Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

CANMET REVIEW 1985-1986

Canada

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FOREWORD

Although 1985-86 saw ongoing economic growth internationally and in Canada, albeit at a slightly lower level than in the previous year, the minerals sector continued to face low market prices for minerals, metals and mineral products. In addition, the energy sector was buffetted by a dramatic decrease in the international price of oil.

Under the guidance of the National Advisory Committee on Mining and Metallurgical Research, CANMET continued to focus on consultations with the relevant industry sectors and on technology transfer. Industry-wide seminars were held on a range of technology areas, including health and safety aspects of underground mining, surface mining, coal preparation, and oil and gas conversion. BIOMINET was created as an effective communications network between researchers and industry interested in applications of biotechnology. The Mobile Foundry Laboratory visited an additional 24 foundries during its second year of operation, reinforced by an economic impact study that identified resultant savings to the industry of some $1 million per year.

CANMET also initiated several major cooperative projects with governments and industry. Notable amongst these are the tripartite agreement with the province of Ontario and the Ontario Mining Industry on rockburst research and a joint project with the U.S. Department of Energy and the Alberta Oil Sands Technology Research Authority on bitumen recovery from oil sand reservoirs.

Technology support for major demonstration projects continued throughout the year with significant efforts being directed toward proving the viability of coal-water fuels as a substitute for oil in the Atlantic provinces. In addition, CANMET provided direct assistance for the successful start-up and commissioning of the CANMET Hydrocracking Process demonstration at Petro-Canada's Montreal refinery.

Starting 1984-85, CANMET has accepted a new role in association with the creation of Federal-Provincial Mineral Development Sub-Agreements: that of administering the federal mineral technology components of the Sub-Agreements. Projects are developed in cooperation with the Provinces, respond to specific Provincial priorities, and are almost entirely conducted under contract to external performers. Sub-Agreements were initiated with five provinces in 1984-85 (Saskatchewan, Manitoba, New Brunswick, Nova Scotia and Newfoundland), and with Ontario in 1985-86. Each Sub-Agreement has a five-year life with an additional year to complete project activity. Total resources associated with each Sub-Agreement and other relevant financial data are listed in the financial summaries.

Federal-Provincial Mineral Development Sub-Agreements

Province	Resources Assigned ($000)	Expenditures ($000)	
		1984-85	1985-86
Newfoundland	1,500	0	236.9
Nova Scotia	3,275	309	464.2
New Brunswick	3,000	215	341.2
Ontario	3,550	—	307.5
Manitoba	4,665	152	1,179.3
Saskatchewan	515	0	39

Of about 200 research projects coordinated by the Research Program Office, a large number have international involvement, either formal or informal. Through the more than 250 contracts implemented by CANMET and the downstream technology transfer efforts, the needs of industry for technology advancement continue to be addressed. This goal is increasingly being recognized as a key factor in restoring the productivity of Canada's mineral and energy industries as well as their international competitiveness. CANMET is well equipped with highly qualified scientists, engineers, technical and support staff to meet the research challenges that lie ahead, and to serve the nonrenewable resource sector industries of Canada.

W.G. Jeffery
Director General
CANMET

CONTENTS

CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY (CANMET)

Mission: ***To enhance the role and contribution of minerals and energy in the Canadian economy by means of mission-oriented research and development in mining, mineral processing and utilization of metals, industrial minerals and fuels.***

Since 1907, scientists at the Canada Centre for Mineral and Energy Technology (CANMET) have been researching and developing safer and more efficient ways to extract, process, and utilize Canadian energy and mineral resources. In so doing, CANMET fulfills its three primary goals:

- — providing information to the Minister for policy-making related to nonrenewable resources;
- — serving government social objectives for health, safety, and the environment;
- — supporting R&D performed by industry in order to improve the economic performance and productivity of industry.

Important input and guidance on project selection and implementation is provided by industry, advisory, and user groups.

ORGANIZATION

CANMET carries out its mandate with a staff of 796 employees, organized into five operational laboratories. The laboratories are supported by several staff units that provide services to all divisions.

The **Energy Research Laboratories** develop technology related to the upgrading of oil sands, heavy oil, and synthetic crude production; coal combustion; coal gasification and liquefaction; and improved oil and gas domestic heating furnaces.

The **Coal Research Laboratories** conduct research related to coal mining, coal preparation, coal transportation, and coal carbonization at their regional laboratories in Edmonton and Cape Breton.

The **Mining Research Laboratories** are concerned with rock mechanics, mining methods and equipment, explosives' testing, mining environments, the certification of equipment for gassy mines, fire and explosion hazards, tailings control, and uranium reserve assessment.

