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Cover Photo: CANMET's mining research facilities at Elliot Lake, Ontario

FOREWORD

The Canada Centre for Mineral and Energy Technology contributes to the department's Mineral and Energy Programs by:

- — performing, contracting and coordinating research on mining, extraction, utilization and conservation of minerals, metals and fuels, and on environmental problems associated with these operations;
- — providing a technical knowledge base as an aid to the development of federal government policies and plans; and
- — disseminating information on advanced technology related to mineral and energy resources to the public, government agencies, industry, and researchers and technologists throughout Canada.

The matrix management system introduced in 1975 is now firmly established, and its advantages in assuring more adequate response to national needs and economic imperatives are clearly evident. The clearest indication of this during 1976/77 was the relative smoothness with which significant financial and personnel resources were shifted from the Minerals Research Program to the Energy Research Program. The system has now been extended to include performance measurements and somewhat closer handling of allocation of resources.

The year 1976/77 also saw significant progress in the implementation of the federal government's "make or buy" policy. A total of 67 contracts were awarded to private research agencies having a combined value of $2.8 million. Of these, 33 were concerned with mineral resources at an aggregate value of $1.2 million; the remaining 34 at $1.6 million, related to energy supply and technology.

D. F. Coates,
Director-General

Figure 1 — Mill and campsite of Granduc Operating Company occupy picturesque glacial setting in northern British Columbia. *Photo — George Hunter*

CANMET MANAGEMENT
1976-77

Director-General — D. F. Coates
Deputy Director-General — V. A. Haw

RESPONSIBILITY CENTRES

Energy Research Program	D. A. Reeve
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Mineral Sciences Laboratories	R. L. Cunningham
Mining Research Laboratories	T. S. Cochrane
Physical Metallurgy Research Laboratories	H. V. Kinsey
Technology Information Division	J. E. Kanasy
Technical Service Division	E. K. Swimmings

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Program Structure

CANMET's management structure is a matrix system in which activities are planned and implemented through a Minerals Research Program and an Energy Research Program operating across six functional units. The latter comprise Mining Research Laboratories, Mineral Sciences Laboratories, Physical Metallurgy Research Laboratories, Energy Research Laboratories, Technology Information Division and Technical Services Division. These are referred to as MRL, MSL, PMRL, ERL, TID, and TSD respectively. Overall direction of the branch is provided by the director-general assisted by the deputy director-general.

The program directors are responsible for determining priorities and objectives and for issuing the detailed work element structure and related statements, budgets and schedules which specify what effort will be accomplished, when it will be performed and which functional unit will be accountable. The functional units are under the management of laboratory or division chiefs who, in response to program demands, are responsible for determining who within their own group will perform detailed work elements, where they will be done and how they will be accomplished. In addition, functional management is responsible for ensuring that the disciplines, skills and equipment needed to meet program objectives are available when required.

This review presents highlights of the various activities and projects which comprise the two programs. The text is organized according to program structure rather than functional units, thus drawing together related research activities taking place in the various laboratories.

Energy Research Program

CANMET's Energy Research Program is part of the department's Energy Program which has as its objective "to ensure the availability of, and to promote the effective use of energy resources for Canada." The department acts as coordinator for the federal energy program within the framework of the Interdepartmental Panel on Energy Research and Development, established to review all new energy research projects in federal departments. The work of the panel is divided into five tasks dealing with conservation, renewable resources, fossil fuels, nuclear energy and energy transportation. EMR acts as the lead agency for conservation and fossil fuels and CANMET, as the technical arm of EMR, conducts research on energy conservation, fossil fuels, and uranium. Advice is also provided to assist decision making on departmental policies.

The CANMET program falls into two main activities — one for Resource Determination and the other for Technology Development, highlights of which are being presented below for the year under review.

Sub-activities under Resource Determination are Oil and Gas, Coal and Peat, and Radioactive Minerals. Within Technology Development, sub-activities are Conservation, Oil and Gas, Coal and Peat, Nuclear Energy, Electricity, Renewable Resources, and Energy Transportation.

The most notable departure from previous years has been the establishment of incremental funding. This allotment has made it possible to expand the CANMET program by contracting out Energy Research and Development (R & D) to private industry, universities and consulting companies. Within this framework of external contract work, considerable funds were expended on coal conversion — both gasification and liquefaction. The intention of this particular program was to transfer existing technology in coal conversion to industry. Proposals which were accepted were funded on a 50:50 partnership basis.

The following sections provide highlights of CANMET's achievements for the 1976-77 fiscal year. Research covered the broad range from mining technology through processing — separation of bitumen from tar sands, coal carbonization and beneficiation, etc. — to supply and materials, including combustion and physical metallurgical aspects of pipeline construction. Also included in the program was a large sector on resource assessment which included funding of drilling programs in partnership with some provinces and with the Department of Regional Economic Expansion (DREE). Although resource assessment could be regarded as not being truly an energy research activity, nevertheless it is vital to have knowledge of Canada's resources to establish a viable R & D program. Much of the work is now being done at the pilot demonstration unit within the Energy Program although more fundamental bench-scale work still remains to be done. It must be stressed that the nucleus of in-house research activities is essential for maintaining necessary expertise to develop large scale demonstration plants in conjunction with Canadian industry, involving major funding.

ENERGY RESOURCE DETERMINATION

The federal government has a broad mandate in the national interest for determining nuclear and fossil fuel resources. In recent years this has been extended to include reserves as well as resources as a further basis for rational policy formulation and resource management. The contribution of CANMET has traditionally been to assess the quality of nuclear and fossil fuels, with emphasis on uranium and coal. Studies are also conducted on heavy oils, bitumen from oil sands, and peat.

It is becoming increasingly apparent that economic exploitation of resources on a long-term planned basis requires regulation based on computerized reserve data banks. The prime example is uranium because overall assessment on a national scale is facilitated by compulsory reporting by all mining and exploration companies of drill core data to federal authorities; it is therefore possible to independently assess reserves for any given set of economic, cost and market conditions. Furthermore, because production and sales are regulated, it is possible to assess and forecast production capabilities. This is more difficult to do for coal because much of the resource and reserve data is not disclosed to federal authorities by the provinces or by private coal companies. Coal production is governed by more normal marketing forces. Assessing coal reserves is made easier for EMR by participation, sometimes with Departments of Regional Economic Expansion (DREE) or Industry, Trade and Commerce (ITC) in provincial coal inventory agreements which provide direct access to all relevant information.

CANMET's long experience with coal and its expertise in mining is enabling two new factors, mineability and economic production, to be added to the criteria at present used for assessing reserves. This will be increasingly difficult as the relatively straightforward surface-mined lignite deposits of Saskatchewan are depleted and efforts must start on the more difficult coals of the prairies, foothills, and mountain regions many of which must be mined by underground methods.

URANIUM RESOURCE, RESERVE AND PRODUCTION ASSESSMENT

Overall surveillance of the department's uranium program is the responsibility of the Uranium Resource Appraisal Group (URAG) chaired by the Deputy Minister, G.M. MacNabb. Subcommittees with delegated responsibilities are identified with the Energy Policy Sector, Geological Survey of Canada and CANMET.

CANMET's specific responsibility in this subactivity is to evaluate uranium ore reserves using available drill core data, especially that supplied by industry. To cope with the burden of annual assessments this work entails the development of advanced geostatistical and computer-based assessment methods. A concomitant responsibility is to assess and maintain under constant review, the productive capacity of current and prospective uranium producers.

In 1976, the Uranium Reserve Assessment Group in CANMET concentrated its efforts on making uranium deposits computer-accessible. The computer-based inventory of primary drill hole assay data on the Denison Main Reef, developed in 1975, was updated and made computer-accessible by establishing computer-based primary assay data inventories for nine separate orebodies. The same treatment was administered to two orebodies on the south limb of the Elliot Lakė Syncline, two in Newfoundland and two in Saskatchewan.

Using the above inventories, geostatistical ore reserve calculations were made for the Elliot Lake orebodies, while those in Newfoundland and Saskatchewan were treated by traditional methods based on computer evaluation of their respective primary data.

Comparison of results of the traditional, deterministic calculations which were done manually in the past, and the geostatistical, probabilistic calculations done by computer, was very encouraging. Company reserve estimates in a test case were confirmed within 17% using only 5% of the company's drill holes.

It is estimated that with one more year of work, it will be possible to make nearly all Canadian uranium deposits computer-accessible by establishing assay data inventories of the drilling and sampling results. Developing satisfactory geostatistical programs for each individual orebody will also be part of the activity. A satisfactory data base, together with geostatistical computer programs will permit a rapid re-evaluation of any of the deposits consistent with possible fluctuations in price and cost.

A start has been made on assessing the future productive capacity of the entire Canadian uranium mining industry taking into account mining, economic, and political factors. While companies are obliged to make geological data available for assessment purposes, they are not obliged to provide production costs. Canada's productive capacity is expected to grow from 7550 short tons of U_3O_8 in 1976 to 15,000 tons by 1984. This projection is based on the production of concentrates from lower-grade ores, decommissioning of facilities as economic reserves are depleted, and production from new mines.

ASSESSMENT OF COAL QUALITY

Historically, coal resource assessment in Canada has depended on geological studies and on volume and tonnage estimates of coal in place with little attention paid to quality. Over the years, CANMET has developed a data base for preparing coal inventories, based on GSC work and samples provided by industry. The matter of a National Coal Inventory has recently assumed a high priority within the department as a result of pressure to develop a national coal policy and formation of a departmental coal committee.

Since 1972, EMR and the Province of Saskatchewan have been evaluating the lignite resources of the Ravenscrag formation of southern Saskatchewan. This has been a pioneering effort using modern assessment logistics and methodology. The data have been compiled into usable computer programs although the necessary corresponding geophysical borehole data and the coal chemistry data have not yet been properly aligned for depth. Until this has been done, the geophysical logs which lack corresponding chemical analyses cannot be interpreted in terms of coal quality.

In 1974, DREE and the Province of Nova Scotia undertook an inventory of coal resources outside the Sydney area. The schedule of diamond drilling and core analyses undertaken by CANMET has since been maintained. The planned termination date of March 1977 has been extended to March 1978 because encouraging results have been obtained in some of the exploration areas. Extending the program to offshore resources beyond present mineable limits is contemplated.

A combined DREE-New Brunswick coal inventory program was initiated with the first drilling early in 1977. Such programs are very important because of the extreme dependence of the Maritimes on imported oil.

Research was also conducted on improved analytical standards and techniques. As a result of both national and international cooperation, a standard method for determining mercury content in coal was developed, and data on mercury in Canadian commercial coals was published. An international standard for determining the major elements in coal ash using atomic absorption spectroscopy is under preparation. Investigations are underway for the determination of fluorine and other trace elements in coal. X-ray fluorescence analysis of coal ash for the major constituents has been perfected, resulting in faster analysis with a high degree of accuracy.

COAL MINING METHODS

Canada has large coal resources but their economic exploitation may be critically dependent on the availability of suitable mining systems. In any event size of reserves depends on mining costs. Now that a sound data file on geology and on the quantity and quality of coal, similar to that for the Ravenscrag lignites in Saskatchewan is available, there is the possibility of developing computer programs that combine these data files with data on mineability, production and markets. To illustrate the potential for such programs in the planned exploitation of a resource, CANMET has developed a detailed program for selecting dragline operations with associated capital and operating costs applicable to Saskatchewan lignites. The program has been checked against operating experience of the Saskatchewan Power Corporation and is ready to be applied as soon as the Saskatchewan coal file becomes available in 1977. For given profit levels and annual production rates, it will be possible to present contour maps of recoverable coal. This information should be of great value in the siting and development of mines, and is expected to induce a demand for further similar programs as inventory data become available.

ENERGY TECHNOLOGY DEVELOPMENT

A major portion of CANMET's energy research effort is directed to the Energy Technology Development Activity with the principal objective of ensuring adequate technical capability for the supply, processing and use of energy. The main efforts in this activity are directed to conservation, oil and gas, coal and peat, and energy transportation with lesser efforts in the nuclear and electrical fields.

Responsibilities include coordinating research, development and demonstration; funding or otherwise stimulating R & D in the private sector and in universities; performing R & D in support of departmental objectives; and encouraging the application of successful research projects to industrial use.

CONSERVATION TECHNOLOGY

CANMET's major effort in conservation technology has been directed towards improved fuel utilization, particularly in securing more efficient combustion of coal and oil. Work is also aimed at determining strategies for substituting one fuel for another so that critical or scarce fuels can be conserved by changing to those which are cheaper or more abundant.

Most of the work on combustion was conducted by the Canadian Combustion Research Laboratory (CCRL) at the Bells Corners site at Ottawa. The past year saw a considerable growth in activity resulting from increased funding and manpower and joint projects with fuel users such as electric utilities.

Domestic Heating

Besides being close to the hearts and pocketbooks of nearly all Canadians, domestic usage accounts for nearly 20% of the total Canadian energy demand. Much of this demand is in the form of oil and gas for which there is a threat of shortage and the certainty of higher prices.

A series of field trials to obtain actual data improved furnace burner performance was conducted in fourteen homes. Retrofit devices and practices studied included various nozzle sizes, solenoid oil shut-off valves, automatic chimney dampers and overnight thermostat cut-back. Fuel savings of over 20% were measured.

In cooperation with Kanata Pollution Probe, furnace efficiency in 120 homes was monitored during the winter of 1975-76. Wide variations in furnace efficiency were found. It was also found that a fairly high smoke number did not lead to as great a deterioration in efficiency as expected.

A booklet "100 Ways to Save Energy" was updated and reprinted in 1976 and over 1.2 million copies distributed. One quarter million copies of a booklet, "The Billpayer's Guide to Furnace Servicing", drafted by CCRL and published by the Office of Energy Conservation, were also distributed.

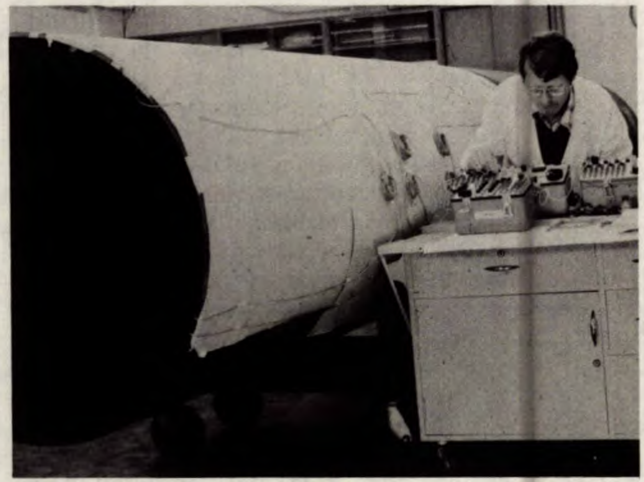

Figure 2 — The size of large gas pipes is impressive. Here measurements are being taken on strain gauges as part of the determination of internal stresses in a pipe of 42 inches (106 cm) diameter and 0.54 inch (13.7 mm) wall thickness.

A furnace manufacturer began to build two prototypes of the new CCRL warm air furnace and blue flame oil burner. These will be tested in 1977.

Fuel Additives

The nation-wide emphasis on energy conservation has produced increased activity in the availability of additives claimed to promote fuel economy. It is often difficult for consumers to assess the value of additives particularly as they are exposed to conflicting information. To obtain more information on the behaviour of additives, CCRL set up a small package steam boiler capable of burning both No. 2 furnace oil and residual oil, and equipped to identify even marginal effects of additives.

As a result of controversy over water-in-oil emulsions, experiments were conducted using varying amounts of water in No. 2 furnace oil. Results showed an apparent optimum gain in fuel efficiency of 1-1.5% with a 5% water emulsion which is within the normal operating variability of a domestic furnace and hence is not considered significant. Nevertheless there are indications that further improvements are possible with water and residual oil emulsions and more experiments are planned.

Increased Utilization of Canadian Coal

The increased use of Canadian coal to replace oil and gas, especially in industry, is a potentially important way of meeting the predicted fuel shortage in the near and intermediate future. Problems with using more coal include the widely varying combustion properties of different coals, some of them being very poor, and maintaining high thermal efficiencies while meeting acceptable pollution emission standards.

Using the pilot-scale boiler, CCRL determined optimum combustion conditions for power station boilers for two Alberta coals that could supplement or substitute for imported coals. The combustion performance of six samples of coal from Hat Creek, B.C. were evaluated and design criteria were determined for a new 5000 MWe power station that could be the largest in the world.

To reduce oil consumption in industrial furnaces in eastern Canada, a program of combustion trials with coal-in-oil slurries was initiated with the Nova Scotia Power Corporation. It is possible to add up to 35% of powdered coal to oil but it is expected that ash from the coal will pass through the narrow spaces between the tubes of the oil-fired boilers.

Fluidized-Bed Combustion

It is anticipated that traditional coal-burning technology will not be able to contend with the wide variation in type and quality of the large amounts of coal expected to be burned, and still meet environmental requirements. Fluidized-bed technology offers the potential for low sulphur and nitrogen oxide emissions and low sensitivity to fuel quality, and appears to hold the most promise for the future. Although known for many years it is only now beginning to be accepted as reliable.

CCRL commissioned a 12-inch diameter fluid bed furnace with a submerged ignition burner, and successful trials were conducted with a series of coals and other fuels. Besides further experiments on fuel characteristics and combustion control on this furnace, it is planned to promote industrial-scale development in the coming year.

Improvement of Fuel Quality

Petroleum coke, especially that from processing of oil sands, frequently has a high sulphur content that limits its use as a fuel and for such components as electrodes. Experiments on electric furnace treatment of coke containing 5.75% sulphur gave samples with as little as 0.1% sulphur, though this was not consistent throughout a batch; further experiments will attempt to achieve consistency. Developments were also undertaken to apply a small computer with appropriate sensors, to increase the data collected from experiments, and to use this to develop programs for more accurate control of furnace operation.

OIL AND GAS

CANMET's R & D in oil and gas has centred on the recovery and processing of bitumen from Alberta's oil sands and heavy crude oils which represent a vast, though expensive to extract, reserve of liquid fuels. The deposits of oil sands that can be mined by present methods are limited and new mining techniques will be needed in the future. Also, the existing and projected oil sands processes produce coke of high sulphur content that cannot be burned without difficulty in meeting environmental standards. A CANMET process eliminates the production of coke by using high pressure thermal and catalytic hydrogenation to increase the yield of synthetic liquid fuels.

