of steels in soils and the absence of data, a contract was let for a survey report assessing the problem and proposing an appropriate testing program. Results are currently being assessed.

Abrasion-Resistant Ceramics - The purpose of this project carried out by an outside contractor, is to develop wear-resistant ceramics for the lining of materials handling systems subject to wear and corrosion. The principle involves the addition to stable hard ceramics of materials that undergo reversible polymorphic phase changes during firing thus trapping unstable phases in the microstructure. The energy of microcracks arising from wear is consumed in delayed crystalline inversion, blunting the crack and increasing wear resistance. Work included a laboratory investigation featuring polymorphs of quartz in a glass matrix of which a limited number were hot pressed. The results established procedures for fabrication and evaluation of products and indicated that the proposed mechanism was operative in abrasion tests. Materials selection and procurement for in-house investigations are in progress.

Grinding Rods - The wear of grinding rods during the milling of ores is a significant cost factor in the Canadian mining industry. Studies were continued on improving grinding rod hardness and wear resistance, by either increasing the rate of cooling after rolling or by adding alloying elements. Microstructure, hardness and fracture toughness of air-cooled C-1090 grinding rods in the as-rolled and worn conditions were observed.

Limited simulations of the effect of air- and enhanced-cooling of forged rounds were carried out. Air-cooled forgings had the same hardness of about 30 Rc as unused Canadian commercially produced rods, whereas, forgings cooled in a fluidized bed at room temperature had hardness of about 37 Rc over most of the section.

Mill and Field Weldability of Line Pipe - A survey was carried out on contract to review automatic field-welding processes for butt welding large diameter pipelines. Five processes currently in use or in the development stage were studied.

Criteria for assessing the various processes were the convenience and suitability of the methodology, weld quality, inspection needs and cost effectiveness. A series of in-house experiments examined the effects of welding voltage and current, electrode stickout and polarity on depth of penetration, bead height and width in submerged-arc welding.

Pressure Vessels - CANMET is working to improve the quality of pressure vessels to help satisfy growing energy requirements. Efforts are being made to improve welding processes. A survey and technical assessment were carried out on narrow-gap welding as practised in North America and Japan. The recommendations will form the basis for an experimental program for welding heavy sections. The strip-overlay process for cladding the internal surfaces of pressure vessels with a corrosion resistant layer was studied in-house. Optimum procedures were established.

Another objective is to construct and evaluate an automated ultrasonic test system for locating and sizing welding defects in heavy-section welds in 2 1/4 Cr 1 Mo pressure-vessel steel. To this end, "defects" were machined into the thick plate prior to multipass submerged-arc welding. Following welding, the plate was radiographed in a high-energy linear accelerator. During the past year, the ultrasonic test system was assembled and its performance compared with the radiographs from the linear accelerator.

Evaluation of microstructure/mechanical property relationships of pressure-vessel steels in the as-fabricated condition and following exposure to service environments is continuing.

Heat-Affected Zone Toughness - Stronger, more weldable plate steels are required for engineering structures. To this end, the objective of this project is to develop HSLA plate steels with improved heat-affected-zone (HAZ) toughness. The microstructure and notch toughness of the HAZ of welds in a series of controlled-rolled steels with various titanium and nitrogen contents were characterized.

The coarse-grained HAZ region, typical of submerged-arc welds in line pipes was simulated using a Gleeble thermal simulator. Steels with a titanium level of the order of 0.01% and a Ti to N ratio of <2 exhibited a significant improvement in HAZ notch toughness, i.e., the fracture energy increased by a factor of two, compared with steels that did not contain titanium. The improved notch toughness was attributed to a reduction in grain size in the HAZ. This work was supported by studies using the scanning transmission electron microscope at McMaster University.

Characterization of Weld Defects - This cooperative project with Interprovincial Pipeline Ltd. and the Welding Institute of Canada is attempting to develop a method of predicting the corrosion fatigue lifetimes for oil pipelines in terms of initial defect size, environment and operational pressure spectrum.

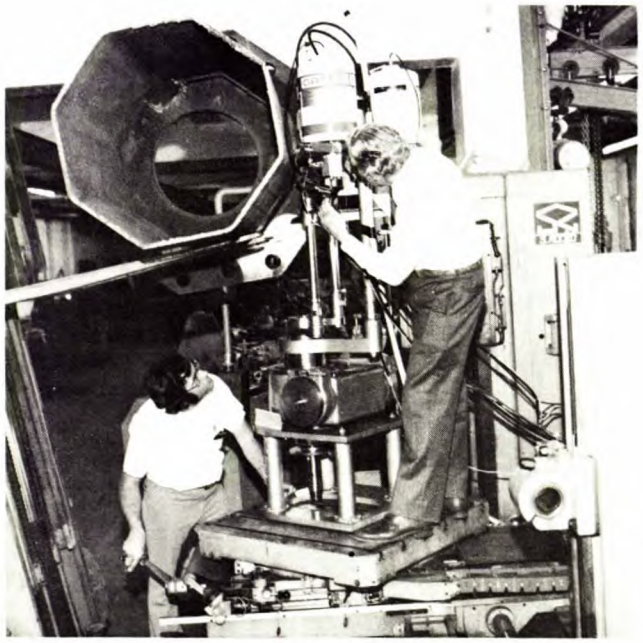
To date, fatigue-crack growth rates have been determined in standard laboratory specimens in contact with crude oil containing hydrogen sulphide. The growth rates of surface cracks in the parent metal and in the weld of welded specimens were determined in a manner simulating service conditions. These data have been combined in a computer model with a pressure spectrum synthesized from the records of an operating pipeline. With this model, the operating lifetimes have been predicted as a function of initial crack size and severity of corrosion environment. The validity of the model is currently being confirmed experimentally in a full-scale pipe test rig operated by Interprovincial Pipelines Ltd. in cooperation with the Welding Institute of Canada.

Welding Mechanics - Welding is the major method by which steel and other metals are joined for engineering structures but welding invariably results in distortion and residual stresses. The aim of this project is to develop a predictive method by which the effects of such process variables as pre- and post-heat, restraint, weld geometry, rate of welding heat input, and rate of heat extraction on distortion and residual stresses can be assessed. During the first year, a contracted review of current methods of thermo-mechanical analysis of welded joints was carried out.

Research in Plastic Flow, Fracture, and Stress Analysis - The objective of this project is to evaluate and develop test methods to measure fracture resistance of ductile materials. Attention was focused on the validity of results from tests on small specimens as a measure of the toughness of materials that may be used for the construction of large structures such as heavy wall pressure vessels. In evaluating results, attempts were made to analyze the morphology of fracture surfaces. Fracture appearance offers an important clue to identifying mechanisms of failure, and detailed interpretation of fracture surfaces can assist in devising strategies for improving material properties and specifications.

X-Ray Stress Diffractometer - Of several methods for determining the stresses present in engineering structures such as aircraft, ships, pipeline, etc., only by X-ray diffraction can it be done non-destructively. Because current X-ray equipment is unsuitable for field measurements, efforts are under way to develop portable equipment. Through contracting out and in-house research CANMET is developing a portable commercially viable instrument that has several advantages, the most important of which is its ability to read out accurate stress values in "real time" from one exposure. Equipment being developed in other laboratories requires separate exposures by the irradiating head in two different orientations with respect to the sample.

Aggregates for the Construction Industry - The objectives of this work are to develop methods for producing new types of lightweight and marginal aggregates and to evaluate their durability in concrete exposed to conventional and



Scientists E. Cousineau (L) and C.M. Mitchell (R) use transportable X-ray stress diffractometer to examine section of electrical transmission tower

aggressive environments. Lightweight aggregates were produced in the laboratory for evaluation purposes by sintering various mixtures of high carbon coal mine shales.

Durability of Concrete - The objective of this project is to evaluate and improve durability of conventional and innovative concretes in aggressive environments and mineral binder systems in which Portland cement has been partially replaced by non-conventional less-energy-intensive materials.

The deterioration of concretes in different environmental conditions was studied to determine the causes. Petrographic analysis of several samples of concrete from highway stuctures was made. Experiments were continued to determine the long-term stability of standard and infiltrated concretes in destructive environments. The destruction of concrete by unstable phases in aggregates was examined.

Regardless of the water to cement ratio, substitution of slag or fly ash for the Portland cement in the concrete was found not to affect the hydration characteristics. This implies that the hydration of Portland cement, slag and fly ash cannot be differentiated by the differential thermal analysis and X-ray diffraction techniques. Work was also conducted on determining the degradation of aggregates stored in dry heat at 150°C. Two unstable minerals were noted in the aggregates - gypsum and pyrite. The degradation was established as due to the conversion of gypsum to anhydrite, oxidation of pyrite to iron sulphates, and hydration of iron sulphates.

Studies are under way on the durability of Portland cement concrete structures exposed to waters typically prevailing in many rivers and lakes of northern Canada. The work is being carried out in close cooperation with Hydro Québec and Société d'Energie de la Baie James. A contractor is to carry out examination of specimens in 1981.

A study on the performance and durability of concrete incorporating less energy intensive materials consists of in-house laboratory research on strength development and freeze-thaw durability of cement/blast furnace slag/fly ash/silica fume concretes and complementary research performed under contract. CANMET work started in 1978 and current investigations are to determine the strength characteristics of cement/silica fume mortars in which cement has been replaced by silica fume to up to 50%. Also, work was started to determine the mechanical and elastic properties of concretes in which cement had been replaced by up to 30% with silica fume. The mixing program is complete and freeze-thaw testing has started.

Experimental work involving a large number of mortar mixes was completed. In these mixes cement was replaced by limestone dust, air-cooled slag, pelletized blast furnace slag or fly ash. Contract work comprises research on the performance of Portland cement/blast furnace slag cements in marine environments for which the third phase was completed in 1980. A number of specimens, covering a wide range of strengths and Portland cement to slag proportions are being exposed to an aggressive marine environment. The freeze-thaw durability and elastic properties of concretes containing high proportions of high-lime fly ash to cement are being investigated in studies extending into 1982.

High-Strength and Heat-Resistant Concretes - The purpose of this investigation is to provide data on the long-term behaviour of concrete at moderately high temperatures and to improve its performance through compositional modifications.