The **Mineral Sciences Laboratories'** efforts are primarily in the areas of mineral processing, and the development of ceramic and other materials for advanced energy storage and conversion systems.

The **Physical Metallurgy Research Laboratories** deal primarily with improved materials for rail lines, coal combustion, offshore structures, pipelines, and pressure vessels. They are also concerned with erosion-corrosion, and the fabrication of metals and alloys.

The **Research Program Office** is charged with planning and designing research programs that are carried out in-house and through CANMET's contracting-out program.

The **Office of Technology Transfer** addresses technology transfer issues, as well as developing guidelines to aid at all stages of research and development — from the planning stage, bench-scale, pilot-plant, and demonstration phases, right through to commercial applications.

The **Technology Information Division** provides library, editorial, and publication production facilities; technical literature analysis and documentation; inquiry response and information dissemination services.

The **Technical Services Division** provides engineering support to all divisions.

In the following pages some highlights of the work of the Branch are outlined.

MINERAL AND ENERGY TECHNOLOGY

MINING

Mining is an important part of Canada's economy since almost every province and territory is well endowed with a variety of metallic ores and industrial minerals. At CANMET, mining research focusses on mining methods and systems, operational research, design of advanced equipment, and ore reserve evaluation. The research is both productivity and protection oriented.

In the future, an increasing proportion of Canadian underground mining will take place under the high-stress conditions of deep mining and where relatively high extraction ratios concentrate the field stresses. The end

result of these high stresses can be pillar or wall failures, either gradual or violent, in the form of rockbursts. Thus, mine planning and design will have to take into account rock mass response and ground support requirements.

A database of information on current and developing technology in the Canadian mining industry was developed and an index of mining technology published.

Mining Methods and Equipment

Engineering studies are carried out annually to determine the production capabilities and costs of producing Canadian uranium mines, as well as to estimate the future production costs and capabilities of Canadian properties. During fiscal year 1985-86, a report outlining uranium production capabilities was issued. Contractors completed studies on the mining technology required and available to mine medium depth, high-grade uranium deposits, and on Canadian mining industry capital and operating indices.

Prototype electro-hydraulic mini-rock scaler developed and constructed by Teledyne Canada under contract to CANMET

Improvements in safety and productivity often result from improvements in mining equipment. Contractors have developed equipment to test a cavitating hydro-impactor, and sensors for the automatic control of a down-the-hole drill. Initial field trials with inclinometer sensors have been completed. CANMET developed a universal borehole installing tool and successfully tested it in an underground environment during ground stress determination measurements. Cut-and-fill mining, used extensively in Manitoba, can cause serious production and safety problems when ground conditions are poor. Therefore, CANMET is evaluating the vertical block method as an alternative.

The metals price depression of the 1980's has placed considerable pressure on the Canadian mining industry to adopt advances in mining technology in order to remain competitive. CANMET's research is focussed on using mathematical modelling and computer control to optimize the usage of mine equipment.

With the participation of industry, CANMET has completed a two-year program of contract research on potash mining. Eight contracts addressing mine design, ground control, and dust monitoring were completed. Present studies are directed toward monitoring excavation behaviour in potash mines under controlled conditions and predicting excavation behaviour by numerical modelling. Progress was made in an on-going review of underground potash-mining methods.

Rock Mechanics

Researchers are concerned with the problems of mining in highly stressed ground, mining in highly fractured ground where gravity-induced instability is a major factor, and mining with high excavation rates. The development of a rock classification system to be used in assessing the stability of rock masses around large multi-opening structures continues, with particular emphasis given to surface crown pillars.

Preparation of rock-bolting guidelines is well advanced and provides detailed information on performance-monitoring techniques and on underlying rock bolt design concepts.

Both MRL's Elliot Lake Laboratory and MRL's Rock Mechanics Laboratory are investigating the causes of rockbursts in underground mines

CANMET's efforts in mine structural analysis resulted in the modification of a general purpose, finite element computer code for mining applications.

A major rockburst project with tripartite funding from the federal and provincial governments and the Ontario mining industry was initiated in 1985. Researchers studied multiple pillar failures in the Elliot Lake mines and measured stresses in rockburst-prone mines. In conjunction with the Seismology Division of EMR, the causes, mechanisms, and locations of the larger sequence of rockbursts for each Ontario mine were documented.

EMR participates in the Canadian Nuclear Fuel Waste Management Program, directed by Atomic Energy of Canada Limited, to find safe and effective means of disposing of high-level nuclear wastes. As part of a program to characterize rocks occurring in sites being examined for possible disposal of nuclear wastes, samples of thirty rocks from the Underground Research Laboratory in Manitoba and from drill cores have been studied and prepared for thermal testing.