Other work included developing analytical methods to permit characterization of feedstocks and products to improve process control and evaluate its effectiveness. Studies have been made of hydrocarbon molecules such as asphaltenes that may play an important role in coke formation, nitrogenous and other materials that may poison catalysts, and sulphur compounds to give information on the desulphurization processes.

Oil Sands Mining

Open pit mining, used at present to recover oil sands, is not considered economical where depth of overburden exceeds about 200 ft (61 m). Alternative in situ extraction methods so far conceived will require at least 1000 ft (305 m) of overburden to contain the pressures. Between these limits lie large deposits of oil-bearing sands, estimated at up to half the total amount, for which underground mining appears to be the only feasible recovery method.

An important engineering project during 1976 was the construction of the Saline Creek Diversion tunnel for the Alberta Department of Transportation, the first major underground excavation in the oil sands. CANMET participated in studies of the project with Alberta Oil Sands Technology Research Association (AOSTRA) being responsible for continuously monitoring the emission of gases such as methane and hydrogen sulphide. Analysis of gas and bitumen has been contracted out.

To complement and extend information obtained from the tunnel project, a contract study entitled "the feasibility of, and requirements for developing near-surface mining systems" has been commissioned. It is expected that the results of this, together with in-house expertise being developed, will permit preliminary mining trials to begin in 1977-78.

Other research is aimed at identifying problems and the potential for developing further open pit mining operations, which will likely continue to be the main method of recovering oil sands for many years.

Separation of Bitumen from Sand

The present process for separating bitumen from sand, uses hot water which, although effective, needs a large settling pond in the water recirculating system because the sand-water tailings contain fine particles of clay that settle very slowly. Through contracts, CANMET is investigating several alternatives to the hot-water process. A small pilot-scale cold water process designed to reduce water recycling problems and to consume less energy is already working and several processes that use microbiological activity to produce surfactants that facilitate the separation of bitumen from the sand are being evaluated in the laboratory.

Refining of Bitumens and Heavy Oils

The CANMET hydrogenation process, sometimes, called "Extendoil" is being developed on a 1-barrel per day pilot plant at the Bells Corners site, and construction of another similar plant is underway to increase experimental capacity.

A pressure of 3500 psi (24.5 MPa) was used previously to ensure hydrogenation without the production of coke particles which foul the reactor. This pressure was considered too high for economic large-scale operation, so experiments were undertaken in

1976 to achieve hydrogenation at lower pressures without fouling from coke formation. At the same time, the liquid hourly space velocity — the number of reactor volumes of liquid passing through the reactor each hour — was raised to increase reactor throughput, and in some experiments, both catalytic and non-catalytic additives were employed.

In a 21-day run with Athabasca bitumen, a significant decrease in the formation of coke deposits at 1500 psi (10.5 MPa) was achieved by adding powdered coal to the feedstock. Similar promising results were obtained on shorter experiments with Cold Lake in situ-produced bitumen. It is not yet known whether the coal acts as catalyst or simply as a scavenger.

Most successful was an iron sulphate catalyst deposited on coal which gave no evidence of reactor deposits. This was in contrast to about 300 grams of deposits per day without additive.

Other experiments included non-catalytic, low-level hydrogenation of bitumen to meet pipeline specifications to enable it to be pumped to a major refinery instead of having to be further refined on site. Cobalt-molybdenum catalysts supported on alumina or on coal were used to improve hydrogenation.

The catalysts themselves introduce additional expense to the hydrogenation processes, and this must be made up in improved yield or better operating conditions. Several research projects were conducted to achieve this including the production of low-cost catalysts using coal as a getter or catalyst support; the development of fouling-resistant catalysts to extend catalyst life by varying its composition; adding promoters; varying the pore size and other properties of the supporting medium; and regeneration of catalysts for which a simple process has been developed and a patent application filed.

Materials Research and Development

Other work has been done to develop abrasion-resistant materials for processing oil sands where the sharp, angular sand particles cause rapid wear of equipment used for both digging the sand and handling sand-water slurries.

Many parts such as digger teeth are at present given wear-resistant hard-facing after casting. CANMET is endeavouring to develop a single-step process in which the hard layer is introduced as an integral part of the casting, thus simplifying the production process. Some success has been achieved with experimental, laboratory-scale castings.

It appears that the rate of wear of pipes by sand-water slurries can be influenced by adding oxidizers and other compounds to the water. The possibility of increasing the life of steel pipes by this means is being investigated.

COAL AND PEAT

Research in this sub-activity during 1976 was confined to coal. Projects were mainly in coal conversion and coke production.

Coal Mining Technology

The annual production of coal in Canada fell from about 20 million tons in 1950 to a low of 10.7 million in 1969, and increased again to about 28 million tons in 1975. Domestic consumption, including imports, in these years was 45, 26.5 and 30 million tons respectively. It is anticipated that in the coming years, coal will play a major role in substituting for dwindling Canadian oil reserves and to provide export income. This will mean further increases in coal production and consequently a need for more mines, both underground and open pit. Much of CANMET's mining research is conducted in cooperation with the mine operators in actual mines rather than in the laboratory, and most of it is based at the Western Office in Calgary.

GROUND CONTROL

An important part of CANMET's coal mining research is aimed at obtaining quantitative data on strata behaviour and surface movement which can be used to improve both mine design and operation for maximum recovery and safety.

Various instruments such as extensometers and stress cells are being used to gather data on deformation of pillars and roadways at two coal mining operations of McIntyre Mines Ltd. Monitoring of strata deformation resulting from multiple-seam mining has identified distinct phases of deformation resulting from undermining. This is the first fully documented record of its kind in western Canada. It has already proven useful for developing preventative maintenance and should be invaluable in the planning of future operations.

Strata behaviour is also being investigated in the hydraulic mining operations of Kaiser Resources Ltd., characterized by very thick inclined seams. Overall displacement, pillar deformation and loading of supports have so far been surprisingly small. In addition to strata deformation, techniques are being developed to monitor surface subsidence as the coal is being extracted underground. Of special importance is the development of instruments to measure subsidence in winter when normal surveying is impossible.

Other work, both in the west and in Nova Scotia, involves the evaluation of various methods of roof support, providing useful information for mine design.

MINE ENVIRONMENT

The second major area of coal mining research is in mine environment. The continuous monitoring of carbon monoxide in mine atmospheres is a means of detecting high rates of oxidation of coal that can generate heat and result in spontaneous combustion. It also acts as a valuable indication of the quality of the atmosphere which is of concern for the health of miners. Of prime importance is the detection of sudden rises in carbon monoxide levels, indicating possible increases in oxidation activity. This is the first time that sophisticated continuous recording equipment has been installed in a Canadian mine.

In addition to the monitoring of carbon monoxide, infrared scanning is being investigated for direct determination of hot spots that represent regions of high oxidation or of hidden fires. This technique should be applicable where carbon monoxide monitoring is difficult.

Methane is a major problem in some mines and has been responsible for explosions. Research is being conducted on controlling the emission of methane from coal seams by its removal from the seams, known as methane drainage. This technique is also being investigated through contracts, as a means of actually producing usable quantities of methane from mines. Work on ventilation, another method of controlling methane, is also underway.

EQUIPMENT SAFETY

The third major area of coal mining research is equipment safety. The risk of improperly designed machinery causing fires in coal mines is considerable. Research at the Canadian Explosive Atmospheres Laboratory (CEAL) is directed towards eliminating the risk of igniting explosive atmospheres by sparks or arcs from electrical equipment, or by flames or hot exhaust systems of diesel engines. During 1976, the cause of failure of a new type of diesel flame arrestor was discovered, resulting in changes in its manufacture to make it acceptable. In cooperation with NRC, it was demonstrated that a high-compression diesel could run on an appropriate air-methane atmosphere after the fuel supply is shut off and that there is need for an air shut-off valve, as well as one for fuel.

Coal Conversion

The conversion of coal to gaseous or liquid products — gasification and liquefaction — was developed during World War II, but was superseded by the use of natural oil and gas. Today the Union of South Africa is the major user of coal conversion but as supplies of natural oil and gas diminish, synthetic products from coal may also become important to Canada. Also seen in 1976 was the initiation of CANMET projects to determine the possibility of introducing coal conversion in Canada, and which systems would be most suitable. A working group was assembled to conduct R & D in coal gasification and liquefaction relevant to Canadian needs. Eight outside contracts funded on an equal basis with industry, totalling over $700,000 were also let for various studies as listed below:

ALGAS

Feasibility of gasification at a local coal deposit for electric power generation in the city of Edmonton.

ALCAN

Solvent refining of coal for the production of electrode coke.

B.C. Hydro and Power

Study of low BTU gasification for electric power generation by simple or combined cycle systems.

Figure 3 — Peat — an alternative source of energy in Canada.

Manalta Coal Ltd.

Conversion of low rank coals to higher rank solid fuel by drying and briquetting.

Nova Scotia Research Foundation

Low-pressure extractive coking processes for the liquefaction of Nova Scotia coal.

Ontario Research Foundation

The impact of partial substitution of gasoline by methanol in industrial and automotive fuels.

Saskatchewan Power Corporation

Technical and economic studies of coal gasification based on coal deposits of the Coronach area of Saskatchewan.

Shell Canada Resources Ltd.

Technical and economic assessment of the gasification of coal to manufacture intermediate BTU gas for local fuel and petrochemical feedstock.

Coal Beneficiation

Many Canadian coals are difficult to beneficiate and some of these difficulties are uniquely Canadian. The conventional carboniferous coals of the Maritimes generally have high content of finely disseminated sulphides and some have high content of ash-forming minerals. The Prairie lignites are high in moisture and mineral content which necessitate specially-designed combustion equipment. The Hat Creek coal is especially high in clay minerals. The foothills and mountain coals are unusually friable and high in ash-forming constituents. Thus beneficiation is often crucial to the economic exploitation of coals and CANMET operates the only laboratory devoted to developing technology specifically adapted to Canadian coals. Over the years, a CANMET Automedium Cyclone (AMC) process has been and continues to be developed.

During the year, the 10-ton per hour AMC pilot plant came on stream. Beneficiation trials on a wide variety of coals were undertaken. Operations to date have shown that the process is viable as a bulk-cleaning system, is easy to control, and has the ability to

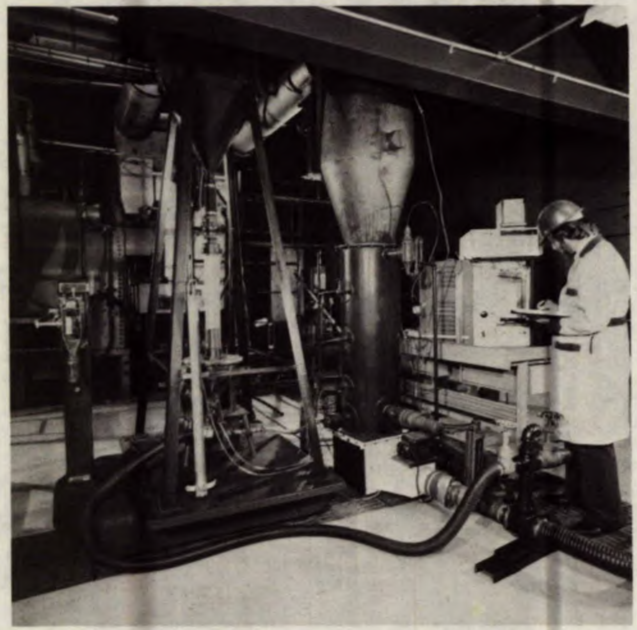

Figure 4 — Fluidized bed combustion promises to be an effective way of burning a wide variety of fuels. This water-cooled pilot scale combustor at the Canadian Combustion Research Laboratory is being used to establish operating parameters for coals and other solid fuels.

tolerate slime. For example, three adit samples of coking coal of varying quality and averaging 8.5 tons were washed to metallurgical specifications of 7-8% ash. Also, improvement in the grade and recovery of fine metallurgical coal and reduction in the amount of recirculating solids from the slimes cleaning section of a washery was shown to be feasible by modifying the existing circuit to include elongated cyclones and froth flotation.

Bench and pilot plant studies on smaller samples of western coal of very high clay content indicated that the clay could be released by scrubbing and attrition and removed by the AMC process. The product would be an effective thermal grade coal.

Research was continued on the chemical and physical characteristics of flocculants and fine particle systems to provide the basic data of practical solid-liquid separation processes. Studies were initiated to determine optimum flocculant dosage as a function of such system properties as particle surface area and solids concentration. Seasonal changes in raw water composition of washeries were also surveyed since this affects flotation and flocculation performance. Finally, an atomizing device was developed for rapid dissolution of high molecular weight polymers used as flocculants. The aim of this work was to virtually eliminate the need for settling ponds in association with coal cleaning plants.

A 45 ft x 12 ft (13.7 m x 3.7 m) trailer is being fitted for mobile field testing of coal washery and other effluent in a 300-igpm prototype of the CANMET process water recovery system which is now an integral part of a complete AMC system. The mobile unit will include a flocculant preparation and feeding section, a bottom-feed thickener and solid-bowl centrifuge for dewatering the thickener sludge. It will permit a reliable evaluation at selected sites of practical aspects of water recovery, such as the effect of build-up of salts in recirculating water and should be a highly effective way of improving, adapting and demonstrating the technology to industry.

Coke Production

Coke is the principal energy source for the blast furnace, which is the major source of new steel in Canada. Coking coal is also a major export commodity, about 13 million tons being exported annually, mainly to Japan.

The Coal Resource and Processing Laboratory, formerly the Canadian Metallurgical Fuel Research Laboratory, was reorganized during 1976, to bring together more of the groups working on the properties of coal and to coordinate research efforts.

Research and development in carbonization covers conventional and non-conventional cokemaking and the characterization of coals and cokes for cokemaking. Projects are formulated in cooperation with the technical committee of the Canadian Carbonization Research Association, which represents coking coal producers, cokemakers and users.

Although non-conventional methods of cokemaking, principally formed coke, are not expected to displace conventional methods in the immediate future, they have numerous advantages including better pollution control, use of cheaper coals, control of product shape, and smaller production units with easier start-up and shutdown. It is anticipated that because of these advantages, formed coke will eventually come into extensive use.

Good progress was made during 1976 on developing facilities for evaluating formed coke processes which included the operation of a new type of ball mill, a sand-bed coker, and a hot-briquetting press. Preli-

Figure 5 — The Saline Creek Diversion Tunnel — the first underground excavation in oil sands.

minary experiments indicated that coke from hot briquettes had reactivity similar to that of conventional metallurgical coke.

In research on the characterization of coals and cokes, a microhardness tester is being developed to estimate the extent of oxidation of coal, which has an important effect on coking properties. Other experiments determined the effect of the depth of cover on the coking properties of coals from two Nova Scotia seams.

URANIUM PROCESSING

In addition to processing coal and oil, CANMET's activities include the development of improved methods of extracting uranium. A substantial proportion of Canadian uranium reserves is of low grade or contains complex ores. Both types require new extraction methods for economic recovery of uranium. Research is concentrated on leaching processes using nitric, hydrochloric or sulphuric acids. A flowsheet was developed for nitric acid leaching, with recycling of the leaching agent, solution of pyrite, precipitation of iron, and solvent extraction of uranium, thorium and radium. Preliminary experiments on hydrochloric acid leaching gave promising results that are being investigated further. To increase the efficiency of extraction in the sulphuric acid process, a fluidized bed ion-exchange column has been developed for uranium extraction and successful results obtained. This process allows the treatment of an unclarified liquor and convenient recovery of thorium which is expected to be needed for advanced CANDU reactors.

Along with this work, it has been necessary to develop improved analytical methods for constituent elements and ions, to give increased accuracy, speed, or compatibility with particular processes.

Materials for Nuclear Energy

Two small projects on nuclear material were underway in 1976. One was the successful production of tubes and the determination of hot working characteristics of a new zirconium-aluminum alloy, carried out in cooperation with Atomic Energy of Canada Limited. The results of this work have been applied successfully on a commercial scale. The other project was the investigation of hydrogen damage in steel plate of the type used for the towers of heavy water plants. This work was done in cooperation with other Canadian nuclear agencies and industries.

ENERGY TRANSPORTATION

The principal CANMET research on energy transportation involves materials for large natural gas pipelines such as those proposed for gas transportation in northern Canada. The objective of the work is to acquire the technical knowledge to ensure integrity of the structures and equipment needed for the pipelines. While materials that can be used for pipelines are available, the design of new lines generally makes use of the most advanced technology and the combination of operating demands and economic considerations means that materials are close to the limits of performance. Part of CANMET's R & D is aimed at establishing criteria of performance and methods of testing and evaluating materials that will give a reliable measure of their expected performance in the field.

Work has continued on evaluating samples of line pipe that could be candidate materials for a new Canadian pipeline. The assessment includes investigations of the homogeneity of composition and mechanical properties, and their correlation with microstructures; weldability and welding methods; initiation and propagation of cracks; and various aspects of corrosion including sulphide stress cracking. In addition, during 1976, an instrumented drop-weight tear testing machine was completed and experiments begun to assess the value of the drop-weight tear test for monitoring the toughness of line pipe and to determine the relationship between dynamic toughness and the more easily measured but less reliable Charpy impact energy.

In addition to evaluating existing materials, work is being undertaken on the potential for developing line pipe material of higher strength that retains high toughness. Results on three experimental low carbon steels containing manganese, molybdenum and niobium, given direct quenching treatments after rolling, have shown that the required toughness was obtained at a yield strength of 100 ksi (700 MPa) compared with 70 ksi (500 MPa) for conventional thermo-mechanical treatment.

Liquid Natural Gas Pipeline

Besides materials studies, CANMET has commissioned a study of the feasibility of liquid natural gas (LNG) pipelines as an alternative to conventional gaseous phase pipelines for long-distance transmission of natural gas in northern Canada. Several previous studies have claimed that LNG transportation would be economical, but recent findings cast some doubt about earlier results. The new study will take account of improvements in available materials and technology of pipeline construction, current experience in LNG storage, and short-distance pipeline transmission.

MATERIALS FOR ELECTRICAL STORAGE AND CONVERSION

The sodium-sulphur battery offers attractive possibilities for efficient, economical, high density energy storage suitable for load levelling and for electrically powered vehicles. Major limitations at present are problems of both conductivity and mechanical strength of the solid electrolyte. One problem in producing single phase sodium-doped β-alumina has been overcome by CANMET, and powders of the single phase compound have been prepared for the first time. Methods of fabricating components from the powders and their electrical properties will be investigated in the coming year.