Testing concrete in simulated adverse environmental conditions

Work completed in 1979 revealed the instability of a local dolostone at 150°C, resulting in complete disintegration of concrete. Studies to explain this behaviour were continued and work also started during the year on testing of a series of concrete mixes using a reference limestone.

Standardization and Transfer of Technology - Because of CANMET's pre-eminence in non-destructive testing of concrete, the branch provides technological expertise and information for Canadian and international standards organizations. It publishes state-of-the-art papers on aggregates, cement and concrete technology and sponsors regional, national and international conferences. A test involving a new apparatus was developed under contract by Queen's University for the determination of permeability of concrete. Its reproducibility and degree of precision remain to be established.

The acoustic emission of concrete was studied under contract by the University of British Columbia with results still to be assessed. In fulfillment of CANMET's role of disseminating information, a comprehensive volume "Progress in Concrete Technology" was published in 1980. A 10-year joint project initiated in 1978 to assess existing cement specifications and testing methods in Canada was continued. It has the purpose of providing an essential tool in the updating of standards or development of new standards on cements. CANMET is coordinating the program and is in charge of the overall organization. The Laboratoire de Béton, Montreal investigated the split sleeve assembly technique for determining in situ strength of concrete. Copies of a film produced by Scott Films Limited with the technical advice of CANMET, have been sold in Mexico, Venezuela and the U.S.A. Several universities are using it as a teaching aid.

Refractories for Vacuum Refining - The objective is to characterize failure mechanisms and to develop improved specifications for refractory materials used in vacuum refining of steel.

The brick lining of the slag zone of VOD vessels from the plant of Atlas Steels at Welland, Ontario was selected for study as this is subject to the greatest wear. Samples of new and used brick and the attendant slags were provided for study.

The refractories lining the slag zone are chrome-magnesia and the failure mechanism appears to be by both slag attack - corrosion/erosion - and spalling. An apparent weakening of the unslagged cold half of the used brick due to opening up of the grain boundaries is likely, which could contribute to spalling. Cup tests are in progress to evaluate mineralogical change and thermal expansion measurements are being conducted to assess thermal shock resistance, as spalling may relate to either mechanism.

Thermal Shock Resistant Ceramics - The purpose of this project is to develop ceramics of improved thermal shock resistance. A better knowledge of the theory of thermal cracking would complement, or replace, current empirical methods of evaluation, which require laborious and time-consuming testing. The analysis of thermophysical parameters of ceramic flue-liner bodies was completed. Good correlation was obtained between the predicted order of failure in thermal shock, calculated by a novel formula and actual ranking determined experimentally. Six types of commercial refractory bricks, representing acid to basic materials, were tested in thermal shock using a water-quench procedure. Development of a heat storage system for domestic applications using a fused salt hydrate as a storage medium was completed under contract.

Metals Processing Technology

Development of Non-Leaded, Free-Machining Steels - A survey was contracted to investigate possible substitutions for lead in free-machining steels because of its almost certain banning in future as a health hazard during steelmaking operations.

Energy Conservation in the Metal-Casting Industry - Work continued on energy conservation measures: ladle preheating with gas torches, cupola melting operations, and liquid metal insulants. Gas torches are used extensively for ladle preheating in ferrous foundries. Experiments with a commercial gas torch and 250-kg capacity ladle determined preheating performance as a function of gas flow rate, position of the torch relative to the ladle, orientation of the ladle and the effect of various ladle covers. These tests showed that there was no advantage in using the ladle in an inverted or horizontal position; the torch tip should be in the centre of the ladle mouth, level with the rim, and the flame approximately coincident with the axis of the ladle; although ladle covers reduce fuel consumption by about 50%, their design is not critical; high alumina linings require greater fuel consumption to attain a given temperature than fireclay linings. Experiments to determine the effectiveness of insulants to protect the surface of molten steel in tundishes and large transfer ladles were delayed by experimental difficulties which eventually were overcome.

Continuous Casting of Metals - Continuous casting offers a method of increasing product yield by 10-15% compared with conventional casting as well as improving consistency and structure of the product. At CANMET, early work led to the development of a closed-head casting process for producing small-size sections of nickel, steel, tool steels and uranium. The work aroused widespread interest and the process has now been developed for industrial pilot-scale testing.

Trial testing of uranium alloy bar stock was conducted at Eldorado Nuclear Limited using a CANMET casting machine. Technical validity of the process as a source of uranium metal feedstock for subsequent fabrication processes was confirmed.

Trials are also under way at Sheritt Gordon Mines Limited to determine the industrial feasibility of the process for producing small-section bars of nickel for evaluation as feedstock for wire-drawing.

In another application, bars of tool steels were cast to determine the feasibility of producing tool bits with little or no hot working. Although as-cast material had inferior impact properties, as-cast and swaged material had comparable impact properties with commercial tool steels.

Mould fluxes for continuous casting are being evaluated in the mill because no laboratory test method exists to assess performance before release. A proposed CANMET method, based on measuring frictional characteristics, is the subject of research contracted-out to the Ontario Research Foundation. An apparatus was designed and partially constructed; calibration testing of specific mould fluxes and comparing the results with production tests will be carried out in future phases.

Technology for the Metal-Casting Industry

Eleven different R & D topics were investigated during the year. Work continued on the development of a nonpetroleum-based sand binder for moulds and cores which is economical, reclaimable and nontoxic; a family of compounds is currently being investigated which appears to have suitable characteristics. Under contract a foundry evaluated the industrial feasibility of the binder. Easy shake-out characteristics as well as the low-fume concentration and good surface finish were reported. A patent application was filed.

Increasing interest in the use of pure magnesium as an inoculant for producing ductile iron led to a study of the assimilation of this highly volatile element into molten irons. Based on water model experiments and the results from a wide range of investigations on the injection of magnesium wire into molten irons, a mechanism of assimilation was proposed. Techniques for introducing magnesium into molten iron were assessed and technical evaluations of new injection techniques were made.

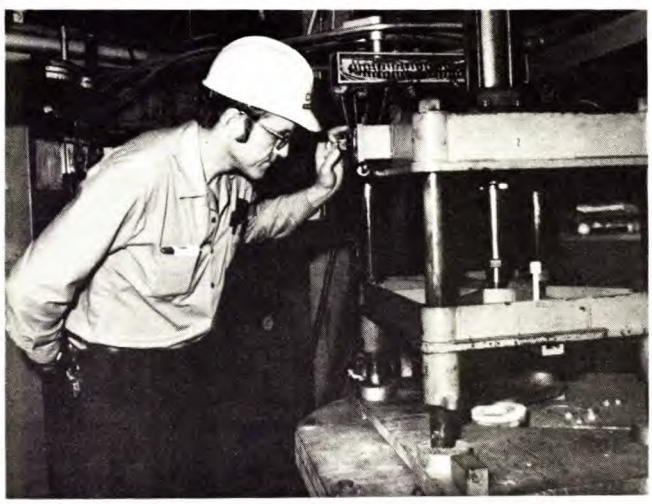
The mechanical properties of "conventionally" heat treated commercial medium-manganese steel castings were compared with the properties of similar castings given an intercritical heat-treatment. The latter had a significantly lower ductile/brittle transition temperature. Because this lowering of the transition temperature was associated with a reduction in hardness, and thus reductions in yield and ultimate strength, work is under way to investigate the effects of intercritical heat treatment on the transition temperature at a number of hardness levels. It has been shown by optical and electron microscopy that the intercritically heat-treated steels contain lath-shaped, relatively carbide-free regions which probably act as energy absorbers to inhibit crack propagation.

In foundry research to date, CANMET has found that for copper-base alloys, cast iron or steels the most promising filter to prevent dross, slag or other undesirable materials from entering into the mould cavity is a bed of granular-refractory material suitably supported within the gating system. Use of permanent mould-casting techniques continues to increase. Low-pressure permanent-mould-casting is a recently introduced variant of these processes. A research project to become familiar with this industrially important process and provide support for its use was started. An experimental low-pressure casting machine was installed in the foundry and trial castings of aluminum were made. The aim is to extend the technology developed for light metals to higher melting point alloys.

Gas dissolved during melting is a major source of casting defects in copper-base castings. As a means of controlling these defects, it is important to have some measure of the gas picked up during melting. An apparatus was constructed to measure gas content of molten copper and was demonstrated in various foundries. Because considerable skill is required to interpret the results properly, the method is likely to remain a research tool only.

Canadian steel producers have long been using single-compartment cast-copper tuyeres in blast furnaces. The performance of these tuyeres is not particularly satisfactory and blast furnace operations must be interrupted as soon as one springs a leak. Two compartment tuyeres have been developed, particularly in the U.K. which permit cooling water to be shut off in the primary cooling circuit when a leak occurs. The tuyere is cooled by water flowing through the secondary chamber. In this way, the blast furnace can be shut down and the tuyere replaced when convenient to the operation, such as immediately after tapping.

Two Canadian foundries which have traditionally supplied the bulk of the domestic market with the single type tuyeres are developing competitive double types along different lines. CANMET is providing support by exploring the technology for embodying copper tubing in a casting.



R.J. Lacroix, PMRL foundry superintendent sets up low pressure die casting machine

A 50% mixture of lithium and potassium chlorides was found to be most effective for extracting heat from the tubes although potassium chloride or nickel shot also produced satisfactory results. If a good bond is to be obtained between the copper tube and the cast metal, there must be a balance between the rate of heat input, pouring rate and temperature and that of heat extraction. The gating system also is an important variable. Successful workshops were held on foundry technology of aluminum-casting alloys during the year.

Premium Rail - During 1980-81, work on evaluating the mechanical properties of a number of commercial and experimental premium rails and developing techniques for achieving acceptable flash butt welds in premium rails and studies aimed at producing premium quality rails by mildly accelerated cooling has been terminated. Research directed towards achieving a superior quality premium rail by methods that can be adapted to commercial practice in Canadian rail mills will continue, but the focus will be narrowed and shifted to a "third generation" rail with a hardness of about Rc 44.

Vanadium has been added to experimental alloys that match the compositions of the Algoma and Sysco premium rails. In amounts up to 0.1%, the effect of vanadium is beneficial; it increases yield strength and hardness with only a marginally adverse effect on toughness.