Mine Environment

In uranium mines, dust particles can carry radon and thoron daughters as well as long-lived radionuclides into the respiratory system where radiation, mostly alpha-particles emitted internally, may give rise to tissue damage. Lubricating oil mists and diesel exhausts also carry noxious dust and gases. Instruments developed for the continuous monitoring of mineral, diesel, and fibrous dust are in the prototype stage, and researchers are studying the use of charged water spray systems to control dust in an underground uranium mine and mill.

The identification and quantification of long-lived radioactive dust depends upon the adequate performance of measuring instruments. CANMET has developed instruments that can monitor radon, thoron, and their decay products continuously. Field measurements showed that the size distribution of long-lived radioactive dust generated at a crusher and at a conveyor belt was significantly different from that at other locations in the uranium mine.

During 1985, a field study to determine the noise exposure index of all workers exposed to noise on the surface and underground at four Saskatchewan potash mines was conducted.

Mineral Reserves' Assessment

CANMET produces biennially a report containing the current status of reasonably assured reserves of uranium and associated inferred resources of thorium in all developed deposits in Canada, regardless of whether they are actively producing or dormant.

Explosive Atmospheres

Explosions of gas or dust occur regularly around the world in coal mines, flour mills, and other hazardous industrial locations, causing a significant loss of life, injuries, and material damage. A better understanding of gas and dust explosion phenomena can lead to improved technologies to eliminate or reduce the hazards. Researchers:

- are developing a technique to measure the minimum ignition energy of dust explosions;
- completed experiments on the minimum explosible concentration, maximum explosion pressure, and rate of pressure rise of Devco coal dust/methane mixtures;
- found, under contract, that the quenching distances for flames of cornstarch and aluminum in air are of the same order of magnitude as gas-air, and that the effect of turbulence on dust-air explosions is similar to gas-air explosions.

Equipment Safety Certification

Activity in the certification and testing of equipment and materials for underground mines was twice that of previous years, reflecting the optimistic mood of suppliers to the mining industry. Several existing certification standards were revised to improve the safety aspects or to reflect changing technology. Ninety-seven certificates were issued.

The conveyor-belting standard was approved by the technical committee and a new draft standard for fire-resistant mine duct material has been prepared. CANMET scientists were involved in field testing three diesel emission reduction technologies in underground mining conditions. The most promising technology, ceramic filters, is currently being transferred to industry.

COAL AND OIL SANDS MINING AND PREPARATION

The mining of coal and its preparation for the customer forms a distinct specialized industry of its own. Canada produces about 60 million tonnes of coal per year. Almost half of that production, worth $2 billion, is exported.

CANMET's activities in fossil fuel mining and preparation are directed toward improving coal recovery, reducing sulphur emissions, improving health and safety aspects, and encouraging industry to adopt new mining technology.

Emphasis was placed on the twin processes of consultation with industry and technology transfer. Industry-wide seminars to review research needs and laboratory programs were hosted, in addition to formal conferences organized jointly with regional universities. The topics covered by these meetings included surface mining equipment selection, methane and coal dust explosion hazards, and mobile pilot plants for coal preparation and water treatment.

During the last year, close contact was maintained and information exchanged with provincial coal authorities and coal mine operators, since both are important sources of information on technological and economic changes affecting the Canadian coal industry.

Because competition in international coal markets is very strong, the Canadian industry must improve the quality of its coal products while maintaining high productivity to remain competitive.

Coal Reserves' Assessment

Orderly development of Canada's domestic and export coal market requires detailed up-to-date knowledge of the nation's coal reserves, coal quality, and production constraints.

A comprehensive coal map file containing relevant information on Canada's coal fields was produced. The National Coal Reserve Inventory, coal mine productivity data, the mine operators' list, as well as associated technical and economic data were updated, and samples of coal collected from all major mines operating in 1984 were analyzed. As part of a Federal-Provincial Resource Development Agreement, 39 coal samples were analyzed and 191 oil shale samples were prepared for analysis on behalf of the Nova Scotia Department of Mines and Energy.

Coal Mining: West

Spontaneous combustion continues to be a problem in coal mines, in coal silos, and in shipholds. Work on methane accumulation in storage silos emphasized the need for adequate ventilation and monitoring systems. Researchers found that susceptibility to spontaneous combustion is in the order: Foothills region thermal > Plains region thermal > metallurgical coals. Spontaneous combustion is more likely when coals are dried below their inherent moisture levels. Contractors determined the reaction mechanism of spontaneous combustion, the susceptibility of coal rejects to spontaneous combustion, and isolated methane-oxidizing bacteria that can remain active in the conditions found in coal mines, silos, and in shipholds.