Other experiments on the production of ionically conducting ceramics in forms suitable for components for fuel cells have been carried out with zirconia and potassium-magnesium-titanium oxides with the hollandite structure.

Minerals Research Program

The CANMET Minerals Research Program (MRP) was established in 1974. It is concerned with research and development (R & D) of non-energy minerals and metals and is organized into three areas — mining, processing and utilization — corresponding to the main operations of the mining and metallurgical industries. Although CANMET still uses this structure to manage the planning and implementation of the R & D projects for which it is responsible, this report has been prepared according to the new program/activity structure adopted by the Department of Energy, Mines and Resources (EMR).

All of the work done in MRP contributes to the EMR Minerals Program which is one of four under the new structure. The Minerals Program has five activity areas of which CANMET contributes to three. The elements of the program with which CANMET is involved are as follows:

MINERAL RESOURCE DETERMINATION ACTIVITY

Sub-activity — Technical Evaluation

MINERAL TECHNOLOGY DEVELOPMENT ACTIVITY

Sub-activities — Development and Mining
— Processing
— Utilization
— Conservation
— Environment, Health and Safety
— Transportation

ADMINISTRATION OF THE CANADIAN EXPLOSIVES ACT ACTIVITY

Sub-activity — Authorization and Testing

The accounts of the R & D done in 1976, either by CANMET staff or under contract to CANMET given in the following pages follow the above tabulation.

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

a) To provide an adequate knowledge base of Canada's mineral resources for the development of policies and programs regarding the exploitation of those resources and to encourage and facilitate their orderly development.
b) To ensure the availability to Canada of adequate technical capability for the supply, processing and use of minerals.
c) To administer the Canada Explosives Act in the interest of public safety.

More specific objectives for R & D efforts on behalf of the Department's Minerals Program are given in the following reports of work done in support of the sub-activities.

Figure 6 — CANMET's multi-million-dollar Pit Slope Project, initiated in 1972 in an effort to develop improved open pit mining procedures, is nearing completion with production of a ten-chapter engineering manual. *Photo — George Hunter*

MINERAL RESOURCE DETERMINATION

The objectives of the Mineral Resource Determination Activity is to provide an adequate knowledge base 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. CANMET is contributing to these objectives by providing necessary data to determine the economic recoverability of known mineral deposits based on present and future technology.

TECHNICAL EVALUATION

The work in this sub-activity is concerned with determining the quantity, quality and productibility of Canadian mineral reserves. In CANMET this is done by providing information and data on the mineralogy, mineability, processing feasibility and development and production costs.

Platinum Mineralogy

Little is known of the nature and distribution of the platinum-group metals in mineral deposits, especially those occurring as co- or by-products. This knowledge could help make borderline deposits economic and others more profitable. A detailed mineralogical investigation was made of samples from nine deposits around the Sudbury Basin. This study resulted in the identification and characterization of 13 platinum-group minerals as well as in a description of their textures, mode of occurrence, mineral associations, and other details relevant to beneficiation.

Resource Inventory

In a joint project with the Geological Survey of Canada and the Mineral Development Sector on an inventory of Canada's copper, molybdenum, nickel, lead, zinc and iron resources, CANMET provided technological information on mineralogy, mining, and metallurgy to permit assessment of their economic recoverability. Two joint reports, one on the base metals and the other on iron will be published in 1977/78.

Resource Evaluation

In 1976, determination of the ceramic properties of typical clays and shales from western Canada was completed. The forming and firing behaviours of some of these have been examined in detail and will be reported in relation to chemical and mineralogical composition. A comprehensive report covering a similar study on clays and shales of the Atlantic provinces is in final preparation. Within the last two years, data presented in previous reports have been among the primary criteria for selecting raw materials for new manufacturing facilities for sewer pipe at Deschaillons and for manufacturing floor and wall tile at Bécancour, both in Quebec.

On the basis of economic and technical considerations, an inventory of domestic anorthosite, nepheline syenite, shales, clays, underclays associated with coal deposits, coal rejects and fly ash is being prepared to provide information on the possible sources of indigenous feed materials for the production of alumina. Although ample resources of bauxite exist in the world, it is important to know Canadian capability for developing lower quality domestic deposits in the event that foreign supplies are affected.

Through an agreement under the Canada - Manitoba Resource Evaluation Program, CANMET is providing scientific support and laboratory facilities to a provincial mineralogist conducting investigations on Manitoba mineral occurrences. The mineral areas being investigated include the Bird River nickel deposits, the Flin Flon belt, Thompson and Lynn Lake.

MINERAL TECHNOLOGY DEVELOPMENT

This activity includes all of the department's responsibilities for performing, funding and coordinating mineral research and development in Canada as well as for acquiring foreign technology and transferring technology to industry. Because of CANMET's role as the department's centre for research and development related to mining, mineral and metal processing, and mineral-based materials, CANMET is a major contributor to the activity.

DEVELOPMENT AND MINING

The work done in the Development and Mining Sub-Activity has as its objective the development and promotion of technology for increasing the efficiency of Canadian development and mining operations exclusive of coal mines. The main investigations in 1976 were in-depth studies of open pit mining, investigations directed to improving the efficiency of pillar recovery and deep mining, and contributing to a study of the feasibility of storing nuclear waste underground.

Open Pit Mining

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

In 1972, CANMET initiated a five-year project with the goal of developing improved open pit mining procedures. The projects has been a cooperative venture between industry and the federal government with much of the development work being done under contract by Canadian mining companies, consulting engineers and universities. The output is a comprehensive manual for use by mining engineers.

The manual is organized into ten chapters as follows:

1. **Summary**
   An outline of the subject material in each chapter.
2. **Structural Geology**
   Methods of gathering, storing and interpreting geological data; dividing a pit into design sectors and assessing likely modes of failure for each; defining geological information required during the feasibility, planning and operating stages of mining; estimating cost of obtaining data.
3. **Mechanical Properties**
   Planning a laboratory and field testing program; describing methods of determining and analyzing the shear strength of discontinuities and rock substances; determining rock strength and physical properties; testing required during the feasibility, design and operating stages.
4. **Groundwater**
   Methods of measuring water pressure and permeability; construction and analysis of flow networks; methods of draining and monitoring; action required during feasibility, design and operating stages; estimating costs; and conducting groundwater investigations.
5. **Design**
   Explanation of probability methods of analyzing slope stability; analysis of plane shear, rotational shear, block flow and toppling modes of instability; financial analysis and economic risk of all factors affecting mining; design activities required during feasibility and planning stages; and estimating costs of design investigations.

6. Mechanical Support

Methods of support using rock anchors, shotcrete and buttresses, design of support systems; monitoring of anchor loads; cost estimates of support systems for bench support, moderate slopes and large slopes.

7. Perimeter Blasting

Effects on blasting of explosives, decoupling and decking, delays and spacing, collar and subgrade drilling, and site conditions; perimeter blasting techniques using buffer blasting, cushion blasting, pre-splitting and line drilling; ground vibration, and damage levels; costs of perimeter blasting.

8. Monitoring

Description of optical and electro-optical surveying instruments to locate areas of potential instability; wire and rock bolt extensometers for detailed monitoring of unstable areas; methods of telemetry of data to central location; and computer methods of data storage and analysis.

9. Waste Embankments

Site data required; design of embankments and modes of instability; construction of embankments; problems with permafrost.

10. Environmental Planning

Environmental management during exploration; ecological, socio-economic and meteorological studies during planning stage; water pollution; reclamation with vegetation; federal and provincial legislation; estimated costs of ecological investigations; water and air sampling, and revegetation.

Besides these main chapters, a number of supplements have been prepared dealing with such aspects as case histories, detailed computer programs and specialized site investigations.

Underground Mining

Although underground mining accounts for only 30% of the ore tonnage mined in Canada it is important in the production of base metals: 92% of the nickel, 55% of the copper, 50% of the zinc and 44% of the lead were produced from underground mines in 1975. CANMET has been involved in the ground control and safety aspects of underground mining for a number of years and present research is involved with problems which occur when converting from open pit to underground, and with mining methods utilizing backfill.

A cooperative project with Texasgulf Canada Limited at the Kidd Creek mine has been underway since 1973. This mine started off as an open pit and then converted to underground without leaving a crown pillar separating the two operations. Any unexpected failure of the hanging-wall slope would be a hazard to the work force as well as disrupting operations in both the open pit and underground mine. A remote laser monitoring system is used to measure the displacement of the hanging-wall pit slope as it is undercut during underground mining operations. Measurements taken during four years have indicated a progressive relaxation of the pit wall into the pit of up to two inches, but this has not resulted in any signs of instability. The company has now expanded this measuring system to the rest of the pit.

Two- and three-dimensional finite element model studies have been carried out at this mine to determine the redistribution of stress due to underground mining and the resulting displacement. These studies are used to evaluate possible modes of failure for the hanging-wall slope.

A program of stress measurements has been completed at the Kidd Creek mine to determine the increase in pre-mining stresses with depth. As with measurements taken in other mines in Northern Ontario, it was found that the horizontal stresses were greater than the vertical stresses. This information will be useful in designing stope and pillar layout as mines become progressively deeper.

Cut-and-fill is an important mining method in Canada and is used almost exclusively below 3000 ft (914 m) depth. It is also one of the most expensive and labour-intensive methods. Conventional cut-and-fill involves the repetitive sequence of removing small slices of ore and then back filling. A recent development in pillar recovery operations has been the blasting of large volumes of ore which in turn exposes a larger area of the fill wall in the adjacent backfilled stope. The stability of these unsupported fill walls is crucial to this mining technique. A study has been done on the free-standing height of backfill in pillar recovery operations. A method using finite difference models has been developed to determine the maximum free-standing height of backfill with varying cement contents and properties. The next step will be to compare this analytical technique against actual examples of exposed backfill wall in selected mines.

Another important aspect of backfill pertains to its in situ drainage properties. Methods have been developed using both tube and twin rod permeameters, based on electrical conductivity, which permits measuring in situ permeability without having to take samples.

Underground Nuclear Waste Repository

Concern has been expressed in Canada and other countries about management of radioactive waste from nuclear power stations. The major problem is the long life — in the thousands of years — of some radioactive substances. Storage in underground excavations a few thousand feet below surface has been proposed as one potential method of dealing with this problem.

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

For the in situ heater test, a special chamber has been excavated on the 2300 ft (701 m) level at the Creighton Mine of Inco Metals Limited in the Sudbury area. The electrical heater has been designed and instrumentation to measure stresses, deformation and temperature in the surrounding rock has been decided upon. Preliminary finite element model studies have been carried out to determine the increase in temperature and thermal stresses in the rock surrounding the heater and chamber.

PROCESSING

Research in this sub-activity is done with a view to developing and promoting technology to increase recovery from Canadian ferrous and nonferrous mineral deposits and upgrading such products to ones of higher value. This is effected by establishing and promoting new and improved techniques, methods or equipment for the processing of minerals. In developing new processing technology, due attention is paid to minimizing any possible adverse impact on public health and safety and on the natural environment.

Processing of Base Metal Ores

Present processes for treating complex fine-grained zinc-lead-copper-silver ores recover an average of 65% of the combined metal values contained in the ores. Research is underway to develop processes to increase this recovery to 85% and to permit exploitation of other known deposits which are dormant because of metallurgical problems. Ores of this type occur generally in New Brunswick but are not confined to the East; major orebodies are also known in Ontario and in the Yukon. A conservative estimate, including the increase in recovery and production from dormant deposits, is that the success of this project could add several billions of dollars to the economy over the years.

CANMET research is based on the concept of producing a bulk concentrate at a minimum recovery of 90% value of the contained metal at grades averaging 30% Zn, 12% Pb, and 1 or 2% Cu. Processes to be investigated as a means of economically refining this concentrate to metal include the Sherritt Gordon pressure-sulphuric acid-leach process, the sulphation-roast-leach process, the dry-way chlorination/oxidation process and atmospheric leaching with ferric ion in chloride or sulphate media.

In 1976, Sherritt Gordon Mines Limited began laboratory and economic feasibility studies on the pressure sulphuric acid leach process while the New Brunswick Research and Productivity Council began work on the sulphation-roast-leach process. The work on both these processes is being financed by DREE through the federal/New Brunswick "General Development Agreement". EMR has representation on the management committee and CANMET is the scientific authority. The dry-way chlorination and ferric ion leaching processes are being investigated by CANMET.

Mineralogical studies are basic to successful development of mineral processing technology. Consequently, mineral, metal and textural zoning is being investigated on samples collected during an extensive field program in 1976. These samples are considered representative ore material from the following properties: Armstrong A, Armstrong B, Rocky Turn, Orvan Brook, McMaster, Caribou, Restigouche, Murray Brook, Canoe Landing Lake, Nine Mile Brook, Wedge, Brunswick 12, Key Anacon, Heath Steele, Captain, and Chester.

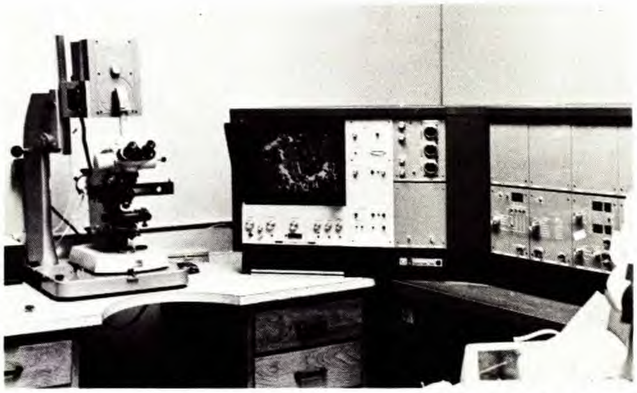

Figure 7 — The Quantimet Image Analyzer, used in the characterization of ores. A camera mounted on the microscope (left) projects an adjustable image of the ore sample surface onto the screen (centre).

In addition, image analysis of sulphide ores of the New Brunswick type is being done to assist in explaining the behaviour of materials during comminution and flotation. Preliminary results on mill products from plant and laboratory facilities indicate that flotation efficiency is the same for all free sphalerite grains in the size range of 6 to 210 μm. Efficiency begins to drop below 6 μm and is only 50% at 2 μm. Image analyses performed on a zinc concentrate from Brunswick Mining & Smelting Ltd., showed that 60% of the sphalerite was present as free grains with the largest grains being 74 μm in diameter.

A CANMET contract to conduct studies on the effect of grinding media on the selective flotation of Cu-Pb-Zn ores was granted to Lakefield Research of Canada Limited as a result of an unsolicited research proposal. A 200-ton copper-zinc sample from a producing mine was processed in a continuous pilot plant using three different grinding methods followed by a flotation procedure similar to that employed at the mine which supplied the feed material. In all three tests, the ore was ground to the same degree of fineness using a steel ball mill with steel balls in the first test, flint and ceramic pebbles in two rubber-lined mills in series in the second test, and fully autogenous grinding in a steel mill for the third test.

The metallurgical results showed that grade of the copper concentrate decreased from 27.8% obtained with steel balls to 26.7% with pebbles to 25.5% with autogenous grinding. However, this decrease in grade was more than offset by an increase in copper recovery from 78.0% with steel balls to 82.2% with pebbles and to 84.8% with autogenous grinding. The improvement in copper recovery was accompanied by a slight increase in both zinc recovery and grade when grinding in the absence of steel. Image analysis studies showed that the improved zinc recoveries and zinc-concentrate grades were fully accounted for by increased sphalerite liberation. The increased copper recovery was only partly explained by increased chalcopyrite liberation.

To improve CANMET capability in flotation process development, an automated mini-flotation plant of 100 lb/hr (0.76 kg/s) capacity is being assembled. The main features of such a system based on XRF methods were worked out through a contract with INAX Instruments Ltd. in 1976. Other problems still to be solved are concerned with automatic level control in miniature flotation cells and methods to automatically vary pumping rates corresponding to changes in recirculating loads.

One of the possible methods for treating the complex Zn-Pb-Cu bulk concentrate involves contacting the sulphide concentrate with dry chlorine gas. The proposed process is attractive because it has the potential for effecting high metal recoveries while producing elemental sulphur. Investigations of the dry-way chlorination method were consequently begun this year.

Work done in 1976 established a set of conditions for extracting the metal values and sulphur from the complex bulk sulphide concentrate. By reacting dry chlorine gas with the sulphides at 300°C for two hours in a rotary reactor, 98% of the zinc, copper and lead were converted to the chloride form while 98% of the sulphur was volatilized as sulphur monochloride. The desulphurized calcine was leached with water to dissolve the soluble zinc, copper and iron chlorides; the lead chloride was leached with a 125-g/l brine solution. Further investigation of the operating variables is planned.

Although satisfactory extraction of the metals was shown to be feasible, many problems must still be solved before a viable commercial process is evolved. These include the continuous bulk transfer of the sticky paste that forms during the reaction. Construction materials suitable for coping with the corrosive reactants and products must be identified, and methods must be evolved for the recovery of chlorine from by-product sulphur monochloride and ferric chloride. Balancing the heat from the exothermic and endothermic reactions involved could result in difficult control problems.

For a concentrate containing 32% Zn, 12.5% Pb, 1% Cu, 17.4% Fe, and 37.1% S, heat balances were calculated for five different chlorination temperatures, and for both two-stage and single-stage oxidation with and without Fe_2O_3 diluent. Based on energy considerations only, the results indicate that chlorination at temperatures slightly above the boiling point of sulphur, 450°C, followed by single-stage oxidation, is the best choice for an autogenous process, with the lowest diluent requirement. This will also reduce reactor design problems, because heat transfer for heating and cooling will be less complex. Based on the above considerations, further testwork on chlorination of concentrates with and without Fe_2O_3 diluent at temperatures of 450°C to 500°C has been planned for 1977.

In addition to chlorination, CANMET staff is investigating ferric ion leaching as a means of processing the Zn-Pb-Cu sulphide concentrates. Experiments have continued on the leaching of high purity sphalerite (ZnS) using the rotating disk technique, both to develop a ferric ion leaching process for sphalerite and to explain certain phenomena observed during the ferric ion percolation leaching of pyritic zinc-lead ores from Bathurst, New Brunswick. As work progressed, other interesting features possibly related to the nature of the iron complexes in solution also appeared. It was previously noted that the sphalerite leaching rate at 80°C increased sharply as the HCl concentration was increased above 1.0M. A series of experiments was performed at 85°C using solutions containing variable amounts of acid but no ferric ion. At low acid concentrations, the dissolution rate was very low, but it increased rapidly as the acid concentration increased. Above 1.0M HC1, the rates obtained with the acid alone were nearly the same as those observed for the acid plus ferric chloride. This indicates that the rapid leaching rate is caused mostly by direct acid attack and is not directly related to the ferric complexes present. At lower acid concentrations, the ferric ion attack is much more important than the direct acid dissolution.