Preliminary results of trials with experimental and commercial premium rail in the FAST (Facility for Accelerated Service Testing) track and in railway service indicate that the best curve wear performance was displayed by Russian (P65) and the Bethlehem Steel Co. fully heat-treated carbon steel rail, although of the alloy rails, fully pearlitic Cr-Mo rail was competitive. Bainitic Cr-Mo rail of identical composition demonstrated inferior performance.

A number of alloy compositions, which in response to mildly accelerated cooling of a kind that could be reproduced in the hot bed of a rail mill to produce a wholly pearlitic rail with a hardness of Rc 38, have been evaluated. A final report summarizing this work is in preparation.

In a second phase of work on process development, the possibility of developing a rail with an incrementally higher hardness than the current generation of premium rails by a non-capital intensive process adaptable to a rail mill is being explored. Preliminary experiments have shown that a hardness of about Rc 44 can be obtained by quasi-isothermal transformation of specimens of suitable composition and section size.

Rail performance is evaluated by wear tests at three levels: in-track tests, tests on the dedicated FAST rail loop at Pueblo, Colorado, and wear tests in the laboratory.

In related work, transmission electron microscopic studies of four steels in various heat-treated conditions were carried out on contract at the Technical University of Nova Scotia.

High-Strength Copper-Base Alloys for Shipboard Systems - The experience gained by CANMET in making high-strength castings in chromium- or niobium-modified cupro-nickel alloys was transferred to a commercial foundry on the strength of contracts wholly funded by Defence Canada (DND).

A two-year undertaking was begun last year with a DND-funded contract being let to produce one sound 317-kg six-valve chest casting. The complex casting is to be poured in niobium-modified 70/30 copper-nickel alloys.

Charpy V-notch impact properties of both chromium- and niobium-modified 70-30 Cu-Ni alloys were measured. In these tests, a comparison was made between test bars cut from sand-cast keel blocks and test bars heated and cooled at a very slow rate characteristic of heavy section castings. The impact properties were determined over a range of temperatures from sub-zero to the boiling point of water.

As part of a project to evaluate and refine the technology of high-strength copper-base sand cast alloys, the weldability of nickel-aluminum bronze is being assessed by a constrained butt weld test. Welding is performed with a specially developed low-aluminum filler wire having good corrosion resistance.

The effect of a range of aluminum contents and of several different nickel-iron ratios in the parent metals was determined. Work on characterizing the microstructure and measuring the mechanical properties of welded plates in the as-welded and post-weld heat-treated conditions is almost finished. Post-weld heat treating restores good corrosion resistance and improves mechanical properties.

Sand cast nickel-aluminum bronzes are more prone than other bronzes to dross formation. Thus, the use of ceramic-foam filters to prevent the entry of dross and oxide inclusions into a mould cavity was evaluated and found effective. Use of these filters will be extended to castings in other bronzes.

A series of icebreaker propeller failures revealed that the impact properties of manganese-nickel-aluminum bronzes can be low in very thick sections of sand castings. A study is under way to assess the effect of manganese and aluminum on impact properties and to determine whether remedial heat treatment can be developed. To date, a series of concast rods of appropriate compositions has been produced for heat treatment to simulate the microstructures characteristic of heavy sections in sand castings.

Thin-Walled Aluminum Castings - A project was undertaken to provide basic foundry data for producing thin-walled aluminum castings. A double-spiral fluidity test was used to compare the effects of certain moulding variables and moulding processes on several aluminum-base alloys. It was found that, with some exceptions, amorphous carbon and zircon-base mould washes increased fluidity, as did inorganic binders, whereas zircon sand moulds and organic binders decreased fluidity.

The properties of permanent-mould test bars were investigated for which no specifications exist. The structure and mechanical properties of the alloys were determined for various mould and pouring temperatures over a range of aluminum contents within specification limits.

Marine Materials - The importance to Canada of the energy and mineral resources in the Arctic and offshore regions, will require knowledge about the fabrication and performance of materials for transporting them. The objective of this project is to provide R & D support and to stimulate the means of producing and fabricating, in Canada, materials resistant to brittle fracture and bare hull corrosion for Arctic marine service. The properties of plate going into ship hulls for ice-infested waters, including several from ships already holed, were evaluated. Work continued on weld-related corrosion of hulls and on characterization of ship plate. Other work was started on welding ship plate and on Arctic marine corrosion.

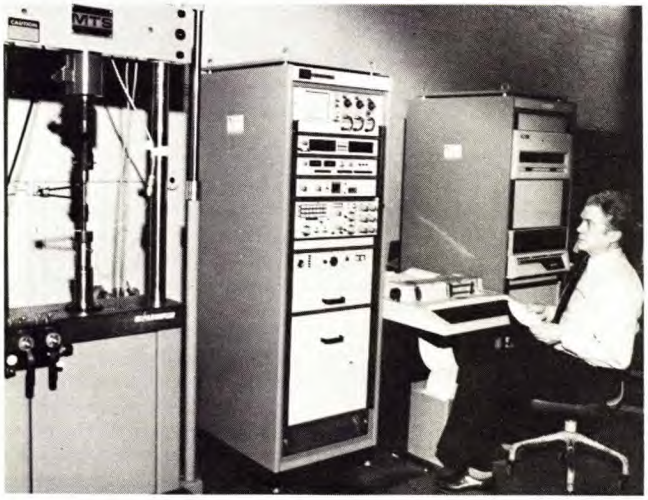
Automotive Materials - The substitution of sheet metals, having higher specific-strength for the deep-drawing quality low-carbon sheet steels currently used has been a major objective in the campaign to reduce automobile weight. Because the higher strength carbon steels are generally less formable, a project was initiated to improve their formability through developments in steel chemistry and mill processing. Current effort has concentrated on a class of steels known as dual-phase. Work has progressed in chemistry selection, processing, characterization of microstructures, and modelling of tensile behaviour.

Two discrete experimental packages were completed on batch-annealed and as-hot-rolled dual-phase steels. It was concluded that within existing specifications based on tensile properties, batch annealing is not a viable method for producing dual-phase steels. For both batch-annealed and as-hot-rolled steels, the microstructures were characterized and correlated with tensile properties.

To provide data for a mathematical model of the tensile properties of dual-phase steels, three sets of alloys were made up. These alloys were mechanically tested and the resulting data entered into the model which relates mechanical properties to structure. It was found that the upper and lower bounds of the results from the model bracket the observed tensile properties of dual-phase steels.

X-ray dispersive analysis of martensite particles demonstrated that significant partitioning of manganese occurs during intercritical annealing. The results showed that the martensite phase in batch-annealed steels had significantly greater hardenability than in continuously annealed steels.

Corrosion susceptibility of several candidate metals for automobile construction, including dual-phase steels, and aluminum alloys has continued with extended under-car and simulated under-car laboratory testing. The aluminum alloy



P. Todkill, scientist operates MTS automated closed loop electro-hydraulic materials testing system interfaced with a mini computer

and coated steels were superior to uncoated steels. As-hot-rolled dual-phase steels had better corrosion resistance than other uncoated steels which was attributed to the alloy content and not to their dual-phase nature. Laboratory tests showed that corrosion rates were decreased by periodic spraying with polyphosphate inhibitors.

Optimization of Rolling Mill Performance - Significant progress was achieved in the third year of a program to acquire a thorough metallurgical and mechanical understanding of the hot rolling process. Aim is to help meet requirements for stronger, tougher, more formable and more weldable steels which are increasingly required for the energy, mining and transportation industries.

The performance of CANMET's laboratory-scale rolling mill was correlated with that of an industrial plate mill for controlled rolling of an X-70 grade line-pipe steel. To improve the accuracy of measuring thickness of the steel rolled at each pass, tests were conducted to calibrate the springback characteristics. A system was designed for automatically controlling roll screwdown and roll speed. The control system will enable accurate, reproducible execution of controlled reduction schedules and thus simulate and optimize industrial processes.

Fluidized-Bed Cooling - The demand for shaped steel products of increased strength produced by processes that conserve energy led to investigations into innovative methods of cooling rolled-shaped steel products, one such method being fluidized-bed cooling. A pilot-scale, high-temperature fluidized bed with a maximum design temperature of 650°C for heat treating shaped steel products on line was designed and constructed; trials are under way to determine operational

capability. During 1980-81, a COPI contract to evaluate the feasibility of fluidized-bed cooling for producing premium rail was awarded to Algoma Steel Corporation.

Standards and Specifications

Reference Materials and Related Work - The Canadian Certified Reference Materials Project (CCRMP) prepares and certifies samples of ores, concentrates, metals and related materials for use as compositional reference materials. In 1980, CCRMP distributed approximately 1300 units of reference materials (RM) to users. Some major changes in procedure were instituted. For the first time, an in-house program was established for the certification of an element in a RM. The homogeneities of an iron ore concentrate, MW-1, and of a tungsten-molybdenum ore, MP-2, were established by CANMET-funded contracts.

A sample preparation was undertaken of particulate dust, PD-1, from Hudson Bay Mining and Smelting Co. Ltd., Flin Flon, Manitoba, in cooperation with the Air Pollution Technology Centre of Environment Canada. Uranium-thorium ore, DL-1a and nickel-copper-cobalt ore, SU-1a, were certified and made available for sale. Niobium ore, OKA-1, was certified and made available early in 1981.

The interlaboratory program to certify MP-1a for copper lead, zinc, silver, tin, arsenic, bismuth, indium, molybdenum, and tungsten is under way; thirty laboratories are participating. Work on the certification of DH-1a for thorium was initiated with twelve laboratories participating.

Analytical Methodology - The objective of this ongoing project is to develop and improve analytical methods, techniques and laboratory facilities, mainly in support of CANMET programs, and to participate in working groups and serve on committees of national and international organizations which develop and disseminate information on standard analytical methods.

Canadian Certified Reference Materials

A spectrophotometric method was developed for the determination of 0.0001% or more of boron in iron and high- and low-alloy steels. An atomic absorption method was developed for the determination of 0.0005% or more of aluminum in iron and high- and low-alloy steels.

Fluoride and chloride were determined in jarosite by a rapid direct method. The determination of trace amounts of arsenic - an environmentally hazardous element - by the hydride generation-flame atomic absorption method is being looked into. Investigations have continued on the standardization of atomic absorption methods for the determination of alloying and major constituents of non-ferrous alloys.