CANMET's computerized telemetry system, developed under contract to monitor subsidence in underground coal mines, was used to monitor movement in an oil sands highwall and provided information on the stability of the tailings dam.

Finite element modelling aided in the interpretation of microseismic monitoring data obtained from an active open pit slope. It was found that the known geology could not be used to predict areas of high stress concentration.

A computer-based theory of the strength of pillars in coal has been verified through laboratory tests of coal properties. This method can be used for designing pillars in soft rocks. A study of resin bolts has provided a thorough evaluation of the mechanics of layered roof supported by nontensioned resin bolts.

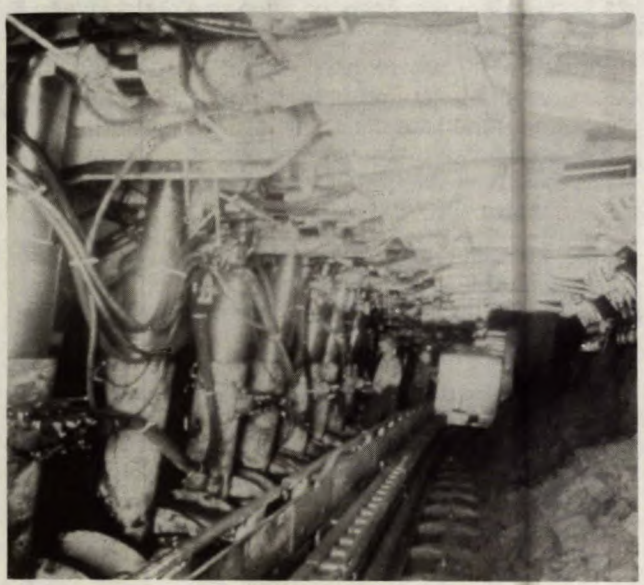
Work on rock characterization continued with the investigation of different techniques available. A correlation between the point load strength and uniaxial compressive strength for soft rocks was established.

Two interactive computer models for surface-mining equipment were developed: truck-shovel-loader and bucket-wheel-conveyor-bin. These models are now being validated using field data from surface coal mines in western Canada.

"State-of-the-art" studies of surface-mining methods and the application of mining equipment included studies of continuous-mining systems, analysis of existing methods for mining oil sands, and overburden handling.

Coal Mining: East

CANMET's support of eastern Canada's underground coal-mining industry is directed principally toward research into enhanced health, safety, and productivity. Much of the work is carried out cooperatively with the Cape Breton Development Corporation (CBDC). The research includes the environmental problems of dust, as well as the safety-related topics of frictional ignition



Longwall face in a coal mine. Chain conveyors and face supports are shown

and methane prediction; strata control and research into rock and coal cutting; and research and development in instrumentation and equipment performance.

Comprehensive field-oriented respirable dust surveys have been conducted to establish the level of exposure of underground workers and to evaluate the dust control effectiveness of new technology like water jet assist or roadheader machines.

Preventing the frictional ignition of the methane released from coal that is cut by shearer drums is a major concern. Researchers evaluated both the performance of the shearer drum and the performance of hollow shaft ventilators that provide the air needed to dilute below the explosive limit any methane that is released.

A major thrust of CANMET's ventilation research program is the continued development of tracer gases to solve complex ventilation problems. An instrument, developed in-house to measure tracer gases in the underground environment, performed well in a field trial and provided a level of information not possible previously.

CANMET researchers proposed and monitored a monolithic packing system to successfully reduce ventilation leakage to an acceptable level; they also developed a new technique to accurately define airflow around the longwall district. This technique can be used to calculate the increase in the gob's resistance to air leakage.

CANMET is promoting substitution of nonflammable materials for the wood used to lag roadways in CBDC collieries and has contracted an assessment of the risk of underground fires, a review of substitute materials available within the Maritime provinces, and a review of fire-retardant treatment of wood.

An understanding of the response of strata surrounding the coal seam is necessary to mine coal safely underground. The following resulted from research conducted or sponsored by CANMET:

- In situ stress determinations at the Lingan Mine provided information for the outburst program.
- A contractor found that outburst phenomena in the Sydney coalfield could be combatted by the hydrofracturing technique.
- A new packing method resembling the traditional maingate pack was used to successfully maintain the tailgate, allowing the tailgate to provide adequate support to control the gateroad.
- Work continues on the development of barrier design criteria and on the evaluation of a seafloor subsidence monitoring system.
- A contractor completed a comprehensive goetechnical study during drivage of the Donkien-Morien No.2 tunnel using the Lovat fullface TBM.
- In situ gas permeability testing was used to compare rock/support interactions when two methods — drill and blast and fullface tunnel boring — were used to excavate coal.