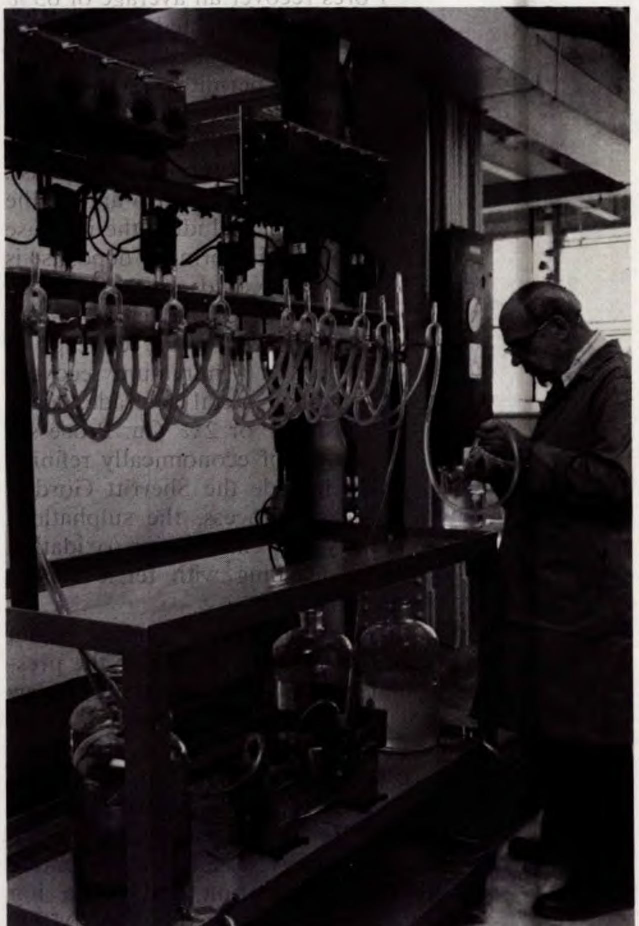

Figure 8 — Research continues at MSL for separating zinc, lead and copper by the Solvent Extraction process.

Work on the ferric ion leaching of chalcopyrite has progressed. The rotating disk method, with disks of synthetic chalcopyrite, has so far been utilized for these studies. It has been demonstrated that the accumulation of the ferrous chloride reaction product does not seriously interfere with the dissolution reaction. This behaviour is in sharp contrast to that observed with ferric sulphate solutions where the formation of ferrous sulphate causes the dissolution rate to fall sharply.

Percolation ferric ion leaching of some of the New Brunswick ores was continued. During the previous year, the effect of the ore column height on the amount of zinc extracted was determined. Under the leaching conditions employed, the total zinc dissolution rate is known to be largely mass transport controlled. Accordingly, the rate of zinc leaching for a fixed amount of lixiviant, would not be expected to increase with the amount of ore being leached. This was confirmed experimentally in the current studies. Decreasing the amount of ore undergoing leaching eventually results in a switch from mass transport control to chemical control.

Research has been initiated to evaluate construction materials for ferric ion and other atmospheric leach processes for zinc-lead-copper concentrates. A complex apparatus has been constructed to evaluate corrosion control techniques and corrosion behaviour of metals, alloys and coatings by electrochemical techniques and by conventional methods. Materials for ferric ion leaching of concentrates in sulphuric acid solutions at temperatures up to 90°C are currently under investigation.

The electrochemical leaching of chalcopyrite is being investigated. Studies have been carried out on the cathodic dissolution of chalcopyrite by cyclic voltammetry. The effects of sweep rate and pH variation on the current-potential curves have been studied, but the data have not yet been fully interpreted. Recent work at CSIRO, Australia, has shown that this is an attractive process but needs detailed investigation.

A paper describing the anodic dissolution of synthetic Cu_2S and CuS compacted anodes in sulphate and mixed sulphate-chloride electrolytes is in the final stages of preparation for publication. The dissolution of these copper sulphide minerals at constant anodic current is a complex process involving a series of solid-state transformations in the sulphide, which results in unusual variations of potential with time. This behaviour makes it difficult to interpret the results quantitatively, but a qualitative interpretation based on anodic film formation and break-down has been developed to explain the observed phenomenon.

The anodic dissolution of galena (PbS) is being investigated. In this work, a powdered concentrate is used rather than a matte anode prepared from a concentrate by pyrometallurgical techniques, so that air pollution by SO_2 can be avoided. Because lead salts of inorganic acids are highly insoluble, the anodic dissolution of PbS in mixed organic-inorganic-aqueous electrolytes is being systematically investigated. Although the anodic dissolution of PbS does not appear to be as complicated as that of Cu_2S and CuS, it is hindered due to a lack of conductivity in both the galena itself and in the organic electrolytes.

Because of the complex nature of the Brunswick-type ores, the solutions eventually produced from either a dry-chlorination process or a sulphate or chloride-based leaching operation will contain a great number of elements. Consequently, solution purification is required to separate zinc, lead and copper and to remove unwanted impurities such as iron. Solvent extraction is an attractive possibility for these purification steps and considerable investigative work has been completed. Several extractants were screened and SME 529 chelate was selected for copper and Alamine 336 for ferric ion and zinc. Copper would be removed first, then stripped with H_2SO_4 and electrolytic copper recovered. The Alamine 336 would extract the ferric ion, followed by water stripping to recover $FeCl_3$. Zinc is extracted with Alamine 336 and $ZnCl_2$ and could be recovered by water stripping. D2EHPA is also satisfactory for zinc extraction.

Some test work was completed towards establishing parameters for designing SX pilot plants based on the above data. It was found that low concentration of lead which is considered an impurity, passes through

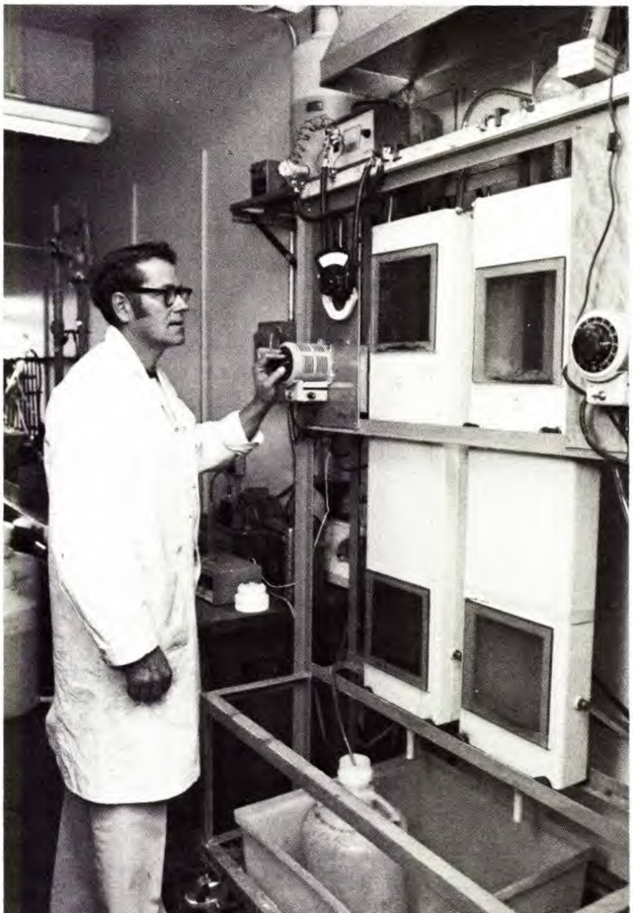

Figure 9 — Electrolysis is a promising method for recovering zinc, lead or copper from process solutions. Here a research technician makes an adjustment to copper electrowinning cells.

the proposed SX circuits and that a quaternary amine could possibly be used to extract lead.

The use of solvent extraction to recover zinc from chloride leach liquors will result in a zinc sulphate solution containing some chloride and entrained or dissolved organic extract. A systematic study on the morphology and orientation of zinc electro-deposits produced from these somewhat impure solutions is under investigation. Completed studies show that chloride up to 500 mg/1 can be tolerated but that dissolved organics are a serious problem.

In another study, CANMET and Cominco Ltd. cooperated in a joint project to develop methods of controlling the growth of zinc deposits such that a smooth level compact deposit is obtained on a routine basis and hence ensures that high current efficiency is maintained over longer periods of time than are presently attainable. The results indicated a definite correlation between the deposit morphology and the additives and impurities present in the electrolyte. The various additives and impurities also affect the polarization curves for zinc deposition in a characteristic manner. Consequently, by monitoring zinc polarization curves it is possible to adjust accurately the amount of modifying agent in the electrolyte so that the overvoltage is maintained at the proper level for producing an acceptable deposit on a regular basis without resorting to guesswork with respect to modifying agents. Another objective of this work is to control the lead contamination of zinc electro-deposits.

The electrowinning of zinc directly from chloride solutions was also investigated as a method for recovering metallic zinc. If feasible, this method would be preferable to electrowinning zinc from a sulphate electrolyte because the chlorine gas generated at the graphite anodes could be recycled to the chlorination step. The morphology, orientation and cross section of the zinc deposits obtained from chloride electrolytes were determined by SEM, XRD and optical microscopy techniques. Electro-deposits produced from simulated leach liquor were unacceptable. However, the effect of adding 60 mg/l of glue and 0.08 mg/l of antimony to the electrolyte resulted in a much improved zinc deposit. This approach was indicated by the CANMET-Cominco project mentioned above. If confirmed, these results would represent a significant break-through in the electrolysis of zinc from chloride electrolytes.

Processing of Ferrous Metals

Investigation of Peace River iron ore was started in 1974 and brought to completion in 1976. The in situ material contains about 30-35% Fe, 17-20% SiO_2, and about 25% water and consists of ooliths of geothite, amorphous nontronite with submicroscopic geothite inclusions, quartz, and an amorphous phosphate in a matrix of ferruginous opal and siderite.

The iron-bearing minerals can be upgraded economically by froth flotation to produce a concentrate containing 52% Fe, 14.8% SiO_2, 5.4% Al_2O_3, 1.1% MgO, 2.3% CuO and 1% P, with a recovery of about 60% of the iron. Slightly higher grade concentrates containing 55% Fe and 11% SiO_2 can be produced by roasting and magnetic separation of the flotation concentrates. Overall ratios of concentrations were in the order of 2.5:1, and rejection of silica was approximately 80%.

Approximately one-half ton per hour of composite briquettes, consisting of Peace River iron ore and lignite char, was smelted to produce 200 lb (90.7 kg) of pig iron per hour in a 16-inch internal diameter cupola. The technical viability of the process appears promising, but the economics are questionable. The pig iron was then converted to steel in a 300-lb (136 kg) capacity experimental top-blown basic oxygen furnace (BOF).

Since the pig iron smelted from Peace River iron ore contained unusually high contents of silicon at 3.5% and phosphorus at 1.5%, a double-slag steelmaking practice was developed. During the first ten minutes of the oxygen blow, the silicon was oxidized and transferred to the slag as calcium silicate by progressive additions of lime. After desiliconizing, the blow was interrupted and the slag removed. For the dephosphorization stage of the process, a mixture of 60% lime and 40% iron oxide was charged together with a small amount of fluorspar.

Processing of Industrial Minerals

Elimination of fine quartz from kaolin is a prevalent problem with Canadian clays. A flocculation and dispersion process has been developed for selectively recovering kaolin from classifier overflows and washing the product free from fine quartz. The process involves treating the overflow with $CaCl_2$ and SO_2 to activate the kaolin and depress, the quartz, then flocculating the kaolin with a high molecular weight polyacrylamide. The flocculated product is dispersed by agitation with sodium silicate to free any entrained quartz particles and then re-flocculated. Kaolin concentrates assaying 36-39% Al_2O_3 have been produced.

Studies are in progress to eliminate undesirable reactions that adversely affect the processing of clays and shales or the properties of products made from them. Current efforts are directed to improving the durability of structural clay products made from high-lime materials. These form the basic raw materials used by all major producers in central Canada, yet owing to their high porosity, the products are subject to degradation caused by moisture expansion and frost action. Such problems are common in the Toronto, Ottawa, Montreal and Quebec City regions. The development of porosity during firing can be traced by dilatometric methods and the primary cause has been determined by the scanning electron microscope, to be related to random growth of crystalline feldspathic compounds. Attempts to alter composition according to phase diagram considerations have met with little or no success, as have attempts to develop denser structures by seeding with additions of feldspars and related compounds. Future efforts will be aimed at nucleating crystallization of alternative phases displaying different morphologies, which should result in denser microstructures.

Much investigative work is being done to determine the technical and economic feasibility of processing Canadian anorthosite, shales, clays, fly ash and nepheline syenite to produce alumina as an alternative to importing bauxite or alumina. Some aspects of this work are being done as a cooperative project with the United States Bureau of Mines.

Laboratory research showed that >98% of the alumina could be extracted from anorthosite by leaching with relatively dilute sulphuric or hydrochloric acids (5 to 25 wt %) or 30 wt % nitric acid. To achieve these yields the anorthosite must be first melted at 1550°C and quenched to an amorphous material. Alumina was recovered from acid-leach liquors as potassium alum, aluminum trichloride hexahydrate and aluminum nitrate monohydrate. The purest alumina was obtained by recovering and calcining aluminum trichloride hexahydrate.

A recent U.S. patent disclosed the use of fluosilicic acid to disrupt the alumina-silicate bonds in clay to eliminate the need for calcining or dehydrating prior to acid leaching. Experimental work has been started to determine whether the addition of fluosilicic acid to hydrochloric and sulphuric acid leaches would increase the extraction of alumina from raw anorthosite. Initial results are encouraging: leaching of 200-mesh anorthosite with 24% hydrochloric acid and 0.8 to 4.8% fluosilicic acid resulted in alumina extractions of 64 to 91% depending upon time and concentration.

Work was done to develop and evaluate the technology for extracting alumina from anorthosite by the lime-soda sinter process. Samples of Canadian and American anorthosite have been examined. Alumina extractions of a maximum of 98% have been obtained for a sample from Lac St. Jean, Que. and 90% for a sample supplied by USBM. Although satisfactory extraction of Al_2O_3 was obtained, no method has been identified yet for producing an alumina of suitable purity from the leach solution, the major problem being silica contamination.

Investigation of the lime sinter process was started in 1976. Extractions of >95% of the alumina were obtained from Canadian anorthosite. As in the lime-soda sinter process, removal of silica from the leach liquor was not successful.

UTILIZATION

Many kinds of structures and articles made and used by modern technological societies are created from primordial rock by a complex series of operations and processes. These processes and their products on which R & D in the Utilization Sub-Activity is carried out, follow in logical sequence prior processes covered in the Mining and Processing Sub-Activities.

The Mining and Processing Sub-Activities lead to a raw material that needs no further refining, be it a metal or an industrial mineral. The material is then in a suitable condition for shaping into a usable article. Usually, a number of operations must be performed on material before producing something useful. Often in the preliminary stages of this sequence, the material is reduced to some standardized form such as tube, sheet, wire, angle, etc. These intermediate or semi-finished products, and the processes which produce them are of principal interest in the Utilization Sub-Activity although some R & D associated with the performance of finished industrial products is also carried out.

Compared with the endless variety of consumer goods and processes for producing them, the range of semi-finished products and processes is limited. The variety, however, is such that it confers on the nature of the R & D in the Utilization Sub-Activity a diversity that is absent in the work performed in the Mining and Processing Sub-Activities.

In implementing Canada's evolving mineral policies, the government has given first priority to "industrial development and diversification". It is the purpose of the Utilization Sub-Activity to serve this goal in the realm of materials development and technology.

Materials for Resource Industries

During the past year, research in materials for the resource industries has been confined to investigating the role of corrosion in wear that occurs in ball and rod mills during ore grinding. It is difficult to ascribe an accurate benefit to this work in dollar terms but certainly the mining companies are much more aware than before of the need for proper PH control in grinding.

Specifically, work has continued on evaluating corrosion resistance of various steels to assess their potential as grinding balls. In parallel studies, the effect of pH and temperature on the rate of corrosion during wet grinding of low-grade copper ore and hematite ore were assessed. Among other findings, a quantitative relationship between additions of sodium nitrite and the reduction in wear rate was also established.

Integrity of Metallic Materials

Metal structures of all kinds — pipelines, bridges, gas bottles, ships, tank cars, railway lines, to name a few — are subject to degradation and failure in service. As Canada's national metal's laboratory, CANMET is regularly called upon to investigate or consult in cases of serious service failures, and to contribute on a number of committees to establish standards and codes designed to prevent failures. This experience indicates where further research is required.

By the end of 1976 a preliminary assessment of the resistance of a number of metals and alloys to atmospheric and sea water corrosion in the Arctic indicated the need for, and feasibility of, a more comprehensive program. Designs for a test to monitor sensitivity to atmospheric corrosion are currently being evaluated and a broader program will be launched once a suitable test has been developed.

With a view to improving the performance and safety of welded structures in northern Canada, techniques for producing welds with high impact strength at low temperatures are being worked out. Already progress has been made towards establishing better welding procedures.

In further work, the toughness of welds in selected steels has been assessed by the explosion-bulge test. This work has indicated that the results are very sensitive to small differences in specific features of weld geometry and has pointed to limitations in which explosion-bulge tests are valid.

Particularly in large structures, economic considerations point to using the cheapest steel that will conform to specifications. Occasionally this philosophy has led to failures at welds, known as lamellar tearing. A simple qualitative test to determine the susceptibility of welded steels to this kind of failure has been developed in CANMET and adopted by a large engineering company in Montreal. CANMET's efforts so far this past year to develop techniques for making this test semi-quantitative have not been entirely successful.

As a side effect of some common industrial processes, including welding, hydrogen can become dissolved in steel. Operating variables of these processes should therefore inhibit as far as possible the solution of hydrogen. Hydrogen embrittles steel, even in minute amounts. As a result, its presence alone can lead to failures, although more often it contributes synergistically with other factors to produce failures. Hydrogen is thought to play a role in lamellar tearing, but the mechanism is still not clearly understood. Studies on hydrogen embrittlement related to work on welding and galvanizing continued throughout the year.