An X-ray fluorescence method, designed for bulk concentrations, has been developed for the determination of yttrium, thorium and individual rare-earth elements in ores and processed products.

An automatic sample changer was designed and constructed for the alpha spectrometer. It is integrated electronically with the counting system, which permits the automatic sequential counting of up to 8 samples. The program ANS has been implemented to produce output sheets and statistics for all samples submitted for analysis.

Toxicity of Ceramic Glazes - The objective of this work is to establish the mechanism and rate of release of toxic Pb and Cd from typical Canadian pottery glazes, as an aid to the development of "safe" glazes as defined under the Hazardous Products Act. The work also lends credibility to the Canadian position in advocating international adoption of limits for safe glazes in specifications being prepared by the International Standards Organization (ISO).

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

Authorization and Testing

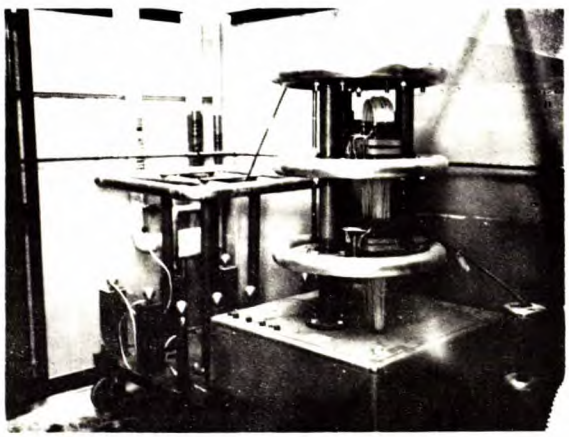
Certification and Technical Advice - The objectives of the Canadian Explosives Research Laboratory projects are: to confirm the safety characteristics of new explosives submitted for authorization under the Canada Explosives Act; to provide technical advice on the manufacture, storage and transportation of explosives; and to investigate accidents involving explosives or hazardous goods.

During the year, 302 new explosives were examined for authorization, involving 2756 sample units. Corresponding figures for 1979-80 were 238 and 2400 respectively. An investigation was made of an accidental deflagration of 3.5 t of smokeless powder which destroyed a drying building at Valleyfield Chemical Products on August 26, 1980, killing two men and fatally injuring a third. It appears certain that the powder was ignited by a discharge of static electricity of which there were at least four possible sources. Preventative

C.W. Smith, scientist performs X-ray analysis to determine thorium yttrium and rare earth elements in ores

measures were recommended but risk analysis of their production stages is continuing.

The investigation of explosion hazards of pyrotechnic mixes, following a 1977 explosion was extended. Attention is currently focused on dust explosion hazards in fireworks factories, and on hazards from dusts sensitive to spark ignition from airborne clouds. Assistance was provided in the development of a fire extinguishing system which functions five milliseconds after inadvertent ignition of a pyrotechnic mixture. In particular, an explosively driven water gun has been shown effective in reducing response times; it is anticipated this will significantly reduce the frequency of disastrous fires in pyrotechnic, propellant and ammunition plants. Ignition and possible detonation by accidental impact is a serious hazard with sensitive explosives. An extensive series of tests with drop weight impact machines indicated that drop weight results were erratic. Future investigations to correct this will involve intensive instrumentation and the use of machines accommodating samples perhaps as large as 500 g.



Generator to deliver current at 60 kV dc to simulate the effect of static electricity discharge on explosives

Requests for technical advice from other federal agencies were received from Transport Canada, Defence Canada, and the Crown Attorney at Whitby, Ontario. Advice concerning problems involving federal-provincial cooperation included a review of regulations for the use of permitted explosives in coal mine operations. An international survey is being done on permissible water gel explosives for Labour Canada and the provinces. Technical assistance was provided in the design and testing of shaped charges to be used as explosive cutters for rock bolts in a roof collapse operation at Elliot Lake. A number of requests for technical advice was received from private citizens and companies. One firm required advice concerning substitution of a cheaper alloy by a manganese bronze to make a nonsparking tool for the placement of seismic explosive charges. A second firm was developing a less hazardous ingredient for slurry explosives and required assistance with proof of performance tests by standardization of explosives test equipment. Finally, after many years, it is proposed to formally restrict the type of instruments used to check electric detonator circuits by users such as mining companies.

Research and Development - A contract for a project on the modelling of ignition and buildup to detonation in slurry explosives was advanced to about 50% completion. The first phase describing the formation and distribution of hot spots under projectile impact was extended to study effects as the volume percentage of air in the explosive is varied and as solid:liquid ratios are changed. The second phase, adopting the Forest Fire Model to the computer for calculating rates of burning, is in progress. This is used to calculate pressure and temperature as a result of the decomposition of explosives under impact during the buildup period. Sound velocity measurements were made using the pulse-echo overlap method. The high attenuative property of the slurries led to determination of their characteristic impendance and the sound velocity in several ingredients. Sound velocity measurements were also made on dummy slurry explosives as a function of pressure. Thermal conductivity of some slurry explosives was determined using a line heat source method. Explosives tested included those in their "as received" packaged state and the method was found to be quick, safe and reproducible. It is planned to extend the method using two probes at a set distance apart to determine diffusivity.

A contract for a research study to investigate the fire and explosion hazard of ammonium nitrate was executed under the joint sponsorship of CANMET, Transport Canada, and Industry, Trade and Commerce Canada with support from the ammonium nitrate manufacturers under the coordination of the Canadian Fertilizer Institute.

MINERAL AND ENERGY TECHNOLOGY INFORMATION

CANMET's Technology Information Division (TID) in close collaboration with the research and administrative staff, contributed to branch objectives by:

(1) selecting, acquiring and organizing relevant information materials to:

   (a) support in-house research;

   (b) act as the national resource centre for mineral and energy technology literature;

(2) preparing machine-processable abstracts and indexes on various aspects of mining, mineral processing, metallurgy and energy technology to facilitate access to and retrieval of essential information;

(3) disseminating scientific and technical information related to mineral and energy technology by:

   (a) editing, transcribing, publishing and arranging for the distribution of the results of research performed by CANMET staff or by private sector researchers working on CANMET-sponsored projects;

   (b) providing information and advice by responding to direct inquiries from scientists and engineers in government, universities and industry as well as from the public at large.

Information Resources Development

Through its library, CANMET is part of the national network of science-technology information centres. CANMET has, therefore, a responsibility to share its comprehensive collection of information in mineral and energy technology. In the first instance, these information resources serve the needs of CANMET research staff. However, within the context of the national network of science-technology information, the resources are also used to backstop specialized information requirements of scientists, technologists and others across the nation.

The library acquired, during the reporting period, 2820 new reference works, specialized monographs, and conference proceedings. In addition, more than 6070 research reports were received on microfiche. Adding 109 new periodical titles on subscription during the year brought the total scientific and technical journal subscription list to 2245. The exchange of publications with organizations similar to our own in both Canada and other countries around the globe continues to expand. Current holdings of mineral and energy technology information items now stand at 187 500 volumes.

Information Processing

The library's Cataloguing and Classification Unit, aided by the computer-based UTLAS cataloguing system introduced during 1980-81, processed 2051 new items. Increased productivity is expected to continue through this mechanism of sharing a common data base with other libraries and information centres. The shared system will also facilitate interlibrary lending and borrowing.

The Mining Technology Information file (MINTEC), publicly accessible through QL Systems since July 1979, continues to be well received. In the reporting period, there were 1500 individual searches of file by researchers in Canada and abroad. In all, 7537 records (including about 6000 which were created prior to 1973 and thus not in machine-readable form) were added to the file. Data for both MINTEC and the Mineral Processing Technology Information file (MINPROC) are now being entered by micro-computer onto magnetic disk for direct communication via DATAPAC to QL Systems. About 4500 MINPROC records are now ready for inclusion in the computer-processable data base. Public access to this file is anticipated in 1981-82.

On-line access to the International Energy Agency's (IEA) Coal Data Base (COAL) will be implemented as a joint effort of the IEA Coal Technology Information Service, CANMET and CISTI in July of 1981. The Canadian effort will be the first anywhere in the world to provide on-line access to this data base. This file currently contains about 26 000 records. Contributions during 1980-81 of Canadian material to the Coal Data Base amounted to 378 records.

Information Dissemination

In 1980-81, 503 reports were generated describing CANMET research and development. These included 69 reports resulting from work done by external contractors under contract. Table 1 summarizes the number and type of reports produced.

Reports not included in the CANMET Report Series (distributed through Supply and Services Canada) continue to be distributed through the services of a private sector vendor in either paper or microfiche form.

The CANMET library loaned 18 710 items to CANMET and other EMR staff. An additional 4050 items were loaned to other government departments, industry and university libraries through the interlibrary loan system. A total of 48 277 journal copies were regularly circulated to CANMET staff. Other current awareness services included 65 SDI profiles based on commercial data bases as well as 40 profiles based on the MINTEC file.

The Technical Inquiries Section (TIS) and the CANMET library responded to 2502 major inquiries for information relating to CANMET's areas of interest and expertise. The breakdown of the specific area of interest and the nature of the clientele for these is documented in Table 2. In addition, TIS handled another 2500 lesser inquiries (either in person or by telephone) which were immediately answerable and therefore not documented.

Although TID is the official information gathering and dissemination arm of CANMET, research staff of the laboratories also continue to be an important link in information dissemination and exchange, as evidenced by their active participation in responding to inquiries directed to them by colleagues in government and the research community, through organizing and participating in conferences, seminars and meetings and by serving as members of national and international scientific and technical committees.

In addition to the coal documentation already mentioned, TID staff, as the Canadian correspondents to 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, acted as distributors of IEA publications on coal science and technology to interested parties in Canada, and acted as the intermediary between suppliers and users of coal information.