Coal Preparation

Coal preparation is generally necessary to remove ash, sulphur, and other contaminants from coals destined for carbonization and conversion, or for liquid fuel mixtures. Coal used to generate thermal power may be upgraded to meet environmental controls for sulphur emissions and to reduce transportation costs. In the past, coal preparation consisted primarily of rejecting shale from coarse run-of-the-mine coals and screening it to meet consumer requirements. Today, international competition in coal supply markets demands that Canada improve the quality of its coal products while maintaining productive, efficient, and safe operations. Ash is generally relatively easy to remove, but reducing the level of the more finely distributed sulphur is more complicated.

CANMET's 10 t/h coal preparation pilot plant at Devon, Alberta, was used to optimize circuit specifications for cleaning three Maritime coals. The limitations and potential for sulphur reduction, together with the mass and thermal recoveries, were evaluated.

When ash and sulphur levels are lowered sufficiently, coal can be used for power generation in the form of coal-water slurries. A unique 2 t/h pilot plant that contains eight process options was designed under contract; when completed, it will be used at CANMET's Devon facilities to "deep clean" coal to exacting market specifications.

CANMET's three mobile pilot plants were used to carry out on-site research and to offer specific assistance services to a number of preparation plants on a cost-recovery basis.

In both eastern and western Canada, finely divided coal presents a major problem in the achievement of higher

CANMET's mobile dewatering plant No. 2 at a coal washery

quality clean coal products. A major effort continues to be in the upgrading, water treatment, and dewatering behaviour of fine coal. Field (mobile plants) and in-house pilot-scale studies are supported by comprehensive laboratory characterization of fine coal systems. Under a Canada-Germany "Memorandum of Understanding on Coal Slurry Systems", combustion tests on a dense coal slurry (prepared in Germany) were carried out in Canada; a contract research program on "Coarse Coal Slurry Short Distance Pipelining" was completed; and an engineering manual for the design of coal slurry pipelines is underway. Environment Canada completed a study on the environmental impact of coal transportation and pipelining.

A thorough knowledge of the rheological properties and behavior of coal-water mixtures (CWM) is needed for the proper design of preparation, handling, and transportation facilities. The rheological parameters needed to characterize CWMs prepared from two western Canadian coals were determined.

Coal Desulphurization

CANMET is developing technology for the economical upgrading of high-sulphur coals to meet the stringent environmental controls for combustion and conversion. Projects either underway or recently completed include:

- — using an open-gradient cryogenic magnetic separator to beneficiate Canadian coals in terms of both sulphur and ash removal;
- — conducting a literature survey on the petrography and mineralogy of eastern coals to support CANMET's work on deep cleaning by progressive grinding, flotation, and magnetic separation;
- — processing a low-grade coal entirely by dry methods;
- — selectively separating pyrite from coal, using a flotation column following fine grinding;
- — continuing in-house and contracted research on the flotation of pyrite before and after treatment with microorganisms, as well as research on large-scale culturing techniques for the microorganism *thiobacillus ferrooxidans*.

MINERAL PROCESSING

After any ore is mined, it must be treated to extract the values from the ore and to produce a material or metal for sale. CANMET investigates the physical aspects of recovering minerals, such as crushing, grinding, sizing, and separating, as well as conducting research into novel and efficient means of processing industrial minerals, ceramics, and concrete. CANMET also develops new or improved chemical and heat treatment processes to economically extract metals from concentrates, by methods such as leaching and other chemical processes.

Increased processing and energy costs, more stringent product specifications, more diverse applications and markets (as well as competition in and for these markets), have focussed attention on the need for more efficient production and processing, as well as greater diversity in product development to maintain a competitive edge in domestic and international markets.

Researchers are working to develop methods to effectively control and dispose of potential environmental contaminants that are discharged from mine or mill operations.

Minerals' Evaluation

CANMET is promoting the development of Canadian mineral resources by assessing their nature, occurrence, and potential for recovery of contained valuable minerals. During the last year:

- Mineralogical and predictive optimum grind studies of the Tally Pond base metal deposit were completed.
- A qualitative geological and mineralogical examination of the Tulks base metal sulphide deposit was completed.