Metallurgical structure, impurity inclusions, and residual stresses are additional factors that affect the integrity of metal structures. Research into these variables sparked by specific instances of service failures, have provided experience that has added to CANMET's failure analysis capability.

Development of Industrial Mineral-Based Materials

Work with industrial mineral-based materials is concerned with studies on concrete, namely: (1) assessing materials for making concrete and (2) determining its properties and performance.

During the year a major program of chemical and physical testing was mounted to evaluate the properties of fly-ashes from a large number number of Canadian sources, and to assess their potential for making concrete. At the same time, work started on determining the feasibility of using selected coal mine shales to produce lightweight aggregates by sintering.

The use of sand for making concrete, produced by crushing limestone, was evaluated on contract by a private company. In the same study, the effects of fly ash and certain chemical additives on the workability and flexural strength of concretes were determined. The use of manufactured sand with crushed rock aggregate and fly ash were shown to produce concrete with very high flexural strengths.

A number of projects are directed to determining the properties of concretes. For example, an extensive study to catalogue the properties of lightweight concretes has been brought one step closer to achievement. Compressive, flexural and tensile strengths have all been determined, as has the shrinkage, modulus of elasticity and the effect of cyclic freezing and thawing. Only measurements of thermal conductivity remain to be done.

Figure 10 — The instrumented drop-weight tester is used to investigate fracture toughness of pipeline steels.

Work continues on an evaluation of the properties of sulphur infiltrated concrete. Field tests have been done in a sulphate treatment plant, a marine test site, and in local farm silos. It is known that sulphur can be leached from infiltrated concrete, and the conditions under which this occurs are being carefully studied in portland cement concretes and in low concretes as well.

A 5-year project in cooperation with Hydro Quebec, Société d'énergie de Baie James and Laboratoire de Béton has been started to determine the resistance of portland cement concretes to the acidic river and lake waters which typically occur in northern Canada. Specimens were prepared and cured at the LG2 James Bay Project site, and after being secured in retaining frames were lowered in place by helicopter.

Concretes made with high alumina cement have certain advantages — good resistance to alkali attack, they are fast setting, and develop good strength quickly in cold conditions. On the other hand, it is known that if concretes made with high alumina cement are exposed for sustained periods to conditions of high humidity or slightly elevated temperatures, crystallographic reordering occurs in the waters of hydration of the cement, and that this transformation is accompanied by a catastrophic loss in strength. Research has addressed the problem of overcoming this effect. Already it has been found that curing at elevated temperatures is beneficial but further work is necessary to define the limits.

Progress in the development of improved cementitious materials generally calls for new and more discriminating methods of assessing the properties of concrete. The energy crisis and the need to improve heat conservation has brought a growing interest in the thermal properties of building materials. With this in mind, work during the past year has been directed to developing better techniques and equipment for measuring thermal conductivity and thermal diffusivity in the laboratory. Other work in test equipment development has focused on the important problem of developing a simple non-destructive test that will provide a reliable measure of the strength of concrete in the field.

Standards, Specifications and Reference Materials

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

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

The strength and ductility of a cast metal is affected by the size and shape of the mould cavity. If there is to be agreement about mechanical properties of any particular casting alloy — for commercial reasons, or perhaps for engineering design purposes — the properties of the metal should be determined from tests on specimens cast in moulds of agreed dimensions. Consistent with its responsibilities as a national metals laboratory, CANMET has discharged a commitment to the ISO by comparing the effects of test bar mould design on the properties of test bars cast from various copper based alloys. Three different moulds were used in this investigation — one of French design and the other two of U.S.

Copper alloys containing aluminum, iron and nickel — the aluminum bronzes — have good casting properties and among other applications are used for casting marine propellers. It is known that significant differences in mechanical properties and corrosion resistance can accompany variations in chemical composition that occur within specification limits. The rate at which a casting cools is known to have an effect as well, but details of the role of cooling rate, particularly in relation to differences in composition have not been well understood. An investigation originally undertaken on behalf of the Royal Canadian Navy has been able to clarify a number of questions during the past year. In essence, the ratio of nickel to iron was found to be critical and its effects on both ductility and corrosion resistance. It is now possible to interpret current alloy specifications in the light of these findings and improvements in quality control in the foundry should follow.

A problem of a similar kind in a magnesium casting alloy has also been dealt with. From time to time, difficulties have been experienced in two Canadian foundries making premium quality castings in a magnesium alloy containing zinc, zirconium and rare earths. Certain combinations of the alloying elements, although within specification limits, do not achieve the minimum strength called for when heat treated according to specifications. Research has enabled the effect to be quantified and has indicated what remedial steps may be taken in heat treatment.

For many years, CANMET has carried out research on premium quality magnesium castings. The knowledge and experience acquired from this work has been useful in a number of ways. For example it has been applied by one foundry in making precision magnesium castings. More recently, radiographic standards for gravity segregation developed in the CANMET foundry have been adopted by the American Society for Testing Materials. Gravity segregation of alloying elements can occur in the crucible or in a casting during solidification and may be accompanied by undesirable changes in the strength and ductility properties of the cast metal. Parallel studies on a number of high strength magnesium alloys concluded during the past year have clarified the various effects gravity segregation can have.

The function of the Canadian Certified Reference Materials Project is to provide certified reference materials otherwise not available. These are used for quality control and calibration purposes in industrial, commercial, and government laboratories in Canada. While the emphasis in producing reference materials is on ores and related materials, some soils and metallic alloys as well are currently in various stages of certification. To date, 26 reference materials have been certified and made available. In 1976 a zinc-copper was certified and added to the CANMET list. Several materials were in various stages of certification including an antimony-arsenic ore, five iron ores for sodium and potassium content, a zinc-lead sulphide concentrate, a copper sulphide concentrate, three low alloy steels, five copper wire bar ingots for impurities, a blast furnace slag and four soil samples.

Work is also carried out on developing new analytical methods. Essentially the purpose is to maintain a level of analytical services commensurate with the laboratories' role as a national focus for mining and metallurgical research.

During the past year analytical methods have been developed for determining tellurium, arsenic and selenium at the ppm level in zinc, lead and copper concentrates. These methods have proved suitable also for nickel and molybdenum ores and concentrates, as well as for high purity copper metal and copper alloys including brasses. In addition, work was started on the development of methods for analyzing for polythionates.

Further Processing of Metals

Research to encourage further processing of metals is directly related to the government goal of emphasizing industrial development and diversification in implementing a mineral policy. The R & D is covered by five projects embracing work on moulding and casting technology, continuous casting of specialty metals and alloys in small section sizes, galvanizing, the forging of preforms made by powder metallurgy and metal forming technology.

Preliminary experiments have begun in the foundry to evaluate the application of a new sand moulding process to magnesium alloys. The process is known as the V process and was developed in Japan. In this process, sand is compacted in each of the two halves of a sand mould by applying a vacuum to the mould flasks. The sand interface and the mould recesses in the top and bottom halves of the mould are sealed off by a sheet of thin plastic which vapourizes when the casting is poured. The process does not require binders, clay, or water to bond the sand. Once the casting has cooled, it is easily shaken out and the sand reclaimed. However, the principal advantages of the process is that it reproduces greater detail than conventional sand moulding or green sand practice. Thus, crisper, more accurate castings can result. Among other things application of the process to the casting of magnesium alloys is attractive for environmental reasons. In conventional moulding practice it is necessary to add inhibitors to the sand mix to prevent porosity in the casting resulting from the reaction of the molten magnesium with water in the mould. Sulphur is one of the few effective inhibitors but its use has environmental consequences it is desirable to avoid.

It is now about 25 years since the discovery of nodular iron was first announced. Early work showed that if small amounts of certain metals were added to molten cast irons with certain compositions, castings could be made that no longer had the characteristic brittleness of cast iron but were quite ductile instead. Nodular iron was essentially a new engineering material which nevertheless retained all the useful properties of cast iron. It was quickly shown that the reason for the remarkable improvement in ductility was to be found in the spheroidal form of the graphite. In cast iron, graphite exists as flakes. Of the metals with this power, magnesium has always been found to be the most effective. Unfortunately, magnesium has a low boiling point and if it is added to molten cast iron at the temperatures of the latter, it can react explosively unless great care is taken. This fact, more than any other, has limited the production of nodular iron. Thus, since its discovery, a great deal of R & D effort in many centres has been devoted to developing methods of introducing magnesium into cast iron in a safe manner. A device has been developed in the CANMET foundry which feeds magnesium in the form of a wire through the bottom of a ladle. Throughout the year work continued to make the operation of this device sufficiently trouble-free that the method could be passed over to a commercial foundry.

There is a systematic trend in foundries towards greater use of quick-setting inorganic binders to bond sand moulds. Those in current use are based on sodium silicate. The moulds they produce are stronger and maintain detail better than green sand moulds bonded with a bentonite clay and water. So strong is the bond

Figure 11 — The temperature of a bath of molten alloy steel is being measured in a direct arc electric furnace in the experimental foundry.

provided by sodium silicate that once the aggregated sand has been removed from the flasks it is difficult to break it up completely and reclaim it. Work has been started to develop a new binder material that will break down more readily and thus enable moulding sand to be recycled indefinitely.

To be mechanically sound, a casting must be completely deoxidized. Ordinarily to produce a deoxidized casting, the molten metal is de-gassed to an acceptable level in the crucible or furnace and is deoxidized just before pouring. To deoxidize, quantities of suitable reagents are added in excess of that required to be certain dissolved gases will be tied up as solid inclusions in the casting. To produce high conductivity copper casting for which there is a growing demand, a different practice must be developed. This is the purpose of some work performed during the past year. The project has four components. First, a technique that can be used in commercial foundries must be developed to indicate when degassing has reached an end point at which the dissolved oxygen is at a minimum. Second, an investigation to determine which element of several prospective candidates has the least effect on the conductivity of copper when dissolved in the metal in trace amounts. Third, foundry techniques must be developed to ensure that the minimal quantity of new oxygen is picked up by the freshly deoxidized copper during pouring and solidification. Fourth, these three separate techniques must be packaged and evaluated in the foundry to ensure that castings of acceptable quality can be produced.

Traditionally, rolled products—plate, bar, shapes, etc. — are reduced during the rolling process from ingots typically 20 inches (0.51 m) or more in cross section thickness and several feet long. But, because of cost advantages, rolled products are increasingly being produced from continuously cast blooms instead of ingots. In cross section, continuously cast blooms are roughly half the size of ingots. Because of the growing technological significance of continuous casting, CANMET carries out some research in the field. However, problems associated with large tonnage production practices are better left to industry. Instead, research has been focused on developing the equipment and techniques for producing specialty alloys in small section sizes. A small continuous casting machine has been built, and research throughout the year has been devoted to determining the operating parameters for producing 7/8-inch (2.2 cm) square bars of tool steels and evaluating them metallurgically. If subsequent work demonstrates that tool bits of acceptable quality can be produced from this stock, then the process will be turned over to a Canadian manufacturer because it will be very competitive with the orthodox methods of making tool bits from ingots.

Galvanizing research in CANMET has been supported for many years by the Canadian Galvanizing Research Association and by the International Lead Zinc Research Organization. Recently, attention has turned to the galvanizing of high strength low alloy (HSLA) steels. In particular, studies have centred on the accelerating effect which the "high" silicon content of some HSLA steels has on the galvanizing reaction. The trend towards lighter cars, and the impending use in cars of thin gauge HSLA steels for body panels, draws attention sharply to the need for protecting these steels effectively against corrosion. During the past year, research has set out to answer three questions. First, to explain the reason why silicon accelerates the galvanizing reaction. Second, to determine the manner in which vanadium or nickel added to the galvanizing bath inhibits the effect of silicon. Third, to explain why vacuum annealing HSLA sheet before galvanizing also eliminates the accelerating effect of silicon. Vacuum annealing is not thought to have commercial potential as a means of controlling the silicon effect but it is hoped that understanding the effect of vacuum annealing might also provide a clue to a better understanding of the behaviour of silicon.

CONSERVATION

The need for conserving minerals and metals is self evident. Conservation can be effected in the main by optimizing the use of metals in fabricated products, developing substitute materials, finding uses for what are now considered waste products, and increasing recycle ratios through technological innovation. In 1976, CANMET efforts in conservation technology were limited to studies related to the use of mineral, metallurgical and chemical wastes and to the increased use of scrap metal.

In an effort to bolster public awareness of existing available mining and mineral processing wastes and to stimulate interest in their reuse, data is being compiled on their occurrences and their physical and chemical characteristics along with suggested reuse possibilities. A report covering Ontario mineral wastes has been issued and one covering Quebec is in preparation.

A study of the technical feasibility of producing mineral wool from molten slag was completed, and experiments have been conducted successfully to produce mineral wool from steel slag with the addition of silica. Work has also been initiated to determine the technical feasibility of producing foamed insulation products from various mill tailings and waste glass. Efforts are now being made to transfer this technology to the industry.

The development of a suitable Zn-Al casting alloy based on secondary zinc requires defining optimum composition limits for certain elements and impurities because: (a) in existing specifications it has been assumed that the alloy behaves like the commonly used 4.5% Al die casting alloy and, (b) there was some prospect that the 12% Al alloy was more tolerant to impurities and hence would permit a greater degree of recycling. The work has established optimum limits for copper and magnesium, and for lead and tin when present separately. It was shown that lead considerably in excess of the present specification limits can be tolerated without detriment to corrosion resistance. An anomalous effect was discovered for tin. If present at the accepted maximum limit of 0.003%, it had a worse effect than at 0.015% where the corrosion resistance was about the same as with 0.001% Sn. The combined effects of lead and tin were found to be greater than the sum of their individuals effects, and for practical purposes, the tolerance of the alloy for tin was so low that the maximum for this impurity was considered to be 0.001%. For lead, 0.01% produced substantially the same corrosive attack as 0.001% and would be considered an acceptable upper limit for this alloy. The new information on the effect of tin content may have significant impact on the commercial specifications for these alloys.

Current awareness has been maintained on various aspects of municipal solid waste with particular reference to materials and energy recovery and recycling.

ENVIRONMENT, HEALTH AND SAFETY

In recent years there has been increasing public concern regarding the impact on the surface environment of industries such as mining, pulp and paper, and pipelines. Sulphur dioxide in stack gases, asbestos particulates, radioactive materials, and mercury and arsenic in watercourses are but some of the problems singled out as special causes for concern. Consequently, the development of technology aimed at reducing hazards to health, safety and the natural environment due to mining and metallurgical operations has a high priority in the CANMET program.

Underground Environment

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

The sampling and analysis of airborne dust in mines has been under investigation by CANMET staff for several years. A gravimetric sampling method in conjunction with X-ray diffraction for analyzing the quartz content of the sample has been developed and is now being introduced into Canadian hard rock mines. During 1976, CANMET, the Mine Accident Prevention Association of Ontario, and Denison Mines Ltd., conducted a cooperative study in selected mining operations to compare the new gravimetric method with the conventional method using a konimeter. In another study done under contract, three types of gravimetric samplers were evaluated. Quartz analysis of dust samples using infrared methods is also being assessed. The emphasis in research on airborne dust is changing from measurement and analysis to how dust is produced in various mining operations and how it can be suppressed.

CANMET and the US Bureau of Mines are conducting a cooperative study of radiation problems related to uranium mining. An extensive system for continuously monitoring radon gas levels was installed at one mine to measure the radon levels produced by various mine operating functions. Preliminary results indicated that mucking operations are the major source of radon gas underground. Blasting produces a surge of radon gas but this is dissipated by the ventilation system between shifts. In another study, radon levels in stopes back filled with tailings were measured. The data obtained in these studies will be used to map out ventilation strategies to reduce radon concentration to safe levels.

In other work related to the radon problem, a prototype instrument was tested instantaneously measuring radon and radon daughter levels in the working place. It gave accurate measurements, but because of its weight could not be considered portable. Other instruments were tested by CANMET staff during an extensive survey of Elliot Lake homes for radon levels. Finally in 1976, a multi-head radon converter was built which will significantly increase CANMET's capabilities for conducting radon analysis.

A data bank on emissions from diesel engines used in mines is being developed so that ventilation requirements can be based on actual emission rather than simply on specifications for new engines. In 1976, tests were continued on worn, reconditioned and new engines on the laboratory dynamometer. This work is being expanded through development of a portable device including a smokemeter for diesel particulates which will permit emission evaluations of partly worn engines to be made in the field. Preliminary test work on the conversion of SO_2 to SO_3 in catalytic purifiers has indicated that the formation of acid mists is a potential problem requiring further investigation. One of the major activities of CANMET's diesel laboratory is the certification of engines which is described under the Energy Program.

In 1976, a start was made on developing a computer ventilation model for underground mines. Initially the model would be used to predict airflow distribution, then at a later date to incorporate data on dust, radon gas, diesel emissions and noxious fumes.

A comprehensive noise survey of the open pit, underground and milling operations at one mine has been completed. The study was directed at establishing the noise exposure index for various work occupations and effectiveness of protective methods and equipment. The attenuation characteristics of several types of ear muffs have been evaluated in the laboratory and field tests on selected muffs are to follow. A prototype noise monitor has been built and the next step is field testing.

Figure 12 — Specialized techniques are needed in the preparation of specimens prior to examination with an electron microscope. A carbon extraction replica of rail steel is being made here for examination at very high magnification.

During 1976, CANMET initiated a number of contracts on health and safety aspects related to the uranium mining industry. A brief summary of the scope of these contracts is as follows:

1. Industrial Hygiene Survey

Document occupational and environmental concerns at the work place; review administrative and engineering controls and surveillance techniques; identify occupational risk; and establish a rationale for identifying environmental surveillance priorities.

2. Accuracy of Dust Samplers

Effect of wind speed, direction and sampler inlet velocity on quantity of dust collected by three types of samplers; effect of sampler location on the body; and effect of wind speed on collection characteristics of three different cyclones.

3. Ventilation Strategies

Documentation of existing ventilation practice and statutory requirements for uranium mines; identification of recent innovations in ventilation practice; reviews of existing ventilation computer models.

4. Alpha Dosimeter Evaluation

Calibration and measuring procedures; field trials of instrument in three mines and evaluation of the measuring technique.

5. Continuous Monitoring

Acquisition and testing of commercially available sensors; development of new measuring devices; field testing of sensors, data transmission and computer systems; evaluation of continuous monitoring systems. Sensors in the system include anemometers, detectors and measuring devices for fire, radon gas and its daughters, carbon monoxide, methane, sulphur dioxide, hydrogen sulphide, oxides of nitrogen, oxygen, dust, temperatures, humidity and barometric pressure.