Table 1 - CANMET publications by category and source, 1980-81

Category	MSL	ERL	MRL	PMRL	RPO	MRP	ERP	ADM	TID	Total
CANMET Reports	15	4		2	1				4	26
Oral presentations and journal submissions	19	28	33	34					3	117
Divisional reports	61	23	71	23			7		12	197
Internal reports	1		7	10						18
Confidential reports	6	42	1	27						76
Contract reports					69					69
Total	102	97	112	96	70		7		19	503

Table 2 - Major inquiries processed by TID staff by subject and origin, 1980-81

	Within Canada						Outside Canada				Total	
	CANMET	Other EMR	Other Government	Educational Institutions	Industry	Other	Government	Educational Institutions	Industry	Other	No.	%
Mining	185	48	120	136	313	61	18	14	56	19	970	39
Min. Proc.	143	33	64	30	157	29	7	9	23	13	508	20
Metallurgy	136	11	37	13	158	10	4	2	18	7	396	16
Energy	62	27	98	34	68	59	3	6	14	4	375	15
Coal	56	23	47	28	41	29	6	6	14	3	253	10
Totals: No.	582	142	336	241	737	188	38	37	125	46	2502	
%	23	6	15	10	29	8	1	1	5	2		100
Total within Canada											2526	91
Total outside Canada											246	9

APPENDIX A

CANMET PROFESSIONAL STAFF

DIRECTOR-GENERAL'S OFFICE

W.G. Jeffery;* B.Sc., M.Sc. (Leeds); Ph.D. (McGill); Director-General
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

V.A. Haw; B.Sc., M.Sc. (Queen's); Director, Minerals Research Program (MRP)
D.A. Reeve; B.Sc., Ph.D. (Birmingham); Director, Energy Research Program (ERP)
D.J. MacKinnon; Ph.D. (Ottawa); Assistant Director, Processing (MRP)
R.J.R. Welwood; B.Sc. (Queen's); Assistant Director, Mining and Supply (MRP)
W.N. Roberts; Ph.D. (Leeds); Assistant Director, Utilization (MRP)
G.S. Bartlett; B.Sc., B.A. (Memorial); Economist
R. Thomson, B.Sc., ARCST, Ph.D. (Glasgow); Director, Utilization & Materials
H. Sawatzky; B.S.A., M.S.A., Ph.D. (Toronto); Assistant Director, Processing

TECHNOLOGY INFORMATION DIVISION

J.E. Kanasy; B.Sc., B.A. (Windsor), M.A. (Michigan), Ph.D. (Pittsburgh); Chief of Division

LIBRARY

G. Peckham; B.A., B.L.S. (McGill); Chief Librarian
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

P.G. Sutterlin; B.Sc. (McMaster), Ph.D. (Northwestern); Section Head
G.M. Blondeau, B.A. (Queen's), M.A. (Guelph); Mining Abstractor
C.F. Dixon; B.Eng., (N.S.T.C.), P.Eng.; Metall. Info. Off.
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.
T.J. Patel; B.Sc. (Oregon State), M.Sc. (Washington State); Min. Proc. Abstractor
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.Com. (Ottawa); Ed. Asst. (French)

TECHNICAL SERVICES DIVISION

E.K. Swimmings; B.Sc. (Queen's), P.Eng.; Chief of Division
D.M. Norman; M.I.Mech. Eng. Borough Polytechnique (U.K.); Engineer

ENERGY RESEARCH LABORATORIES

B.I. Parsons; B.Sc., Ph.D. (McGill), D.Phil. (Oxford); Director

CANADIAN COMBUSTION RESEARCH LABORATORY

G.K. Lee; B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.; Manager

*Appointed 01/05/81
**Seconded to Science and Technology 09/01/80

*Retired 09/05/80
**Retired 29/12/80

EMERGING ENERGY TECHNOLOGY

F.D. Friedrich; B.Sc. (Saskatchewan), M.Sc. (Queen's), P.Eng.; Res. Sci.
E.J. Anthony; B.Sc., Ph.D. (Swansea), C.Chem.; Res. Sci.
D.L. Desai; B.E. (Sardar Patel), M.Eng. (Ottawa); Engineer

CONVENTIONAL COAL COMBUSTION

H. Whaley; B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.; Res. Sci.
G.N. Banks; B.A. (British Columbia); Res. Sci.
R.G. Fouhse; B.Sc. (Saskatchewan), P.Eng.; Engineer

ENERGY CONSERVATION AND RENEWABLES

A.C.S. Hayden; B.Eng., M.Eng. (Carleton), P.Eng.; Res. Sci.
R.W. Braaten; B.Eng. (Carleton), P.Eng.; Engineer
N.S.H. Stover; B.Sc. (Western Ontario); Engineer

ENGINEERING DESIGN AND PROJECT MONITORING

S.I. Steindl; Dipl. Eng. (Budapest), M.Sc. (Queen's), P.Eng.; Engineer

QUALITY ASSURANCE

R. Prokopuk; B.Sc. (Alberta); Chemist

COAL RESOURCE AND PROCESSING LABORATORY

T.D. Brown; B.Sc. (Durham), Ph.D. (Sheffield), C. Eng.; Manager

COAL ANALYSIS AND EVALUATION

Analyses and Standardization

W.J. Montgomery; B.S.A. (Toronto); Phys. Sci.
L.C.G. Janke; B.Sc. (Wilfrid Laurier), B.Ed. (Queen's); Phys. Sci.
J.Z. Skulski; Chem. Eng. (Wroclaw, Poland); Chemist

Coal Treatment

T.A. Lloyd; B.Sc. (Carleton); Phys. Sci.

Coal Petrography

J.G. Jorgensen; B.Sc. (Carleton); Phys. Sci.

COAL AND PEAT RESOURCES

T.E. Tibbetts; B.Sc., B.Ed. (Dalhousie); Res. Sci.
D.K. Faurschou; B.A.Sc. (Toronto); Res. Sci.
J.R. Donaldson; B.A. (Acadia); Phys. Sci.

Evaluation Laboratory - Sydney, N.S.

G.W. Bonnell; B.Sc. (Dalhousie); Chemist

NEW PROCESS INVESTIGATIONS

C.J. Adams; B.Sc., M.Sc. (McGill), Ph.D. (McMaster), P.Eng.; Res. Sci.
M. Skubnik; B.Eng., M.Eng. (Bratislava, Czech.); Phys. Sci.
I. Lau; B.Sc. (Taiwan), M.A.Sc. (Ottawa); Engineer
B.J.P. Whalley; B.Sc., Ph.D. (McGill); Res. Sci.

COAL AND COKE CONSTITUTION

B.N. Nandi; B.Sc., M.Sc. (Calcutta), Dr. Ing.; Res. Sci.
J.A. MacPhee; B.Sc. (St. Francis Xavier), Ph.D. (British Columbia); Phys. Sci.
L. Ciavaglia; B.Eng. (Carleton); Phys. Sci.

CARBONIZATION RESEARCH

J.T. Price; B.Sc., M.Sc. (Calgary), Ph.D. (Western, Ont.); Res. Sci.
J.F. Gransden; B.Sc. (London), A.R.S.M., Ph.D. (Western Ontario); Res. Sci.
V. Marwaha; B.Sc., (Punjab), M.A.Sc. (Windsor); Engineer

GASIFICATION RESEARCH

G.V. Sirianni; B.Sc. (Ottawa); Res. Sci.
R.A. Campbell;* B.Sc., M.Sc. (Queen's); Res. Sci.
D.P.C. Fung; B.Sc. (British Columbia), Ph.D. (Windsor); Res. Sci.
G.N. Banks; B.A. (British Columbia); Res. Sci.

SYNTHETIC FUELS RESEARCH LABORATORY

J.M. Denis; B.A.Sc. (Ottawa), P.Eng.; Manager
R. Ranganathan; B.E. (Annamalai, India), M.E. (Indian Inst. Sci.), Ph.D. (Saskatchewan); Res. Sci.
R.B. Logie; B.Sc. (New Brunswick), P.Eng.; Engineer
C.P. Khulbe; B.Sc., M.Sc. (Agra, India), M.A.Sc., Ph.D. (Ottawa); Res. Sci.
D.J. Patmore; B.Sc. (Bristol), Ph.D. (Alberta); Res. Sci.
K. Belinko; B.Sc. Ph.D. (Carleton); Res. Sci.
J. Tscheng; B.Sc. (Taiwan), M.Sc. (W. Virginia), Ph.D. (British Columbia); Res. Sci.
T. de Bruijn; B.Sc., Ph.D. (University of Technology, Delft); PDF

CATALYSIS RESEARCH

M. Ternan; B.A.Sc. (British Columbia), Ph.D. (McGill), P.Eng.; Res. Sci.
J.F. Kriz; Dipl. Eng. (Prague), Ph.D. (Dalhousie), P.Eng.; Res. Sci.
J.R. Brown; B.Sc., Ph.D. (Western Ontario); Res. Sci.

COAL LIQUEFACTION

J.F. Kelly; B.Eng., Ph.D. (McGill), P.Eng.; Res. Sci.
S. Fouda; B.Eng., (Cairo), Ph.D. (Waterloo); Res. Sci.

RESEARCH ON BITUMINOUS SUBSTANCES

A.E. George; B.Sc., M.Sc., Ph.D. (Cairo); Res. Sci.

*Retired 05/12/80

M.A. Poirier; B.Sc., M.Sc., Ph.D. (Montreal); Res. Sci.
S.M. Ahmed; B.Sc., M.Sc. (Osmania, India); Chemist
J.E. Beshai; B.Sc. (McMaster); Chemist

ANALYTICAL SECTION

E. Furimsky; Dipl. Eng. (Prague), Ph.D. (Ottawa); Chemist
D.M. Clugston; B.Sc., Ph.D. (McMaster); Chemist
L. Vancea; B.Sc., (Cluj), Ph.D. (Alberta); Chemist

EQUIPMENT DEVELOPMENT

L.P. Mysak; B.A.Sc. (Ottawa), P.Eng.; Engineer

WESTERN RESEARCH LABORATORY (EDMONTON)

W.R. Leeder; B.Sc., Ph.D. (British Columbia); Manager
J.L. Picard; B.Sc. (Alberta); Phys. Sci.