Automated image analyzer uses an electron beam microscope and a complex computer software package to analyze elements in ore, measure the size of the grains, and determine the grind needed to liberate the valuable minerals from the ore

Detailed mineralogical and crystallographic investigations of rare-earth-bearing minerals have resulted in improved understanding of several large rare-earth deposits in Canada. In the ongoing characterization of secondary copper-ore minerals, the physically similar

minerals rosasite and malachite can now be differentiated in complex intergrowths.

Automated image analysis techniques that are now well established are being used on ore feeds, concentrates, intermediate products, and tailings on a routine basis. The technique has most recently been extended to characterize uranium and base metal tailings piles. The first annual "Workshop on Image Analysis Applied to Ore Dressing" was attended by representatives of industry, universities, and consultants.

Contractors determined which mineral deposits in Newfoundland are suitable for research, evaluated the Point Leamington deposit, determined the mineralogical characteristics that affect recoveries of various concentrates and ores from Manitoba, and analyzed manganese deposits in New Brunswick.

Beneficiation of Metallic Minerals

Canada is well endowed with mineral resources. The challenge for survival facing the industry today is to become more efficient and consequently more competitive in world markets. CANMET is focussing its research efforts on increasing the productivity of existing plants and processes.

CANMET provided the mineral and coal industries with computer methodology (SPOC Program) for circuit and equipment optimization and design. During the year under review, three circuit simulator programs were written for grinding, classification, and flotation circuits.

If Canada, with its abundant iron ore resources, is to remain a major supplier in a buyer's market then efficiency, product quality, and product recovery must be improved and energy input costs reduced. CANMET:

- is investigating binders to replace the bentonite used in making iron pellets;
- is determining whether additional iron units can be recovered from tailings;
- extended a contract to implement a grade control program at a concentrator;
- identified the cause of the build-up of deposits on the spirals used in preparing concentrates;
- studied the preparation of low-silica iron concentrates using various amine and reverse flotation methods, and found scavenging to be more effective than flotation;
- evaluated the performance of equipment used for mineral processing.

Generally, valuable mineral losses in the minus 10-μm fraction are much higher than those sustained in coarser sizes. Investigations to develop new concepts to float the very fine fractions now being discarded to tailings are underway.

Tin occurs in varying amounts in many Canadian base metal sulphide ores, but only a small fraction is being recovered. Over 7000 t/a of tin worth about $90 million are lost by three operations — Kidd Creek Mines, Brunswick Mining and Smelting Corporation, and Health Steele. Preliminary work identified the problems of processing fine particles and reviewed methods to process them. Research on the chemico-physical and mineralogical characteristics was initiated and recovery methods developed.

CANMET is developing a liberation model to simulate the mechanical separation of minerals attained during comminution. Data on the size distribution of minerals in a variety of unbroken ores and the mineral liberations in mill products obtained from these ores have been collected. Close correlations were observed between predicted and measured liberations for most minerals in most ores.

Beneficiation of Industrial Minerals

CANMET is developing and improving existing methods to recover minerals and mineral products. Work in progress during the review period includes studies on silica, barite, potash, kaolin, and asbestos. The major component of energy input in the processing of many industrial minerals is concerned with reducing the size of the as-mined materials to meet processing or end-use requirements. Improved grinding techniques will reduce this element of energy and dollar cost. Contractors are developing, on the basis of pilot-plant tests, a statement of technical requirements for implementing state-of-the-art comminution technology in the Canadian mineral-processing industry, and are comparing the potential for energy savings in utilizing the wet (with and without surfactants) grinding process for asbestos with the conventional dry process.

Improvements that increase the thermal efficiency of firing clay products, or that reduce the firing time or temperature, will result in substantial energy savings. A contractor is optimizing a refractory blend that allows much lower firing temperatures in the manufacture of molds for casting Al/Cu alloys.

The manufacture of cement is especially energy intensive. CANMET supports the development of supplementary cement materials such as Canadian pozzolanic materials and blast furnace slag as substitutes, in part, for the cement in many concrete applications.

Treatment of Industrial Minerals

CANMET is increasingly involved in research associated with high-performance concrete for offshore struc-

tures. In-house development of high-strength, lightweight, superplasticized concrete continued. Testing methodology and apparatus have been designed to determine resistance of concrete to ice abrasion and impact. Development of high-performance grouts and repair materials continues. Because the production of portland cement is highly energy intensive, CANMET supports the development of supplementary cementing materials such as Canadian fly ashes, condensed silica fume, and granulated blast furnace slags.

Under contract, a durable low-cost asbestos-cement cooling tower fill incorporating supplementary cementing materials is being developed. A two-level fractional design has been implemented to study the effects of 15 variables and to assess their effect on the durability of cooling tower fill.