6. Uranium Tailings Backfill

Review of present mining practice; properties of uranium tailings; radon emission potential of tailings; use of cement or synthetic resins to seal the fill; assessment of benefits of using backfill.

7. Hydrocarbon Inhalation

Identification of main factors affecting pulmonary function and the respiratory diseases expected from long-term exposure to the underground environment; review of medical evidence on inhalation of hydrocarbons including cigarettes and diesel exhaust and its effect on pulmonary disability.

8. Miners Work Suit and Helmet

Development of prototype work suits to provide optimum conditions of water resistance and vapour permeability; development of a helmet with integrated lamp, full face visor, filtered air system and hearing protection; development of improved battery to power lamp and air filter system.

9. Diesel Exhaust Treatment Systems

Testing commercially available water scrubbers and catalytic converters to determine the retention of diesel soot in the exhaust; feasibility of collecting diesel soot with dry filters.

Waste Disposal

For the last two years, CANMET has increased its research activities on uranium tailings which covers water contamination from radioactive materials as well as acidity caused by the oxidation of pyrite in tailings.

A five-year study on the physical and chemical properties of tailings, followed by vegetation growth tests in environmental chambers, and finally field trials, has resulted in a method of establishing a vegetative cover on uranium tailings at Elliot Lake. Initial treatment involves neutralizing the acidity and providing nutrients, followed by cultivation and seeding, then fertilizer applications over a five-year period, after which the vegetation is self-sustaining. A number of grass types can be used, but a mixture of Redtop and Creeping Red Fescue is recommended. Tests have also been carried out with trees, and while some deciduous trees can readily be established, coniferous trees are not. Microbiological tests on the vegetated areas of the tailings have indicated that sufficient numbers of microorganisms exist to support a recycling process. A brief study has been done on the uptake of radioisotopes by grasses. It was found that uranium, radium-226 and lead-210 contents were higher in the grasses than in a control soil.

Another area of research is to identify acid producing mechanisms within the tailings basin, the pathways to which acid, metals and radioisotopes are leached and enter the watercourses, and to develop suitable control methods. A system of sampling wells and weirs have been established on one abandoned tailings area. Results indicate that most oxidation of pyrite, predominantly by bacterial action, occurs in the top ten inches (25.4 cm) of the tailings. It was also found that the coarse tailings overlie highly acidic and radioactive water, whereas the water under the finer tailings is much less contaminated except in the case of radium-226. Although this is considered the major source of radioactive contamination, a state-of-the-art report has been written dealing with the thorium aspects.

A preliminary study has been done under contract on the stability of radium-barium sulphate sludges such as are deposited in the settling lagoons after barium chloride treatment of effluents. In many respects, the results were inconclusive but did indicate that the sulphate concentration of the solution was the major factor affecting the release of radium.

In cooperation with Rio Algom Limited, a five year test program was started in 1975 to assess the effects of various surface treatments including vegetation on the quality of the seepage water. Four tailings pits 30 ft x 30 ft x 5 ft (9.1 x 9.1 x 1.5 m) deep have been constructed. One pit has been vegetated using the CANMET method, other surface coverings are six inches (15 cm) of alluvial till and a layer of sawdust. The fourth pit has no surface treatment and is used as a control. The experiment will run for three more years to allow sufficient time for oxidation of the pyrite. Bi-weekly measurements are taken on the contamination levels in the seepage water from each pit.

Tests have been completed on the effects of Pentachlorophenol to inhibit the bacterial oxidation of pyrite in tailings. It was found that it did not diffuse adequately through the tailings and the concentration required would itself be toxic in the effluent discharge.

An alternative method of dealing with the pyrite in tailings is to remove it by flotation in the mill. Preliminary tests on old tailings indicate that up to 96% of the pyrite can be removed by flotation. Furthermore, preliminary results have indicated that a substantial concentration of radium-226 is achieved by flotation. This research is continuing with more emphasis on fresh tailings.

Another environmental problem being tackled is the presence of polythionates in sulphide tailings from flotation operations. Where polythionates occur in the overflow from tailing ponds they tend to oxidize in the receiving stream with the result that the pH value is lowered to the point that the stream life system is threatened.

The formation of thiosalts in the grinding of New Brunswick sulphide ores is an especially troublesome problem being investigated. Experimental results to date show that the reactions producing sulphur compounds are extremely sensitive to pH.

If the production of thiosulphates cannot be prevented, oxidizing them to sulphate with air followed by neutralization ahead of discharge to the environment may be a solution. This reaction is slow and studies are being done to find means for catalysing it.

An extensive investigation of methods for removing soluble cyanide and base-metal cyanide complexes from gold-mill effluents started in 1975 was completed in 1976. Four methods were investigated. These were acidification, chlorination, ozonation, and ion exchange treatment of the cyanide-bearing effluent. Economic analyses of the four processes indicated that the chlorination route was the least expensive, mainly because of low capital cost. However, in the final analysis, the choice of process will depend on the complexity of the solution to be treated, and it may be necessary to adopt a more expensive route to meet environmental standards.

In previous work related to air pollution, a packed-bed filter was developed to suppress the release of particulates into the atmosphere from smelters, refineries and processing plants. Work was continued in 1977 on an experimental model. After increasing the size of the laboratory-scale unit to handle 40 cfm (1.1 m^3/min) of gas and making other modifications, collection of submicron size fume from the experimental basic oxygen furnace was achieved with 95-99% efficiency. By means of attaching a special elongated bed retention screen to the outside of the exhaust louvres, the capacity of the experimental unit was effectively doubled and the bed pressure operating range was also considerably extended.

Assistance was provided to Canadian Patent Development Limited in a successful U.S. patent application, and also to Canadian and U.S. licensees on the joint design and installation of a second commercial packed-bed filter at a Winnipeg foundry, capable of handling 14,000 cfm (400 m^3/min.). In this fullscale unit, efficiencies of over 99% were obtained for simulated foundry cupola dusts.

Plant Environment

A wet processing system was investigated for asbestos with the aim of reducing the health hazard from airborne fibres while still maintaining a product comparable with that obtained by the dry processing system.

A new piece of equipment has been developed for wet separation of asbestos fibre from rock. This has overcome the disadvantages of conventional classifiers and jigs which provided poor separation and had low capacities. The new equipment requires relatively small amounts of water and has a high capacity per unit area. It has been tested on a batch basis, using $<$1-¼-in. (0.5-cm) feed, and has a capacity of 3 t/hr (0.75 kg/s) recovering more fibre than by the dry methods used in industry.

TRANSPORTATION

Work in the transportation field involves two projects. The object of the first is to develop a fully weldable rail with superior wear properties. The second is directed towards evaluating materials, particularly high strength low alloy (HSLA) steels and aluminum alloys, suitable for the production of lightweight automobiles.

Materials for Transportation

Railways are vital to the bulk transportation of minerals. On lines carrying heavy traffic, the standard carbon-steel rail is quickly degraded in service when installed on sharp curves. Adequate supplies of a suitable rail are not available in Canada and it is the purpose of this work to develop a satisfactory premium rail in cooperation with Canada's only two rail producers, the two major railways, the Transportation Development Centre (TDC), and the Railway Advisory Committee.

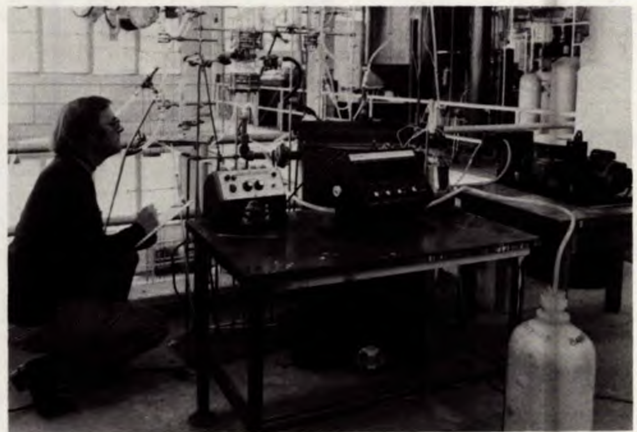

Figure 13 — Apparatus for removal and recovery of cyanide from gold-mill effluents.

To date, activities in this project have been of a preliminary nature only. A research scientist spent six months with British Rail Research Laboratories on what was essentially a familiarization exercise; work has begun on evaluating the metallurgical characteristics and properties of the premium rails currently available to provide an adequate data base for future research; a literature review on the welding of rail steels was undertaken and the decision was made to focus research effort on flash welding methods.

Automotive Materials

To achieve better fuel economy, automobiles in future will be constructed of lighter materials. Among other considerations, this means high-strength steels will be used in thinner gauges. It may also mean that aluminum will be used far more extensively in automobile construction. These possibilities pose a number of problems in steel forming and corrosion technology, as well as in the technology of producing suitable aluminum sheet by similar methods to those used for steel.

HSLA steels are not as readily formable as the low carbon steels presently used extensively in the manufacture of automobiles. Developing techniques to form such steels, and understanding their limitations are currently an important problem. During the past year, CANMET research has addressed two aspects. First, it has built the equipment for performing cup tests to assess the limits of formability of HSLA steel sheet. Second, it has embarked on an investigation to determine the possibility of adjusting controlled rolling schedules used in producing the steels to improve formability of the steel sheet.

A study of the potential application of aluminum alloys in the manufacture of automobiles has shown that significant energy savings can be achieved. Savings can result both from increased fuel economy by reducing the automobile body weight as well as from an increase in automobile life because of the superior atmospheric corrosion resistance of aluminum alloys. On the basis of this information, work was started to evaluate the response of certain aluminum alloys to controlled rolling schedules of the kind used in producing HSLA steels. In particular, the effect of various controlled rolling schedules on the formability of aluminum alloy sheet was assessed. It is recognized that if aluminum companies are to produce the quantities of aluminum sheet that the automobile manufacturers will require, they will have to adopt the same kind of mass production methods used by the steel companies.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

AUTHORIZATION AND TESTING

Under the Explosives Act of Canada, the Canadian Explosives Research Laboratory carries out certification tests and provides technical advice to the Chief Inspector of Explosives. During 1976, about 400 samples of explosives were tested and reports written covering chemical analysis, friction, tests, and determination of levels of sensitivity to mechanical shock and heat. Samples submitted ranged from toy caps, fireworks, automobile flares, to high explosives used in mining and civil engineering operations.

CANMET is active in the international sphere and provides the chairman for the Ammonium Nitrate and Ammonium Nitrate Mix Subcommittee. Continued effort is being made to establish international standards for explosives classifications. Expert advice has been given in court proceedings involving violations of the Explosives Act and to the Department of Transport regarding the crash of an aircraft believed to have been caused by a bomb.

Research and development is concentrated on slurry explosives following the accidental explosion at McMasterville in October 1975. The prime purpose of this study has been to develop classification standards and related test procedures. The Swedish nut and bolt test has been evaluated and found suitable for incorporation in classification procedures for cap sensitive slurries. The present rifle projectile test for impacting sensitive slurries was found inadequate, but tests using the USA and Swedish .50 calibre projectiles were found to be suitable replacements. In the past, a graded series of blasting cap strengths have been used to test the shock sensitivity of explosives. A more continuous grading of shock strength is required and different weight detonating fuse, card gap tests and exploding wires are being investigated. In conjunction with developing new testing procedures, a mathematical model is being developed to correlate the physical and chemical properties of slurry explosives with the mechanisms of initiating explosion by shock, mechanical impact and heat pulses.

In joint funding with the Canadian Fertilizer Institute and other federal government departments, a three-year contract has been given to investigate the fire and explosion hazards of ammonium nitrate.

Mineral and Energy Information

The information program is the primary expression of CANMET's R & D output in mining, mineral processing, metallurgy and energy, and of data obtained from contacts developed over many years as a consequence of its leading federal role in technology development.

The program contributes to branch objectives by:

(a) disseminating the results of research and development activities of CANMET's own research scientists to industry, universities and provincial agencies;

(b) advising and supplying data to other EMR offices;

(c) providing information services to the branch's staff of researchers, and — as part of the developing national science-technology information network — to industrial, university and government scientists at large.

Activities of research scientists in technology information transfer are mentioned explicitly or implicitly in other parts of the review. The following is a brief

Figure 14 — A cup test is widely used to determine the formability of sheet metals. This machine is used to measure the forming characteristics of sheet aluminum or steel for possible use in automobiles.

summary of developments and accomplishments primarily in the Technology Information Division.

TECHNOLOGY INFORMATION DISSEMINATION

A significant development of the year was the growth in size and scope of the Technical Inquiries Section. Staff now includes professionals specializing in technology information relating to energy, mining, metallurgy, and mineral processing. Much effort was devoted to establishing interaction with CANMET research personnel and industrial clientele which the division aims to serve. Mailing campaigns, notices in journals, exhibits, presentations and personal contacts were used as the initial elements of a plan to inform Canadians of CANMET's extensive information capabilities. More than six hundred inquiries for technical information, many requiring extensive literature searches, were handled, in addition to more than a thousand requests for advice and consultation in person, by telephone, or by mail, dealt with directly by individual researchers.

Information specialists now routinely employ on-line access to about forty large computer-stored data bases in answering technical inquiries. Of particular value are the METADEX file of the American Society for Metals, COMPENDEX, the machine-readable form of Engineering Index, and files generated by the U.S. Energy Research and Development Administration and the American Petroleum Institute. These sources are supplemented by in-house files developed over many years, library holdings, and the expertise of CANMET's research staff. A current awareness service is also offered in collaboration with the Canadian Selective Dissemination of Information Network (CAN/SDI) of the National Research Council.

The energy information service covers conventional oil and natural gas, oil from tar sands, heavy oils, coal and peat. It relies heavily on several key data bases available on-line through the division's computer hook-up. The division also has access to all reports originating from the U.S. Energy Research and Development Administration on non-nuclear energy subjects, as well as a growing collection of journals, monographs and report literature from around the world.

A sub-unit within the Technical Inquiries Section, consisting of specialists and support staff, was established during the year to fulfill obligations assumed through the department's membership in coal projects of the International Energy Agency, notably the Coal Technical Information Service, and the Mining Technology Clearing House.

Staff of this unit completed a questionnaire on Canadian R & D in "Mechanized Drivage of Roads, Slopes and Shafts" for the Mining Technology Clearing House and is routinely submitting abstracts of Canadian, Australian and South African coal-related literature to the Coal Technical Information Service. The information officers are also available to answer technical inquiries originating both within and outside CANMET on coal.

More than 2500 new abstracts were added to the mining technology information data base, a computerized bibliographic file generated in-house. This file, initially established in 1968, now holds about 15,000 abstracts covering all aspects of the mining — from discovery to processing — of metallic and non-metallic minerals, construction materials and solid fuels. In addition to file building, the mining technology information unit responded to nearly 400 queries and produced a number of technical and statistical summaries on various aspects of Canadian mining.

Information services in metallurgy were begun in May 1975 when a full-time information officer was seconded from the Physical Metallurgy Research Laboratories to operate the CAN/SDI current awareness service for metallurgists based on the METADEX tapes of the American Society for Metals. At present, the information officer also coordinates CAN/SDI services for the Division in the other subject fields and answers technical inquiries in metallurgy through access to computerized and conventional files.

Originating in the former Extraction Metallurgy Division many years ago, the mineral processing information service is presently based on an inhouse file in which items are indexed and retrieved as numerically-coded titles. The file now holds almost 10,000 entries. In a move to strengthen this service, an information officer and an abstractor were appointed. Abstracts of reports selected from the world's mineral processing literature are being prepared as first input to an expanded computerized reference file.

The division's Slavic Language Specialist conducts background studies of Soviet and Polish technical literature and assists departmental officials involved in exchanges with these countries. The work also includes regular translation and dissemination of the tables of contents of Russian journals to keep departmental personnel aware of new developments in mineral — and energy-related fields in the USSR.

The division provides a referral service to ensure that callers reach the best source of information without delay. Since 1973, the division also participated in a structured referral service — "ASK" — organized as a pilot project by the National Research Council in the Toronto-Hamilton industrial area to test the technical information needs of a community. A detailed profile of CANMET expertise is registered in the ASK knowledge base, and the Technical Inquiries Section has been receiving a steady flow of referrals from the service.

LIBRARY SERVICES

With well over 100,000 volumes, the CANMET Library is Canada's best single collection of mining and mineral processing literature. To meet the responsibilities implicit in this status, it has actively participated in recent years in the national system of interlibrary lending. This participation includes coordinated collection development and other forms of cooperation with the Canada Institute for Scientific and Technical Information of the National Research Council and other information centres. The library also operates satellite libraries in the Physical Metallurgy Research Laboratories and at other CANMET laboratories at Elliot Lake, Edmonton and Calgary.

The collection grew by over 6,000 volumes and now totals 35,000 books, 85,000 volumes of serials, and more than 15,000 technical reports, for a total in excess of 135,000. The film and microfiche collections also experienced significant growth mainly through the addition of some 12,000 ERDA reports on microfiche.

In the past the library's acquisition policy has relied heavily on the recommendations of CANMET staff. This year, as the basis for systematic collection-building, staff recommendations were supplemented by acquisitions based on an interest profile for current awareness of new publications. Special arrangements were also made with a large book-jobbing firm to ensure comprehensive and rapid acquisition of materials of interest.

Loans of books, serials, etc. to CANMET staff increased to 61,432 in 1976/77, while loans to other libraries totalled 4,474. The library borrowed 2,226 items on behalf of CANMET's research staff, mostly in disciplines peripheral to CANMET's central concerns. Library staff also answered 882 major reference inquiries.

PUBLISHING SERVICES

The Publications Section of the Technology Information Division in collaboration with laboratory editors and other support staff, is responsible for the technical production and dissemination of research results achieved by CANMET scientists. The principal activities include technical and literary editing of CANMET reports, printing, physical processing and dissemination of all reports, translations in the two official languages and maintaining files of photographs and slides for illustrative purposes.

The past year saw the introduction of programmable word processing equipment as a means of speeding up the production process and reducing costs and manpower requirements. Initially used for the production of the Pit Slope Manual, this type of equipment will be phased in gradually as resources permit, to handle production of all reports prepared by CANMET staff.