COAL BENEFICIATION

M.W. Mikhail; B.Sc. (Assiut), M.Sc. (Alberta), P.Eng.; Engineer
L.C. Bird; B.Sc. (Alberta); Engineer

CARBONIZATION

A.B. Fung; B.Sc. (Waterloo), P.Eng.; Engineer

COLLOID AND SURFACE SCIENCE APPLICATIONS

H.A. Hamza; B.Sc. (Cairo), Ph.D. (Newcastle-on-Tyne); Res. Sci.
A.R. Gélot; Ph.D. (Bordeaux); PDF
N.E. Andersen; B.Sc. (Alberta); Phys. Sci.
K.A. Hashmi; B.Sc. (Alberta); Engineer

MINING RESEARCH LABORATORY

T.S. Cochrane; B.A.Sc., M.Sc. (Washington); P.Eng.; Director

ROCK MECHANICS LABORATORY

G.E. Larocque; B.Sc. (Carleton); Manager
A. Boyer; B.Sc. (Montreal); Phys. Sci.
R. Boyle; B.Sc. (Ottawa); Comp. Sci.
A. Fustos; B.S.F./F.E., B.Sc. (UBC); P.Eng.; Engineer
L. Geller; Dipl. Mech. Eng. (Budapest); B.Sc. (Eng.) (London), M.A.Sc. (Toronto); Phys. Sci.
M. Gyenge; Dipl. Eng. (Budapest), P.Eng.; Res. Sci.
R.L. Sabourin; B.Sc., M.Eng. (Ecole Polytechnique) P.Eng.; Engineer
N.A. Toews; B.Sc. (Queen's); Res. Sci.
Y.S. Yu; B.Sc., M.Eng. (McGill); Res. Sci.
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A.S. Wong; B.Sc. (National Taiwan University), M.Sc. (Ottawa); Phys. Sci.
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ELLIOT LAKE LABORATORY

R.O. Tervo; B.A.Sc. (Toronto), Ph.D. (Bradford), P.Eng.; Manager
J. Bigu; M.Sc. (Barcelona), Ph.D.; Res.Sci.
V. deKorompay; Dipl. Min. Eng. (Hungary); Phys. Sci.
M. Gangal; B.Sc. (Agra, India), M.Sc. (Rokee, India & McGill), Ph.D. (Calgary); Res. Sci.
D.G.F. Hedley; B.Sc., Ph.D. (Newcastle), P.Eng. Res. Sci.
B. Kirk; B.Sc., (Waterloo); Phys. Sci.
G. Knight; B.Sc. (Birbeck, London); Res. Sci.
B. Muir; B.Sc. (Queen's); Phys. Sci.
D.R. Murray; B.A.Sc. (McDonald College); Phys. Sci.
M. Savich; Dipl. Min. Eng. (Ljobljan, Yugoslavia), B.Eng., M.Eng. (McGill); Res. Sci.
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T.P. Lim; B.Sc. (Ottawa); Phys. Sci.

CANADIAN EXPLOSIVES RESEARCH LABORATORY

J.A. Darling; B.A. (Queen's); Manager
K.C. Cheng; B.Sc., M.Eng. (Tainan Chen-Kung, Taiwan); Engineer
E. Contestabile; B.Sc. (Carleton); Phys. Sci.
K.K. Feng; B.Sc., M.Sc., Ph.D. (Iowa); Res. Sci.
R.R. Vandebeek; B.Sc., M.Sc. (Carleton); Chemist
C.A. Vary; B.Sc. (Ottawa); Tech. Off.
P. Lee; B.Sc. (Hong Kong Baptist); Chemist

WESTERN OFFICE, CALGARY

G. Zahary; B.Sc., M.Eng. (McGill); P.Eng.; Manager
R.N. Chakravorty; B.Che., (Jadavpur, India), Ph.D. (Nottingham); Res. Sci.
B. Das; B.ME (School of Mines, India), Ph.D. (Tech. Univ. of Mines, Czechoslovakia); Engineer
M.Y. Fisekci; Dipl. Eng., M.Eng., Ph.D. (Sheffield); Res. Sci.
A.S. Romaniuk; B.Sc. (Queen's); P.Eng.; Phys. Sci.
V. Srajer; M.A.Sc. (Mining) (Univ. of Applied Science, Czechoslovakia); Engineer

CANADIAN EXPLOSIVE ATMOSPHERES LABORATORY

J.A. Bossert; B.Sc., (Queen's); Manager
E.D. Dainty; B.Sc., M.Sc., (Toronto) P.Eng.; Res. Sci.
G. Lobay; B.Sc., (Manitoba); Engineer
P. Mogan; B.A.Sc. (Toronto), P.Eng.; Res. Sci.
N. Sarin; Dipl. (Mech. & Auto Eng.) (Oxford College of Technology), B.A.Sc. Mech.Eng. (Waterloo); Engineer
S. Silver; B.Sc., (Manitoba); Res. Sci.
K. Katsuyama; B.Eng., M.Eng., Ph.D. (Kyoto, Japan); PDF
J. Szymanski; B.Sc., M.Sc. (M.Eng.), M.Sc. (Mech. Eng.), Ph.D. (Mech. Eng.) (Wroclaw, Poland); PDF

MINERAL SCIENCES LABORATORIES

W.A. Gow; B.A.Sc. (Toronto); Director
E.G. Joe; B.Sc. (Queen's); Phys. Sci.

CHEMICAL LABORATORY

R.G. Sabourin; B.Sc. (Ottawa); Manager
C.H. McMaster; B.Sc., M.Sc. (Queen's); Assistant Manager

METALS AND ALLOYS

D.J. Barkley; B.Sc. (Carleton); Chemist
E.H. MacEachern; B.Sc. (Mount Allison); Chemist
A.L. Letendre; B.Sc. (Sherbrooke); Chemist

ORES AND FIRE ASSAY

J.C. Hole; B.A. (Toronto); Chemist
R.R. Craig; B.Sc. (Glasgow); Chemist

RADIATION AND MINERAL PHYSICS

M.G. Townsend; B.Sc., Ph.D. (Southampton); Res. Sci.
A. Leclerc; B.Sc., Ph.D. (Ottawa); Res. Sci.

SOLUTION CHEMISTRY

R.J. Guest; B.Sc. (Acadia); Res. Sci.
G.A. Hunt; B.Sc. (Carleton); Chemist
J.E. Atkinson; B.A. (Queen's); Chemist
A.D. King; B.Sc. (UBC); Chemist

SPECTROCHEMISTRY

G.L. Mason; A.Metallurgy (Sheffield); Chemist
J.L. Dalton; B.S., M.Eng. (Carleton); Chemist
C.W. Smith; M.Sc., Ph.D. (Queen's); Chemist
T.R. Churchill; B.Sc. (Western Ontario); Chemist
R.E. Horton; B.Sc. (Carleton); Chemist

SPECIAL ANALYSES

A. Hitchen; B.Sc. (McMaster); Chemist
B. Nebesar; M.Sc. (McGill); Res. Sci.
M.E. Leaver; B.Sc. (Queen's); Chemist

SPECIAL PROJECTS
(Research, standard methods and reference materials)
E.M. Donaldson; B.Sc. (Manitoba); Res. Sci.
E. Mark; B.A. (Toronto); Chemist
H.F. Steger; B.Sc., Ph.D. (McMaster); Res. Sci.

EXTRACTIVE METALLURGY LABORATORY

M.C. Campbell; B.Sc. (St. Francis Xavier), B.Eng. (N.S.T.C.), D.I.C., M.Sc. (London), P.Eng.; Manager

ENGINEERING AND EVALUATION

W.J. Craigen; B.Sc. (Queen's); Phys. Sci.
F.J. Kelly; B.Eng. (N.S.T.C.); Res. Sci.
J. Palmer; B.Sc. (Aberdeen), P.Eng.; Engineer
W.S. Wong; B.Eng. (McMaster), P.Eng.; Engineer

METALLURGICAL CHEMISTRY

J.E. Dutrizac; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
D.J. MacKinnon; B.Sc., M.A., Ph.D. (Ottawa); Res. Sci.
P. Pint; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
K. Bartels; B.Sc. (Carleton); Chemist
E. Rolia; B.A. (UBC); Chemist
O. Dinardo; B.Sc. (Carleton); Phys. Sci.

PHYSICAL CHEMISTRY

A.H. Webster; B.A., M.A., Ph.D. (UBC); Res. Sci.
S.M. Ahmed; B.Sc., Ph.D. (Saskatchewan); Res. Sci.
R.F. Pilgrim; B.Sc. (Queen's); Res. Sci.
R. Sutarno; B.E., M.E., Ph.D. (N.S.T.C.), P.Eng.; Res. Sci.
S.A. Mikhail; B.Sc., M.Sc., Ph.D. (Cairo); Dr. Eng. (Norway); Res. Sci.
L.G. Ripley; B.Sc., M.A. (Queen's); Res. Sci.
V.H.E. Rolko; B.Sc. (Manitoba); Chemist

PROCESS METALLURGY

G.M. Ritcey; B.Sc. (Dalhousie); Res. Sci.
B.H. Lucas; B.Sc. (Queen's), P.Eng.; Res. Sci.
A.J. Gilmore; B.Sc. (Manitoba); Res. Sci.
K.E. Haque; M.Sc., Ph.D. (Ottawa); Res. Sci.
V.N. Saleh; B.A.Sc. (Ottawa); Engineer
C. Hamer; B.E. (N.S.T.C.), M.Sc. (Queen's) P.Eng.; Res. Sci.
H.W. Parsons; B.Sc. (Alberta); Res. Sci.
V.M. McNamara; B.Sc., B.Eng., M.A.Sc. (Toronto), P.Eng.; Res. Sci.
J.M. Skeaff; B.A.Sc., M.A.Sc., Ph.D. (Toronto); Res. Sci.
A. Jongejan; Geol. Can. Drs. (Amsterdam), Ph.D.; Res. Sci.
M. Silver; B.Sc., M.Sc. (Manitoba); Ph.D. (Syracuse); Res. Sci.

MINERAL PROCESSING LABORATORY

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

CERAMICS

K.E. Bell; B.E. (Saskatchewan), P.Eng.; Res. Sci.
V.V. Mirkovich; Ph.D. (Toronto); Res. Sci.
D.H.H. Quon; B.Sc. (National Sun Yat Sen U.), M.Sc. (Ohio State), Ph.D. (Michigan); Res. Sci.
T.A. Wheat; Ph.D. (Leeds); Res. Sci.