Treatment of Ceramics

CANMET is developing the materials technology for energy storage and conversion devices, specifically those that exploit solid electrolytes. During the past year, the electrical and micro-structural properties of spray dried beta-beta aluminas containing various levels of Li^+ and Mg^{2+} stabilizer were determined. Work continued on the isotropic sodium-conducting silicate systems. The development of techniques to detect small subsurface flaws in sintered ceramic is important if the material is to be stressed electrically or mechanically. Under contract, efforts to lower the limits of detection of fine defects in ceramic using ultrasonic techniques continued. The ability to produce transducers, used to detect defects, operating over 50 MHz with a focussed beam of any focal length has been developed and used to characterize the changing microstructure that occurs on ion-exchanging solid electrolytes used to produce hydrogen-conducting materials. A number of hydrogen-conducting electrolytes, based on various zirpsios and beta-aluminas, have been produced and shown to have high conductivity as well as much higher strength than materials produced from sintered bodies. Under the PILP program with assistance from CANMET, demonstration of a small-scale thermoelectric generator that produces power directly from heat sources such as industrial stacks continues.

Work continued during 1985 toward developing improved semiconductor electrodes, mainly Fe_2O_3 and GaAs with thin Co films for photoelectrochemical processes. CANMET's participation has continued in the IEA program of research and development for the production of hydrogen by photocatalytic electrolysis of water using solar energy.

Changing technology in steelmaking has seen continuing adoption of electric arc furnace melting and attendant transfer of secondary steelmaking processes to ladles and associated transfer vessels. The linings of these intermittently operated vessels are subject to degradation by thermal shock, as well as to increased erosion and corrosion. Among those recording the shortest lifetimes are ladles used in the VOD and VAD processes for making high-alloy speciality steels. Previous work at CANMET revealed an inherent deficiency in the chrome-magnesia bricks used to line these vessels. With the cooperation of a steel company, the degradation of the lining of the VOD/VAD vessels is being studied. The company has been conducting trials with alternate refractory materials, which CANMET has been examining.

A comprehensive evaluation of the physical, chemical, and electrical properties of carbon electrodes for arc furnaces and their methods of measurement was completed.

Biotechnology

CANMET researchers are investigating ways to utilize microorganisms to extract and to beneficiate mineral deposits that cannot be treated economically by normal processes. With bacterially assisted leaching, an average copper extraction rate of 1 per cent per month has been achieved for two copper ores. Contractors are studying the microbial control of tailings dump leaching, microbial degradation/alteration of carbonaceous species in Canadian ores and concentrates, the biological reactivity of mineral ash in eastern Canadian coal, the bioadsorption capacity of biomass isolates, and biological polishing agents.

Scientists examining the growth of microbiological culture for bacterial leaching

Extraction: Metallic

Conventional processing of complex zinc, lead, and silver sulphide ore deposits, such as those found in New Brunswick, generally results in inefficient recoveries of high-value saleable products. Metal extraction efficiency can be improved by producing a bulk concentrate, which because of its complexity is not amenable to conventional processing. CANMET has been develop-

ing and evaluating chloride-based processes for the treatment of these complex sulphide concentrates that will eliminate SO_2 emissions by yielding elemental sulphur as a saleable by-product.

New and improved processes to increase the recovery and to reduce costs in the extraction of gold and associated precious metals are being developed:

- Under contract, a new ultra-sensitive micro-analytical technique for in situ analysis of minerals was explored.
- Tests by Aggen Inc. indicate that many gold resources in Ontario are amenable to electronic sorting.
- The Knelson concentrator, a newly developed centrifugal separator for gold and other heavy minerals, offers good potential for recovery of liberated heavy minerals.
- Thiourea and chloride have been investigated as possible alternatives to cyanide in leaching of conventional and refractory gold ores.
- Work on the development and optimization of a solvent extraction separation flowsheet for the stagewise recovery of Au, Pt, and Pd from chloride solutions continues.

CANMET is supporting identification of the technical and economic potential for applications of plasma technology in Canada in the fields of energy utilization and pyrometallurgy.

Canada is a major producer of primary copper for both domestic and export markets. CANMET is working with industry to improve electrorefining technologies to meet market requirements for copper ductility and conductivity, and to recuperate valuable by-products. During smelting, many of the impurities contained in the copper concentrates are collected in the blister copper smelter product and are later removed — usually by electrorefining. During the year under review:

- Metallographic studies on copper anodes obtained from Canadian copper producers were conducted.
- Analytical methods were developed for the analysis of As(III) and As(IV) in copper-refining solutions, because arsenic is difficult to control in copper refining and creates hygiene problems in the copper liberator circuits.