During the previous year there had been two categories of senior reports directed to the public. The current year saw the consolidation of the two categories into a single series, collectively titled CANMET Reports, and sold to the public through the Department of Supply and Services and CANMET's own distribution facilities. This year more than 900 new reports and papers were produced by CANMET staff, as follows:

CANMET Reports	50
Presentations and Journal Submissions	180
Unclassified, limited external distribution	381
Unclassified, internal distribution	145
Confidential	161
Total	917

In addition, 115 reports, previously confidential, were declassified and placed on open file in the CANMET Library.

Technical Services Division

During 1976, the Technical Services Division (TSD) continued its active technical support of the various R & D laboratory and pilot-plant projects organized under the Energy and Minerals Research Programs. The division developed and manufactured several items of prototype equipment, carried out large-scale mechanical and electrical installations for applied R & D in combustion research, petroleum processing, minerals processing and metals processing, and provided ongoing operational and maintenance support for plant, equipment, vehicles and utilities.

The divisional cost-accounting system processed 2,435 work projects and completed 82,831 direct labour hours. The rate of direct to indirect hours was 1 to 0.90 and the total output was distributed among the CANMET research laboratories as follows: PMRL - 45%, MSL - 21%, ERL - 21%, MRL - 3%, and Administration and Services - 4%. The balance of 6% went to other EMR branches and divisions and to authorized outside work projects. Distributed by research program, TSD output was estimated to be 46% on behalf of the Minerals and 40% for the Energy Programs.

Energy and utilities continued to be a significant part of the total cost of providing effective technical support and other operational services. For example, electrical energy consumption in 1976 was 11.049 megawatt hours at an average load factor of 48.2%. The peak demand at the Booth Street complex was 1804 kw and at the Bells Corners complex, 1261 kw. The cost of power was $214,777 for the whole of CANMET. In effect, total electrical consumption was down by 18% compared with that for 1975, greatly exceeding the 10% saving required by the Office of Energy Conservation.

Some examples of bench-scale and pilot-plant equipment development are presented. Some of these required special electrical control and instrumentation feeder. The output of 100 lb/hr (45.4 kg/h) from this systems to be designed and built, and additional power distribution equipment and circuits to be installed on site to supply the additional loads.

HOT BRIQUETTING APPARATUS

Some time ago a pilot study was conducted by an outside consultant under the Formed Coke Project to determine the feasibility and design parameters of a hot briquetting unit. The result of this work was subsequently published and provided the basis for building an apparatus of pilot-plant size.

The apparatus was designed and built in the TSD Model Shop and consisted of specially made ribbon feed screws to feed coal and char from separate pre-heated hoppers into a double ribbon screw mixer-feeder. The output of 100 lb/hr (45.4 kg/h) from this mixer-feeder is fed directly to a briquetting press. Because the coal and char feed temperatures are up to 750°F, it meant that the unit had to be entirely constructed in stainless steel. The mixer-feeder screw is about three feet in length and provision was made to accommodate expansion due to temperature. The bearings for the feed screws are made of graphite and are retained in water cooler housings. To provide flexibility of operation, each feed screw is individually driven by a variable speed drive. There was considerable electrical involvement as power was required for the various drive motors, for the electrical heaters around the hoppers and for the feed-mixer furnace. Instrumentation was also provided to sense and control the heaters and furnace so that precise operating conditions could be obtained.

METAL FORMABILITY TESTING DIE

Parts for a 100-ton hemispherical cup tester, designed by PMRL, was manufactured in the division to study formability of high-strength steel and aluminum alloy sheet. The principal parts of the equipment are an existing 100-ton hydraulic press, the hemispherical cup itself, a die set and a secondary press for clamping sheet metal. The design required that the platens of the press be modified to integrate with the 100-ton press. Furthermore, the hydraulic system of the press was altered to allow variability of the ram speed.

To conduct a test, a load is applied through the hemispherical cup to a sheet metal specimen clamped in the die set by the secondary press. Deformation of the sheet is allowed to continue until just before the onset of fracture. The clamping pressure is then removed, the die set opened and the specimen removed. Formability is assessed by measurements of the localized deformation of a circle grid pattern originally etched on the sheet metal sample.

THICKENER DRIVE

A tailings thickener drive was modified for the hydrometallurgical pilot plant. The complete stirring and drive assembly is mounted on the structural members or spider which spans the vessel. The unit is 96 in. (244 cm) in diameter by 84 in. (213 cm) deep and has a single vertical shaft and paddle assembly designed for a 3-rpm stirring speed. During the course of stirring, there is the possibility that the material may become too thick and stall the paddle wheel. If this should happen the retraction mechanism on the top of the paddle can be operated manually.

The drive for the paddle consists of ¾ hp (0.56 km), 4-pole motor flange-mounted to a double reduction speed reducer having a pinion mounted on its output shaft.

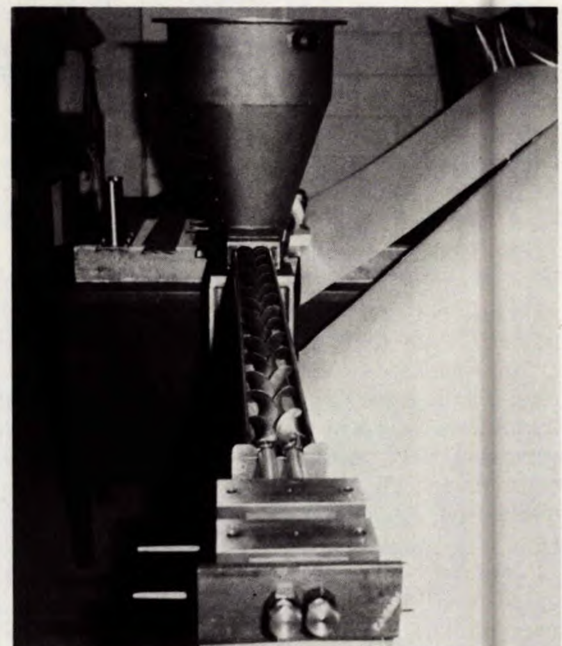

Figure 15 — Twin screw mixer-feeder for hot briquetting apparatus designed and built at CANMET.

The pinion engages a large gear which is keyed to the paddle shaft bearing thereby allowing for longitudinal retraction.

OTHER FABRICATION EXAMPLES

An air-to-air boiler heat exchanger was installed in the Combustion Research Laboratory which houses 72 2-in. (5 cm) tubes, 84 in. (213 cm) long. The overall dimensions of the equipment are 72 in. wide, 30 in. deep and 144 in. high (183 x 76 x 366 cm). Provision was made to accommodate dimensional changes of the tubes due to expansion and contraction. A combustion chamber extension was installed on a flame tunnel furnace located in the same laboratory. The overall dimensions of this unit are 48 in. (122 cm) diameter by 41 in. (104 cm) long. A short section at the rear of the extension is water cooled as thickness of the refractory lining in this area had to be reduced to allow for installation of other services.

The Technical Services Division specified and installed a reliable air supply for the petroleum processing pilot plant and the Combustion Research Laboratory. It is a packaged, water-cooled air compressor-intercooler-receiver assembly with fail-safe controls. The equipment if of low speed, low noise level design and is rated at 106 cfm (3 m^3/min) at 100 psig (7 x 10^4 kg/m^2) with a 25-hp (18.6 kw) drive motor.

Appendix A
Canmet Professional Staff

Name	Degrees	Class Title
D. F. Coates	B.Eng., M.Eng., Ph.D. (McGill), B.A., M.A. (Oxford)	Director-General
V. A. Haw	B.S., M.S. (Queen's)	Deputy Director-General

RESEARCH PROGRAM OFFICE

W. A. Gow	B.A.Sc. (Toronto), P.Eng.	Director, Minerals
D. A. Reeve	B.Sc., Ph.D. (Birmingham)	Director, Energy
L. L. Sirois	B.A., B.Eng., M.Eng. (McGill), P.Eng.	Act. Ldr. MRP
D. G. F. Hedley	B.Sc., Ph.D. (Newcastle), P.Eng.	Act. Ldr. MRP
D. W. G. White	M.Sc. D.Sc., (M.I.T.)	Act. Ldr. MRP
G. S. Bartlett	B.Sc., B.A. (Memorial)	Economist
R. Sage	B.Sc. (England), M.A.Sc. (Ottawa)	Eng.
E. D. Dainty	B.Sc., M.Sc. (Toronto), P.Eng.	Act. Ldr. ERP
D. K. Faurschou	B.A.Sc. (Toronto)	Act. Ldr. ERP
E. Smith	M.A., Ph.D. (Cambridge)	Act. Ldr. ERP

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
A. Hobson	B.A., B.L.S. (Toronto)	Librarian
K. Nagy	B.A., B.L.S. (McGill)	Librarian

TECHNICAL INQUIRIES

A. S. Romaniuk	B.Sc. (Queen's), P.Eng.	Phys. Sci.
G. M. Blondeau	B.A. (Queen's), M.A. (Guelph)	Mining Abstractor
C. F. Dixon	B.Eng. (N.S. Tech.), P.Eng.	Phys. Sci.
A. L. Job	A.C.S.M. (Eng.), C.Eng.	Phys. Sci.
C. Lafkas	B.Eng. (McGill's), M.Sc. (Queen's)	Phys. Sci.
B. E. Lawton	B.Sc. (Queen's), P.Eng.	Phys. Sci.
R. J. C. MacDonald	B.Sc. (St. Francis Xavier)	Phys. Sci.
T. J. Patel	B.Sc. (Oregon State), M.Sc. (Washington State)	Min. Proc. Abstractor
I. Slowikowski	M.A. (Ottawa), D.D.S. (Beirut)	Slavic Lang. Spec.
G. W. Taylor	B.Sc. (Queen's)	Phys. Sci.

PUBLICATIONS

C. Mamen	B.Eng. (McGill), Eng. (Que.)	Phys. Sci.
L. Carreau	B.A. (Ottawa)	French Tech. Sp.

TECHNICAL SERVICES DIVISION

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

ENERGY RESEARCH LABORATORIES

B. I. Parsons	B.Sc., Ph.D., D.Phil. (Oxford)	Chief of Laboratories

ENGINEERING, DESIGN AND CONSTRUCTION GROUP

R. E. Carson	B.Sc. (Queen's), P.Eng.	Engineer
L. P. Mysak	B.A.Sc. (Ottawa), P.Eng.	Engineer

SPECIAL STUDIES

B. J. P. Whalley	B.Sc., Ph.D. (McGill)	Res. Sci.
I. Lau	M.A.Sc. (Ottawa)	Engineer
D. Desai	M.A.Sc. (Ottawa)	Engineer
J. Beshai	B.Sc. (McMaster)	Eng. Support

CANADIAN SYNTHETIC FUELS RESEARCH LABORATORY

W. H. Merrill	B.A.Sc. (Ottawa), P.Eng.	Manager

Petroleum Process Engineering

J. M. Denis	B.A.Sc. (Ottawa), P.Eng.	Res. Sci.
B. B. Pruden	B.Eng. (Sask.), M.A.Sc. (UBC), Ph.D. (McGill), P.Eng.	Res. Sci.
R. Ranganathan	B.E., M.E. (India), Ph.D. (Sask.)	Res. Sci.
R. B. Logie	B.Sc. (UNB)	Res. Sci.
C. P. Khulbe	B.Sc., M.Sc. (India), M.A.Sc., Ph.D. (Ottawa)	Res. Sci.
A. M. Shah	B.Sc. (India), B.A.Sc., M.A.Sc., Ph.D. (Ottawa)	Res. Sci.
K. Belinko	B.Sc., Ph.D. (Carleton)	Res. Sci.

Catalysis Research

M. Ternan	B.A.Sc. (UBC), Ph.D. (McGill), P.Eng.	Res. Sci.
A. H. Hardin	B.Sc. (UBC), Ph.D. (UBC)	Res. Sci.
J. F. Kriz	Dipl. Eng.-M.Eng. (Prague), Ph.D. (Dalhousie), P.Eng.	Res. Sci.
J. F. Kelly	B.Eng. (McGill), Ph.D. (McGill), P.Eng.	Res. Sci.
L. E. Galbraith	B.A. (Carleton)	Eng. Support
J. B. Aarts	B.Sc., M.Sc. (Eindhoven), Ph.D. (UNB)	Eng. Support

Research on Bituminous Substances

H. Sawatzky	B.S.A., M.S.A., Ph.D. (Toronto)	Res. Sci.
A. George	B.Sc., M.Sc., Ph.D. (Cairo)	Res. Sci.
S. M. Ahmed	B.Sc., M.Sc. (India)	Chemist
R. C. Banerjee	B.Sc., M.Sc., D.Phil. (India)	Chemist
B. Nunn	B.Sc. (Carleton)	Eng. Support

Petroleum and Gas Laboratory

R. Draper*	B.Sc. (Saskatchewan)	Chemist
E. Furimsky	Dipl. Eng. (Prague), Ph.D. (Ottawa)	Chemist
D. M. Clugston	B.Sc., Ph.D. (McMaster)	Chemist
A. Yates	B.Sc. (Manitoba)	Chemist
R. E. Gill	B.Sc. (St. Francis Xavier)	Chemist

CANADIAN COMBUSTION RESEARCH LABORATORY

E. R. Mitchell**	B.Sc. (Queen's), P.Eng., C.Eng.	Manager
G. K. Lee	B.Sc., M.Sc. (Queen's), P.Eng., C.Eng.	Res. Sci.
F. D. Friedrich	B.Sc., (Sask.), M.Sc. (Queen's), P.Eng.	Res. Sci.
T. D. Brown	B.Sc. (Durham), Ph.D. (Sheffield), C.Eng.	Res. Sci.
H. Whaley	B.Sc., Ph.D. (Sheffield), P.Eng., C.Eng.	Res. Sci.
A. C. S. Hayden	B.Eng., M.Eng. (Carleton), P.Eng.	Res. Sci.
T. J. Cyr	B.Sc., M.Sc., Ph.D. (UBC)	Chemist
S. I. Steindl	Dipl. Eng. (Budapest), M.Sc. (Queen's), P.Eng.	Engineer
R. G. Fouhse	B.Sc. (Sask.), P.Eng.	Engineer
R. W. Braaten	B.Sc. (Carleton)	Eng. Support
G. D. Sergeant	B.Sc., Ph.D. (Cardiff)	Visiting Sci.

COAL RESOURCE AND PROCESSING LABORATORY

J. C. Botham	B.Sc. (Queen's), P.Eng.	Res. Sci.
T. A. Lloyd	B.Sc. (Carleton)	Phys. Sci.
J. G. Jorgensen	B.Sc. (Carleton)	Phys. Sci.
W. R. Leeder	B.Sc., Ph.D. (UBC)	Res. Sci.
W. Gardiner	C.Chem., E.Eng. (U.K.)	Eng. Support
A. B. Fung	B.Sc., Eng. (Waterloo)	Engineer
R. Zrobock	B.Sc. (Alberta)	Eng. Support
T. E. Tibbetts	B.Sc., B.Ed. (Dalhousie)	Res. Sci.
B. N. Nandi	B.Sc., M.Sc. (Calcutta), Dr. Ing. (Karlsruke)	Res. Sci.

L. Ciavaglia	B.Eng. (Carleton)	Phys. Sci.
J. R. Donaldson	B.A. (Acadia)	Phys. Sci.
W. J. Montgomery	B.S.A. (Toronto)	Phys. Sci.
J. Z. Skulski	Chem. Eng. (Poland)	Chemist
J. F. Gransden	B.Sc. (London), A.R.S.M., Ph.D. (UWO)	Res. Sci.
J. T. Price	B.Sc., M.Sc. (Calgary), Ph.D. (UWO)	Res. Sci.
K. Belinko	B.Sc., Ph.D. (Carleton)	Res. Sci.
R. H. Lomas	B.Sc. (Queen's)	Eng. Support
L. C. G. Janke	B.Sc. (Wilfrid Laurier), B.Ed. (Queen's)	Eng. Support

**Retired 30/12/76*
***Deceased 18/3/77*

PYROMETALLURGY RESEARCH LABORATORY

G. E. Viens	B.A. (McMaster)	Res. Sci.
R. A. Campbell	B.Sc., M.Sc. (Queen's)	Res. Sci.
G. N. Banks	B.A. (UBC)	Res. Sci.
G. V. Sirianni	B.Sc. (Ottawa)	Res. Sci.
E. W. Montgomery	B.Eng. (McGill), P.Eng.	Res. Sci.

WESTERN RESEARCH LABORATORY (Edmonton)

J. Visman	M.I.Dr. T.W. (Delft), P.Eng.	Manager
H. A. Hamza	B.Sc. (Cairo), Ph.D. (Newcastle-on-Tyne)	Res. Sci.
M. W. Mikhail	B.Sc. (Assiut), M.Sc. (Alberta), P.Eng.	Engineer
J. L. Picard	B.Sc. (Alberta)	Phys. Sci.
C. F. Rozenhart	Chem. Eng. (Heerlen MTS)	Eng. Support
A. Mo	B.Sc. (Alberta)	Eng. Support
G. Potter	B.Sc. (McMaster)	Eng. Support
R. Santos	B.Sc. (Mapua Inst. Tech.)	Eng. Support

MINING RESEARCH LABORATORIES

T. S. Cochrane	B.A.Sc., M.Sc. (Washington), P.Eng.	Chief of Laboratories
W. M. Gray	B.A., M.A., Ph.D. (Toronto)	Res. Sci. Senior Scientific Adviser
F. L. Casey	B.Sc. (Queen's)	Engineer

ROCK MECHANICS LABORATORY

G. E. Larocque	B.Sc. (Carleton)	Res. Sci.
A. Boyer	B.Sc. (Montreal)	Phys. Sci.
A. Fustos	B.S.F./F.E., B.Sc. (UBC), P.Eng.	Engineer
L. Geller	Dipl. Mech. Eng. (Budapest), B.Sc. (Eng.) (England), 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.
J. Tomica	B.Sc., M.Sc., Dipl. Expln. Tech., M.Sc., VSCHT (Czechoslovakia), M.Sc. (Queen's), P.Eng.	Engineer
Y. S. Yu	B.Sc., M.Eng. (McGill)	Res. Sci.
D. F. Walsh	B.Sc. (St. John's, Newfoundland)	Phys. Sci.
R. J. R. Welwood	B.Sc. (Queen's)	Phys. Sci.
A. S. Wong	B.Sc. (Taiwan), M.Sc. (Ottawa)	Phys. Sci.