CONSTRUCTION MATERIALS

V.M. Malhotra; B.Sc., B.E. (W. Australia); Res. Sci.
H.S. Wilson; B.E. (Saskatchewan); Res. Sci.
G.G. Carette; B.Sc. (Laval); Engineer

CRYSTAL STRUCTURE

J.T. Szymanski; B.Sc., Ph.D. (London); Res. Sci.
J.F. Rowland; B.Sc., M.Sc. (Queen's); Res. Sci.

MINERAL DRESSING

L.L. Sirois; B.A., B.Eng., M.Eng. (McGill), P.Eng.; Res. Sci.
G.I. Mathieu; B.A., B.Sc. (Laval); Res. Sci.
D. Raicevic; B.Sc. (Belgrade); Res. Sci.

A.I. Stemerowicz; B.Sc. (Queen's), P.Eng.; Res. Sci.
D. Laguitton; Chem. Eng. (Rennes), D.Sc. (Laval); Res. Sci.
K.S. Moon; B.Sc., M.Eng. (Seoul National U.); M.A.Sc., M.Eng. (British Columbia), Ph.D. (California); Res. Sci.
J.H.C. Leung; B.Sc. (Taiwan), M.Sc. (Waterloo); Phys. Sci.
J.M.D. Wilson; B.Sc., M.A.Sc. (Queen's); Phys. Sci.
W.H. Cameron; B.Sc. (Queen's); Phys. Sci.

MINERALOGY

R.M. Buchanan; B.A., M.A. (Toronto); Phys. Sci.
L.J. Cabri; B.Sc., M.Sc., Ph.D. (McGill); Res. Sci.
J.L. Jambor; B.A., M.Sc., Ph.D. (Carleton); Res. Sci.
D.C. Harris; B.Sc., M.A., Ph.D. (Toronto); Res. Sci.
W. Petruk; B.Eng., M.Sc., Ph.D. (McGill); Res. Sci.
T.T. Chen; B.Sc. M.Sc., Ph.D. (Cornell); Res. Sci.
J.A. Soles; B.A.Sc., M.A.Sc. (British Columbia), Ph.D. (McGill), P.Eng.; Phys. Sci.
M.R. Hughson; B.A. (Western Ontario); Phys. Sci.
R.S. Dean; B.Sc., M.Sc., Ph.D. (McGill); Res. Sci.

NON-METALLIC AND WASTE MINERALS

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

VISITING RESEARCH FELLOWS

A. Ahmed; B.Sc., M.Sc., Ph.D. (New Brunswick)
R. McMillan; Ph.D. (British Columbia)
R.M. Morrison; Ph.D. (British Columbia)

PHYSICAL METALLURGY RESEARCH LABORATORIES

W.H. Erickson; B.Sc., M.Sc. (Mich. Tech); Ph.D. (Durham), P.Eng.; Director

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. (British Columbia); Res. Sci.
J.L. Dion; B.A.Sc. (Montreal), P.Eng.; Phys. 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. (British Columbia), Ph.D. (Cambridge); Res. Sci.
L. Whiting; B.Sc., M.Sc., Ph.D. (McGill), MBA (Ottawa); Res. 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.

NONDESTRUCTIVE TESTING

V.L. Caron; B.A.Sc. (Laval), M.Eng. (Paris) P.Eng.; Phys. Sci.

WELDING

J.T. McGrath; B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.; Res. Sci.
Z. Paley; B.Sc., M.Sc. (Haifax), Ph.D. (McGill); Res. Sci.
R.D. McDonald; B.Sc. (Queen's), P.Eng.; Res. Sci.

METAL DEVELOPMENT LABORATORY

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

CORROSION SCIENCE

G.J. Biefer; B.Sc., Ph.D. (McGill); Res. Sci.
R.J. Brigham; B.Sc., Ph.D. (McGill); Res. Sci.
D.C. Briggs; B.Eng., M.Eng. (McGill), Ph.D. (Queen's); Res. Sci.
J.B. Gilmour; B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.; Res. Sci.
G.R. Hoey; B.Sc., M.Sc., Ph.D. (Toronto); Res. Sci.
A.W. Lui; B.Sc., M.A.Sc., Ph.D. (Windsor); 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.
W.R. Tyson; B.A.Sc. (Toronto), Ph.D. (Cambridge); Res. Sci.

*Retired 19/09/80
**Retired 17/10/81

METALLURGY

J.D. Boyd; B.A.Sc. (Toronto), Ph.D. (Cambridge); 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.
A. Couture; B.A., B.A.Sc. (Laval), P.Eng.; 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.
M.T. Shehata; B.Eng. (Cairo), Ph.D. (McMaster); Res. Sci.

CANMET STAFF AS OF MARCH 31, 1981

Division	Professionals	Non-professionals	Total
Administration and Central Services	4	88	92
Research Program Office	9	8	14
Energy Research Laboratories	57	78	135
Mining Research Laboratories	45	36	81
Mineral Sciences Laboratories	82	87	169
Physical Metallurgy Research Laboratories	46	74	120
Technology Information Division	12	23	35
Totals	255	394	646

APPENDIX B

CANMET REPRESENTATION ON TECHNICAL COMMITTEES 1980-81

INTERNATIONAL

BRITISH FLAME RESEARCH COMMITTEE (member)	G.K. Lee (ERL)
CANADA/JAPAN COAL LIQUEFACTION COORDINATING COMMITTEE	
Coal Liquefaction Experimental Testing Program (secretary)	J.F. Kelly (ERL)
FUEL (London) (Eastern Regional Editor)	A.E. George (ERL)
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 COMMITTEE ON COAL 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 STRENGTH OF METALS AND ALLOYS	
Organizing Committee (member)	W.K. Tyson (PMRL)
INTERNATIONAL CONFERENCE ON THERMAL CONDUCTIVITY CONFERENCE (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)
Technical Information Service	
Executive Committee (member)	D.A. Reeve (RPO)

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 Committee (member)	J.E. Kanasy (TID)
Coal-Oil Mixture Implementing Agreement	H. Whaley (ERL)
Atmospheric Fluidized Bed Combustion Agreement	F.D. Friedrich (ERL)
Task VI (Photocatalytic Water Electrolysis) of the Program of Research and Development on Production of Hydrogen from Water (Canadian Technical Contact Person)	S.M. Ahmed (MSL)

INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL SYMPOSIUM ON AUTOMATION IN MINING, MINERAL AND METAL PROCESSING

Organizing Committee (member)	L.L. Sirois (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 (vice-chairman)	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 JOURNAL OF PRESSURE VESSEL AND PIPING

Editorial Board (member)	J.T. McGrath (PMRL)

INTERNATIONAL MINERAL PROCESSING CONGRESS (14th) (1982)

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 of Ore Microscopy (Canadian representative)	L.J. Cabri (MSL)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION - CANADIAN ADVISORY COMMITTEE

CERTICO, Certification (member)	J.A. Bossert (MRL)
REMCO, Reference Materials (chairman)	R.G. Sabourin (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)
TC24, Sieves, Sieving and other Sizing Methods (member)	G.W. Riley (MSL)
TC25, Cast Iron (member)	R.K. Buhr (PMRL)
TC26, SC1, Copper and Copper Alloys (member)	R.G. Sabourin (MSL)
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)	W.R. Leeder (ERL)
WG6, Evaluation of Flocculants for use in Coal Preparation (convener)	H.A. Hamza (ERL)
WG9, Grindability (member)	W.J. Montgomery (ERL)
WG12, Plasticity (member)	T.A. Lloyd (ERL)
WG13, Ash Analysis (secretary)	W.J. Montgomery (ERL)
TC33, Refractories (member)	K.E. Bell (MSL)
TC56, Mica (chairman)	G.W. Riley (MSL)

TC69, Application of Statistics (member) ..... R. Sutarno (MSL)
SC6, Precision (Canadian representative) ..... R. Sutarno (MSL)
TC71, Concrete (chairman) ..... V.M. Malhotra (MSL)
TC77, Asbestos (member) ..... G.W. Riley (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 (RPO)
(member) ..... A.L. Job (TID)
TC102, Iron Ores (chairman) ..... G.W. Riley (MSL)
(member) ..... R. Sutarno (MSL)
SC1, Sampling (chairman) ..... R. Sutarno (MSL)
(member) ..... G.W. Riley (MSL)
SC2, Chemical Analysis (chairman) ..... R. Sutarno (MSL)
(member) ..... G.W. Riley (MSL)
Reference Materials (Canadian representative) ..... R. Sutarno (MSL)
WG7, Statistics (chairman) ..... R. Sutarno (MSL)
ISO/TC102/WG12, Statistical Methods (convener) ..... R. Sutarno (MSL)
SC3, Physical Testing of Iron Ores (chairman) ..... J.T. Price (ERL)
(member) ..... G.W. Riley (MSL)
SC4, Size Determination, Iron Ores (chairman) ..... G.W. Riley (MSL)
(member) ..... G.W. Riley (MSL)
TC107/SC6, Metallic and other Inorganic Coatings (member) .... K.E. Bell (MSL)
TC109, Domestic Oil Burners (member) ..... A.C.S. Hayden (ERL)
TC111/SC1, Chain (member) ..... R.K. Buhr (PMRL)
TC119, Testing of Powder Metallurgical Materials and
Products (member) ..... H.M. Skelly (PMRL)
TC146 Air Quality
SC1, Stationary Source Emissions (member) ..... H. Whaley (ERL)
SC2/WG5, Inorganic Fibres (chairman) ..... G.W. Riley (MSL)
SC2/WG1, 5, (member) ..... G. Knight (MRL)
TC155, Nickel and Nickel Alloys (members) ..... M.J. Lavigne (PMRL)
..... R. Sutarno (MSL)
TC156/WG1 Corrosion of Metals and Alloys/Terminology (member). G.J. Beifer (PMRL)
TC163/SC3, 4, Insulation (member) ..... S.S. Wang (MSL)
TC164, Mechanical Testing of Metals (chairman) ..... P.J. Todkill (PMRL)
(members) ..... A.F. Crawley(PMRL)
..... O. Vosikovsky (PMRL)
TC166, Ceramic Ware in Contact with Foods (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 SOCIETY FOR ROCK MECHANICS

Commission on Standardization of Laboratory
and Field Tests (member) ..... G. Herget (MRL)

INTERNATIONAL SOLVENT EXTRACTION TECHNOLOGY COMMITTEE (member) ... G.M. Ritcey (MSL)

INTERNATIONAL STRATA CONTROL CONFERENCE (7th) (1982)

International Organizing Committee (member) ..... T.S. Cochrane (MRL)

INTERNATIONAL SYMPOSIUM ON AEROSOLS IN THE MINING
AND INDUSTRIAL WORK ENVIRONMENT

Program Committee (member) ..... G. Knight (MRL)

INTERNATIONAL THERMAL CONDUCTIVITY CONFERENCE (director) ..... V.V. Mirkovich (MSL)

INTERNATIONAL TUNNELLING ASSOCIATION

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

INTERNATIONAL UNION OF CRYSTALLOGRAPHY 13th CONGRESS
AND GENERAL ASSEMBLY

Organizing Committee (members) ..... K.S. Milliken (PMRL)
..... C.M. Mitchell (PMRL)

Micro Symposium on New Detectors (co-chairman)	K.S. Milliken (PMRL)
Commercial Exhibits Committee (chairman)	C.M. Mitchell (PMRL)
(member)	K.S. Milliken (PMRL)
Non-Commercial Exhibit Committee (chairman)	C.M. Mitchell (PMRL)
(member)	K.S. Milliken (PMRL)
Crystallographic Studies at Controlled Pressure (co-chairman).	C.M. Mitchell (PMRL)
Renaissance of Powder Diffraction (co-chairman)	C.M. Mitchell (PMRL)
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)
JOURNAL OF SEPARATION PROCESS TECHNOLOGY	
Editorial Board (member)	G.M. Ritcey (MSL)
NATIONAL COMMITTEE FOR WORLD HYDROGEN ENERGY CONFERENCE 1984 (member)	S.M. Ahmed (MSL)
NUCLEAR ENERGY AGENCY/INTERNATIONAL ATOMIC ENERGY AGENCY	
Working Group on Uranium Extraction (vice-chairman)	M.C. Campbell (MSL)
ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT	
Ammonium Nitrate Subcommittee (member)	J.A. Darling (MRL)
International Group of Experts on Unstable Substances (member)	J.A. Darling (MRL)
Long-Range Transport of Air Pollution (member)	H. Whaley (ERL)
Waste-Heat Utilization (member)	F.D. Friedrich (ERL)
Scientific and Technological Policy Committee (departmental representative)	V. Caron (PMRL)
SCIENCE AND TECHNOLOGY OF TRIBUTYL PHOSPHATE	
Editorial Board (member)	G.M. Ritcey (MSL)

UNITED STATES OF AMERICA

AIR POLLUTION CONTROL ASSOCIATION	
Residential Heating (member)	A.C.S. Hayden (ERL)
AMERICAN CONCRETE INSTITUTE	
Committee 214, Strength Evaluation (chairman)	V.M. Malhotra (MSL)
AMERICAN CONFERENCE ON GOVERNMENTAL INDUSTRIAL HYGIENISTS - AMERICAN INDUSTRIAL HYGIENE ASSOCIATION	
Aerosol Technology Committee	G. Knight (MRL)
AMERICAN DEEP DRAWING RESEARCH GROUP (member)	A.F. Crawley (PMRL)
AMERICAN FOUNDRYMEN'S SOCIETY	
Brass and Bronze Division (member)	M. Sahoo (PMRL)
Ductile Iron Division Research Committee (secretary)	R.K. Buhr (PMRL)
Editorial Board, International Cast Metals Journal (member)	R.K. Buhr (PMRL)

AMERICAN INSTITUTE OF MINING, METALLURGICAL AND PETROLEUM ENGINEERS

Electrolytic Processes Committee (member)	D.J. MacKinnon (MSL)
Hydrometallurgy Session, Las Vegas (chairman)	G.M. Ritcey (MSL)
Metal. Trans. (key reader)	J.E. Dutrizac (MSL)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Air Pollution Control Division Research Committee (member)	H. Whaley (ERL)
Fuels Division Research Committee (members)	G.K. Lee (ERL)
	T.D. Brown (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

Advisory Technical Awareness Council (member)	J.D. Boyd (PMRL)
Ottawa Valley Chapter (secretary-treasurer)	R.W. Revie (PMRL)
(asst. secretary-treasurer)	J.T. McGrath (PMRL)
(education chairman)	M. Sahoo (PMRL)

AMERICAN SOCIETY FOR TESTING AND MATERIALS

Task Groups on Mining Wastes and Process Wastes (member)	R.K. Collings (MSL)
C-9, Concrete (secretary)	V.M. Malhotra (MSL)
C-9-02-05, Nondestructive Testing of Concrete (chairman)	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)	T.A. Lloyd (ERL)
D-5-21, Methods of Analysis (member)	W.J. Montgomery (ERL)
D-5-22, Physical Testing of Coke (member)	T.A. Lloyd (ERL)
D-5-27, American Group ISO/TC-27 (member)	W.J. Montgomery (ERL)
D-5-28, Petrographic Analysis of Coal (members)	B.N. Nandi (ERL)
	J.G. Jorgensen (ERL)
D-5-29, Major and Trace Elements (member)	W.J. Montgomery (ERL)
E07-02-01, Magnesium Alloys (chairman)	B. Lagowski (PMRL)
E-9, Fatigue (member)	O. Vosikovsky (PMRL)
E-16, Sampling and Analysis of Metal-Bearing Ores and Related Materials (member)	R. Sutarno (MSL)
E-24, Fracture Testing of Metals (member)	O. Vosikovsky (PMRL)
E-24-04-05, Fatigue crack growth rate testing in aqueous environments (member)	O. Vosikovsky (PMRL)
E-28, Mechanical Testing (member)	P.J. Todkill (PMRL)
E-38-06, Materials of Construction from Recovered Materials (member)	R.K. Collings (MSL)

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)

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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

Task Group T-1F-17, Sulphide Stress Cracking Data by NACE Tensile Test Procedure (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)
NATIONAL RESEARCH COUNCIL	
Transportation Research Board Committee A2-E03, Mechanical Properties of Concrete (chairman)	V.M. Malhotra (MSL)
USBM ALUMINA STEERING COMMITTEE (observer)	C.A. Hamer (MSL)
U.S./CANADA COOPERATIVE AGREEMENT ON OIL SANDS	
Joint Water Treatment Committee (member)	H.A. Hamza (ERL)
U.S./CANADA INTERAGENCY WOOD COMBUSTION RESEARCH GROUP (member)	A.C.S. Hayden (ERL)
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)
U.S. DEPARTMENT OF ENERGY	
Coal-Oil Mixtures Standards and Practice Committee (member)	H. Whaley (ERL)
Combustion Subcommittee (chairman)	H. Whaley (ERL)
WELDING RESEARCH COUNCIL	
High Alloys Committee (member)	M.J. Lavigne (PMRL)
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

ATOMIC ENERGY CONTROL BOARD	
Mine Safety Advisory Committee (alternate member)	A.S. Romaniuk (MRL)
CANADIAN ARMED FORCES CORROSION PREVENTION COMMITTEE	
Ottawa Subcommittee (member)	J.B. Gilmour (PMRL)
CANADIAN GOVERNMENT SPECIFICATIONS BOARD	
Subcommittee on Middle Distillates Diesel Fuel Panel (member)	J.P. Mogan (MRL)
3-GP, Petroleum Test Methods Subcommittee (member)	E. Furimsky (ERL)
Middle Distillate Fuels Subcommittee (member)	A.C.S. Hayden (ERL)
8-GP, Sieves, Testing, Woven Wire (member)	G.W. Riley (MSL)
10-GP, Refractories (member)	K.E. Bell (MSL)
18-GP, Solid Fuels (member)	W.J. Montgomery (ERL)
Stationary Combustion (chairman)	A.C.S. Hayden (ERL)
48-GP, Nondestructive testing (member)	V. Caron (PMRL)
51-GP, Thermal Insulation (members)	S.S. Wang (MSL)
	A.C.S. Hayden (ERL)
52-GP, Major Kitchen Equipment (member)	R.D. McDonald (PMRL)
53-GP, Shears (member)	D.E. Parsons (PMRL)
75-GP, Ceramic Tile (member)	K.E. Bell (MSL)

CANADIAN TRANSPORT COMMISSION

Cast Steel Propeller Specifications Committee (member)	D.E. Parsons (PMRL)

CANMET

Environment Improvement Committee (member)	R.K. Buhr (PMRL)
Editorial and Publications Committee (chairman)	C. Mamen (TID)
(members)	J. Collins-DeCotret (TID)
.....	J. Metz (TID)
.....	J. Scott (MRL)

COUNCIL OF FEDERAL LIBRARIES

Steering Committee (member)	J.E. Kanasy (TID)
Committee on Collections Rationalization (vice-chairman)	J.E. Kanasy (TID)
Subcommittee on Library Delivery Services (member)	G.M. Peckham (TID)

ENERGY, MINES AND RESOURCES CANADA

Canada/Saskatchewan Heavy Oil Management Committee (member) ..	H.A. Hamza (ERL)
Canadian Advisory Committee on Hydrogen (member)	S.M. Ahmed (MSL)
CANMET Hydrocracking Liaison Committee (chairman)	J.M. Denis (ERL)
CANMET Metric Committee (metric conversion officer)	B. Nebesar (MSL)
Steering Committee 4 (members)	M.J. Lavigne (PMRL)
.....	B. Nebesar (MSL)
Sector Committee 4.1 (members)	M.J. Lavigne (PMRL)
.....	B. Nebesar (MSL)
CANMET SPOC (Simulated Processing of Ore and Coal) Project Technical Committee (member)	M.W. Mikhail (ERL)
Coal Committee (members)	J.S. Cochrane (MRL)
.....	T.E. Tibbetts (ERL)
Coal Reserve Assessment Subcommittee (member)	A.S. Romaniuk (MRL)
Coal Coordinating Committee (member)	D.A. Reeve (RPO)
Committee of Chief Librarians (member)	G.M. Peckham (TID)
Committee on Energy Conservation (member)	V.A. Haw (DGO)
Committee on Occupational Health and Safety (member)	A. Hitchen (MSL)
Committee on Ocean Mining (members)	D.J. MacKinnon (MSL)
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