ELLIOT LAKE LABORATORY

G. Zahary	B.Sc., M.Eng. (McGill), P.Eng.	Res. Sci.
G. Allen	M.A.Sc., M.Eng. (South Dakota)	Engineer
K. K. Cheng	B.Sc., M.Eng. (Taiwan)	Engineer
V. deKorompay	Dipl. Min. Eng. (Hungary)	Phys. Sci.
M. Gangal	B.Sc. (India), M.Sc. (India & McGill), Ph.D. (Calgary)	Res. Sci.
D. G. F. Hedley	B.Sc., Ph.D. (Newcastle), P.Eng.	Res. Sci.
G. Herget	Dipl. Geol., Ph.D. (Munich), P.Eng.	Res. Sci.
B. Kirk	B.Sc. (Waterloo)	Phys. Sci.
G. Knight	B.Sc. (Birbeck, London)	Res. Sci.
P. C. Miles	B.Sc. (Windsor)	Engineer
D. Moffett	B.A. (Dublin), Ph.D. (Ottawa)	Res. Sci.
D. R. Murray	B.A.Sc. (McDonald College)	Phys. Sci.
R. G. L. McCready	B.Sc., M.Sc., (Alberta), Ph.D. (Calgary)	Phys. Sci.

M. Savich	Dipl. Min. Eng. (Yugoslavia), B.Eng. M.Eng. (McGill)	Res. Sci.
R. O. Tervo	B.A.Sc. (Toronto), Ph.D. (Bradford), P.Eng.	Res. Sci.
R. A. Washington	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
G. Just	B.E., Ph.D. (Queensland)	Post Doctorate Fellow

CANADIAN EXPLOSIVES RESEARCH LABORATORY

J. A. Darling	B.A. (Queen's)	Res. Sci.
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. Offr.

WESTERN OFFICE, CALGARY

K. Barron	B.Sc., M.Sc., Ph.D. (London)	Res. Sci.
W. Baxter	B.Sc., (Calgary)	Phys. Sci.
H. U. Bielenstein	B.Sc., M.Sc. (Alberta), Ph.D. (Queen's)	Res. Sci.
R. N. Chakravorty	B.Che., (India), Ph.D. (Nottingham)	Res. Sci.
M. Y. Fisekci	Dipl. Eng., M.Eng., Ph.D. (Sheffield)	Res. Sci.
F. Grant	B.Sc. (Alberta), P.Eng.	Res. Sci.
J. B. Livesey	B.Sc., Ph.D. (Cardiff)	Res. Sci.
D. Mikalson	B.Sc., M.Eng. (Alberta)	Engineer
V. Srajer	M.A.Sc. (Czechoslovakia)	Engineer

CANADIAN EXPLOSIVE ATMOSPHERES LABORATORY

J. A. Bossert	B.Sc. (Queen's)	Res. Sci.
G. Lobay	B.Sc. (Manitoba)	Engineer
P. Mogan	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
N. Sarin	Dipl. (Mech. & Auto Eng.) (England), B.A.Sc. (Waterloo)	Engineer
S. Silver	B.Sc. (Manitoba)	Res. Sci.
D. B. Stewart	B.Sc., M.Sc. (Queen's)	Res. Sci.

MINERAL SCIENCES LABORATORIES

R. L. Cunningham	B.Sc., M.Sc., Ph.D. (McGill)	Chief of Laboratories
J. C. Ingles	B.A. (Western Ontario)	Assistant Chief

CHEMICAL LABORATORY

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

Metals and Alloys

J. F. Fydell	B.A.Sc. (Toronto)	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

Solution Chemistry

R. J. Guest	B.Sc. (Acadia)	Res. Sci.
G. A. Hunt	B.Sc. (Carleton)	Chemist
D. J. Barkley	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)	Phys. Sci.

Special Analyses

A. Hitchen	B.Sc. (McMaster)	Chemist
B. Nebesar	M.Sc. (McGill)	Res. Sci.
V. H. Rolko	B.Sc. (Manitoba)	Chemist

Special Projects

D. J. Charette	B.Sc. (Ottawa)	Chemist
E. M. Donaldson	B.Sc. (Manitoba)	Res. Sci.
E. Mark	B.A. (Toronto)	Chemist
H. F. Steger	B.Sc., Ph.D. (McMaster)	Res. Sci.

ORE PROCESSING LABORATORY

M. C. Campbell	B.Sc. (St. F.X.), B.E. (N.S.T.C.), D.I.C., M.Sc. (London)	Manager

Hydrometallurgy

G. M. Ritcey	B.Sc. (Dalhousie)	Res. Sci.
B. H. Lucas	B.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.
A. J. Gilmore	B.Sc. (Manitoba)	Res. Sci.
H. H. McCreedy	B.Sc., M.Sc. (Alberta) P.Eng.	Res. Sci.
J. M. Skeaff	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Res. Sci.
N. St. Martin	B.A.Sc., M.A.Sc. (Ottawa)	Phys. Sci.
A. Jongejan	Geol.Can.Drs. (Amsterdam), Ph.D.	Res. Sci.

Metallic Minerals

R. W. Bruce	B.Sc. (Queen's), P.Eng.	Res. Sci.
A. I. Stemerowicz	B.Sc. (Queen's), P.Eng.	Res. Sci.
D. Raicevic	B.Sc. (Belgrade)	Res. Sci.
G. I. Mathieu	B.A., B.Sc. (Laval)	Res. Sci.
R. H. Yoon	M.Eng. (McGill)	Res. Sci.

Engineering and Economic Evaluation

W. J. S. Craigen	B.Sc. (Queen's)	Phys. Sci.
V. F. Harrison	B.Sc. (Queen's)	Res. Sci.
F. J. Kelly	B.Ch.Eng. (N.S. Tech. College)	Res. Sci.

Non-Metallic Processing

R. A. Wyman	B.Sc. (Manitoba)	Res. Sci.
I. B. Klymowsky	M.Eng. (McGill), P.Eng.	Res. Sci.
W. H. Cameron	B.Sc. (Queen's)	Phys. Sci.
G. A. Kent	B.Sc., M.Sc. (McGill)	Chemist

Industrial Liaison

E. G. Joe	B.Sc. (Queen's)	Phys. Sci.

PHYSICAL SCIENCES LABORATORY

D. C. Harris	B.Sc., M.A., Ph.D. (Toronto)	Manager

Crystal Structure

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

Solid State

M. G. Townsend	B.Sc., Ph.D. (Southampton)	Res. Sci.
J. L. Horwood	B.A. (Toronto)	Res. Sci.

Corrosion

G. R. Hoey	B.Sc., M.Sc., Ph.D. (Toronto)	Res. Sci.
R. J. Brigham	B.Sc., M.Sc., Ph.D. (McMaster)	Res. Sci.
A. W. Lui	B.Sc., M.A.Sc. (Windsor)	Res. Sci.
J. C. Saiddington	Chem.Eng., M.A.Sc. (Toronto)	Phys. Sci.

Mineralogy

L. J. Cabri	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.
W. Petruk	B.Eng., M.Sc., Ph.D. (McGill)	Res. Sci.
S. Kaiman	B.S., M.A. (Toronto)	Phys. Sci.
M. R. Hughson	B.Sc. (Western Ontario)	Phys. Sci.
J. L. Jambor	B.A., M.Sc. (UBC), Ph.D. (Carleton)	Res. Sci.
T. T. Chen	B.Sc. (Taiwan), M.Sc. (Carleton), Ph.D. (Cornell)	Res. Sci.

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.
E. Rolia	B.A. (UBC)	Chemist
D. J. Francis	B.Sc., Ph.D. (Alberta)	Res. Sci.
R. J. C. MacDonald	B.Sc. (St. Francis Xavier)	Phys. Sci.
V. S. Sastri	B.Sc., M.A., Ph.D. (State U. of N.Y.)	Chemist

Physical Chemistry

A. H. Webster	B.A., M.A., Ph.D. (UBC)	Res. Sci.
S. A. Mikhail	B.Sc., M.Sc., Ph.D. (Cairo), Dr. Eng. (Norway)	P.D.F.
S. M. Ahmed	B.Sc., M.Sc., Ph.D. (Saskatchewan)	Res. Sci.
R. Sutarno	B.E., M.E., Ph.D. (N.S. Tech.)	Res. Sci.
R. F. Pilgrim	B.Sc. (Queen's)	Res. Sci.
L. G. Ripley	B.Sc., M.A. (Queen's)	Res. Sci.
D. M. Farrell	B.Sc. (UBC)	Chemist

INDUSTRIAL MINERALS LABORATORY

G. W. Riley	B.Sc. (Camborne School of Mines), P.Eng.	Manager

Construction Materials

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

Non-Metallic and Waste Minerals

R. K. Collings	Eng. Dipl., B.E. (N.S. Tech.), P.Eng.	Res. Sci.
A. A. Winer	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
S. S. Wang	B.Sc. (Hong Kong Baptist), M.Sc. (U. of California), Ph.D. (Toronto)	Phys. Sci.
C. A. Hamer	Dip. Eng. (Dalhousie), B.E. (Nova Scotia), M.Sc. (Queen's)	Res. Sci.

Ore Mineralogy

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

Ceramics

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

PHYSICAL METALLURGY RESEARCH LABORATORIES

H. V. Kinsey	B.Sc. (Queen's), P.Eng.	Chief of Laboratories Seconded to Director-General's Office
R. K. Buhr	B.Eng. (McGill)	Acting Chief

Corrosion

G. J. Biefer	B.Sc., Ph.D. (McGill)	Res. Sci.
J. B. Gilmour	B.Sc. (Queen's), Ph.D. (McMaster), P.Eng.	Res. Sci.
R. D. McDonald	B.Sc. (Queen's)	Res. Sci.
I. C. G. Ogle	B.Sc., Ph.D. (UBC)	Res. Sci.

Engineering Physics

A. J. Williams	B.Sc., M.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
D. M. Fegredo	B.Sc., M.Sc., Dipl. I.I.Sc., Ph.D. (Sheffield), A.I.M.	Res. Sci.
L. P. Trudeau	B.A.Sc., M.A. (Toronto)	Res. Sci.
O. Vosikovsky	B.A.Sc., Ph.D. (Prague)	Res. Sci.

Ferrous Metals

J. D. Boyd	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Res. Sci.
D. R. Bell	B.Eng. (McGill)	Res. Sci.
M. J. Godden	B.Met., Ph.D. (Sheffield)	Res. Sci.
R. F. Knight	B.Sc., M.Sc. (Queen's)	Res. Sci.
M. J. Lavigne	B.A., B.A.Sc., Ph.D. (Laval)	Res. Sci.
D. E. Parsons	B.A.Sc. (Toronto)	Res. Sci.
W. R. Tyson	B.A.Sc. (Toronto), Ph.D. (Cambridge)	Res. Sci.

Foundry

K. G. Davis	B.Sc., M.A.Sc., Ph.D. (UBC)	Res. Sci.
C. J. Adams	B.Sc. (Sir George Williams), M.Sc. (Met) (McGill)	Res. Sci.
E. I. Szabo	M.Sc., Ph.D. (Nottingham)	Res. Sci.
R. D. Warda	B.A.Sc. (UBC), Ph.D. (Cambridge)	Res. Sci.

Mechanical Testing

P. J. Todkill	B.A.Sc. (Toronto)	Engineer
J. Harbec	B.Eng. (McGill), P.Eng.	Engineer

Metal Processing

M. J. Stewart	B.A.Sc., Ph.D. (UBC)	Res. Sci.
A. F. Crawley	B.Sc., Ph.D. (Glasgow)	Res. Sci.
J. T. Jubb	B.A.Sc., M.A.Sc. Ph.D. (Toronto)	Res. Sci.
H. M. Skelly	B.Sc., Ph.D. (Glasgow)	Res. Sci.

Metal Physics

W. N. Roberts	M.A., Ph.D. (Leeds)	Res. Sci.
E. E. Laufer	B.Sc., M.Sc. (Dalhousie), Ph.D. (Virginia)	Res. 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.Sc. (Ottawa)	Phys. Sci.
R. H. Packwood	B.Sc., Ph.D. (Birmingham)	Res. Sci.
K. M. Pickwick	B.Sc. (Tech.), Ph.D. (Manchester)	Res. Sci.
Y. L. Yao	B.Sc., M.Eng., Ph.D. (Lehigh)	Res. Sci.

Nondestructive Testing

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

Non-Ferrous Metals

J. O. Edwards	B.Sc., M.Sc. (Manchester), P.Eng.	Res. Sci.
D. C. Briggs	B.Eng., M.Eng. (McGill), Ph.D. (Queen's)	Res. Sci.
A. Couture	B.A., B.A.Sc. (Laval), P.Eng.	Res. Sci.

J.-L. Dion	B.A.Sc. (Montreal)	Engineer
B. Lagowski	B.Sc., M.Sc. (Polish Univ., London)	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.
J. J. Sebisty	B.A.Sc. (Toronto), P.Eng.	Res. Sci.
R. Thomson	B.Sc., ARCST, Ph.D. (Glasgow)	Res. Sci.
L. V. Whiting	B.Sc., M.Sc., Ph.D. (McGill)	Res. Sci.

Welding

K. Winterton	B.Sc., Ph.D. (Birmingham), P.Eng.	Res. Sci.
W. P. Campbell	B.Sc. (Queen's), P.Eng.	Res. Sci.
J. Gordine	B.Sc., Ph.D. (Leeds)	Res. Sci.
Z. Paley	B.Sc., M.Sc. (Haifa), Ph.D. (McGill)	Res. Sci.

CANMET STAFF AS OF MARCH 31, 1977 (F.T.C.)

Division	Professionals	Non-Professionals	Total
Administration	2	21	23
Research Program Office	10	5	15
Energy Research Laboratories	49	71	120
Mining Research Laboratories	47	39	86
Mineral Sciences Laboratories	92	117	209
Physical Metallurgy Research Laboratories	49	83	132
Technology Information Division	12	19	31
Technical Services Division	2	67	69
Totals	263	422	685

Appendix B

CANMET Representation on Technical Committees 1976-77

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

International

BRITISH FLAME RESEARCH COMMITTEE (director) .... E. R. Mitchell (ERL)

CANADA/SOVIET MIXED COMMISSION FOR COOPERATION IN THE INDUSTRIAL APPLICATION OF SCIENCE AND TECHNOLOGY
- Non-Ferrous Metals Industry Working Group (chairman) .... V. A. Haw (DGO)

COMMONWEALTH ADVISORY AERONAUTICAL RESEARCH COUNCIL
- Materials Panel (member) .... A. J. Williams (PMRL)
- Tripartite Technical Co-operation Program Sub-Group P, Technical Panel (Metals) L. P. Trudeau (PMRL)

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)

INSTITUTE OF FUEL
- Commonwealth Liaison Group (chairman) .... E. R. Mitchell (ERL)

INSTITUTE OF MINES, YUGOSLAVIA
- Sigurnost u Rudnicima (Safety in Mines) Editorial Board (member) .... M. Savich (MRL)

INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION
- Advisory Subcommittee to the Canadian delegate (member) .... J. A. Darling (MRL)
- Bulk Cargoes Committee (member) .... H. F. Steger (MSL)

INTERNATIONAL COAL PREPARATION CONGRESS
- (National correspondent) .... J. Visman (ERL)

INTERNATIONAL COMMISSION ON ILLUMINATION
- Canadian National Committee TC-4.1, Interior Lighting Subcommittee on Mine Lighting (member) .... A. L. Job (TID)

INTERNATIONAL COMMITTEE ON COAL PETROGRAPHY
- Petrography (working member) .... B. N. Nandi (ERL)
- Subcommittee on Industrial Applications of Coal Petrology (member) .... B. N. Nandi (ERL)

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

INTERNATIONAL CONFERENCE ON COAL GASIFICATION AND COAL LIQUEFACTION
- Advisory Board (member) .... M. Ternan (ERL)

INTERNATIONAL CONFERENCE ON THERMAL CONDUCTIVITY (15th)
- (chairman) .... V. V. Mirkovich (MSL)

INTERNATIONAL ELECTROTECHNICAL COMMISSION
- Technical Committee 31, Electrical Apparatus for Explosive Atmospheres
  - Canadian Subcommittee (chairman) .... J. A. Bossert (MRL)

INTERNATIONAL INSTITUTE OF WELDING
- Canadian Council (members) .... W. P. Campbell (PMRL), K. Winterton (PMRL)
- Commission IX, Behaviour of Metals Subjected to Welding (chairman) .... K. Winterton (PMRL)
  - (member) .... W. P. Campbell (PMRL)
- Subcommittee IX-F, Study of Recommendation Relating to Steels for Welding
  - Construction (member) .... L. P. Trudeau (PMRL)

INTERNATIONAL JOURNAL OF HYDROMETALLURGY (co-editor) .... G. M. Ritcey (MSL)

INTERNATIONAL MINERAL PROCESSING CONGRESS
- International Scientific Committee (member) .... L. L. Sirois (RPO)

INTERNATIONAL MINERALOGICAL ASSOCIATION
- Commission of New Minerals and Mineral Names (member) .... D. C. Harris (MSL)
- 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. L. Cunningham (MSL)
  - (member) .... G. H. Faye (MSL)
- TC17/SC1, Analysis of Steel and Cast Iron (member) .... R. G. Sabourin (MSL)
  - SC4, Heat Treated Alloy and Free-Cutting Steels (members) .... R. K. Buhr (PMRL), D. E. Parsons (PMRL)
  - SC4, Resulphurized Carbon and Alloy Steels (member) .... 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)
(member) .... V. Caron (PMRL)
SC15, Rail Steels (member) .... D. E. Parsons (PMRL)
TC18/SC1, Zinc and Zinc Alloys (member) .... C. H. McMaster (MSL)
TC25, Cast Iron (member) .... R. K. Buhr (PMRL)
TC26, Copper and Copper Alloys (chairman) .... J. O. Edwards (PMRL)
SC1, Analysis of Copper and Copper Alloys (members) .... C. H. McMaster (MSL)
R. G. Sabourin (MSL)
SC3, Cast Copper Alloys (member) .... J. O. Edwards (PMRL)
WG5, Terminology .... J. O. Edwards (PMRL)
TC27, Solid Mineral Fuels (chairman) .... W. J. Montgomery (ERL)
SC2, Brown Coals & Lignites (member) .... W. J. Montgomery (ERL)
SC3, Coke (member) .... J. C. Botham (ERL)
WG9, Grindability (member) .... W. J. Montgomery (ERL)
WG12, Plasticity (member) .... J. C. Botham (ERL)
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Figure 16 — Coke being removed from an oven in which coking properties of Canadian coals are tested.