Extraction: Radioactive

Although present technology for uranium ore processing gives high recoveries, improvements could increase process efficiency and decrease both in-plant health hazards and the environmental problems posed by process effluents. At CANMET, a systematic review of the existing process identified areas for improvement. Researchers:

— continued pressure leaching of low-grade and complex ores both in-house and under contract;

— continued work on the recovery of rare earths from process effluents;

— continued development of a new stripping sequence that would permit the recycling of reagents while providing a high-purity product;

— investigated different methods of adsorbing Ra-226 from uranium tailings seepage water;

— determined directly, without prior separation of uranium, aluminum, arsenic, calcium, iron, magnesium, molybdenum, sodium, silicon, vanadium, and zirconium in a series of acid leachates and solvent extracts;

— studied the feasibility of acid chloride leaching of Midwest Lake uranium ore;

— developed a promising new approach to leaching uranium ore.

Standards and Specifications

Through the Canadian Certified Reference Materials Project, CANMET strives to fulfill the demand from Canadian industrial, commercial, and research laboratories for geochemical reference materials. CANMET offers the expertise, the facilities, the continuity, and the impartiality necessary for long-term credibility and public acceptance of these materials. In 1985-86, approximately 1350 units of reference materials were distributed to users in Canada and abroad, generating a revenue of approximately $105 000.

CANMET scientists continued to participate in the International Organization for Standardization (ISO) and the American Society for the Testing of Materials (ASTM) in the areas of reference materials and internationally accepted analytical methods. To meet the increasing demand for faster and more accurate analytical results, new analytical techniques are being developed and existing methods are being refined. CANMET has developed methods to:

— determine trace metallic elements in sulphide ores and concentrates;

— determine gold in gold refinery by-products;

— determine tellurium in precious metal leach solutions;

— determine rare-earth elements in uranium ore-pricing solutions;

— determine organic components of leach solutions and solvent extraction effluents;

— characterize minerals by magnetic properties.

Sample preparation for chemical analysis

By-Product Recovery

To obtain the maximum economic return from Canadian and imported mineral resources, it is necessary to economically recover as by-products minor constituents in ores or other materials that have been mined, milled, or processed.

Canadian zinc ores contain potentially recoverable quantities of silver but much of the silver is lost, either in tailings during milling or in zinc plant residues. The following research is being conducted or supported by CANMET:

— the identification of the mineral forms of silver in zinc concentrates and residues;

— studies of the loss of silver in the jarosite-type compounds formed during zinc processing. To date, the conditions affecting silver losses have been defined and the incorporation of silver in lead jarosites has been elucidated;

— a study of the flotation of silver zinc plant leach residues and the effect of leaching parameters on flotation;

— jointly with Cominco, a determination of the effect of various impurities on the zinc electrowinning process.

CANMET is studying the possibility of recovering the molybdenum and zinc that occur in minor amounts in concentrates of copper, lead, and nickel ores.

Environmental Controls

Researchers are focussing their attention on the treatment of liquid effluents from the mining industry. These include heavy metals, cyanide, arsenic, and thiosalts.

Researchers found that placing wetland (bog) vegetation on the surface of tailings that contain pyrite inhibits bacterial sulphide mineral oxidation, which is the primary cause of sulphuric acid generation. Experiments simulating deep water disposal of tailings indicated that acid production was inhibited.

The emission of noxious elements and their compounds during pyrometallurgical processing of Canadian ores and concentrates is a matter of concern to federal and provincial health and environmental protection organizations as well as to industry. Of particular concern are non-ferrous roasting and smelting operations that produce emissions of SO_2, of arsenic, of mercury, and in many cases small quantities of other toxic elements such as cadmium, selenium, tellurium, and lead. CANMET is investigating the thermochemical properties of certain arsenates and arsenides to enable calculations leading to the development of improved pyrometallurgical processes for handling arsenic-bearing concentrates.

Research into the long-term effects of uranium mill tailings is being carried out by the National Uranium Tailings Program (NUTP). Greater understanding of the chemical, physical, and biological processes that occur in the tailings and in the transport of contaminants in the surrounding environment has been achieved. This knowledge has been used in the further development of a mathematical model that predicts the long-term effects from uranium tailings, such as radiation dose to man, pH in surface waters, and environmental concentrations of non-radioactive contaminants. Major field studies, in support of the program, have been completed at the Key Lake and Gunnar tailings sites in Saskatchewan, at the Lancor tailings site in Ontario, and at Portland Creek in Newfoundland.

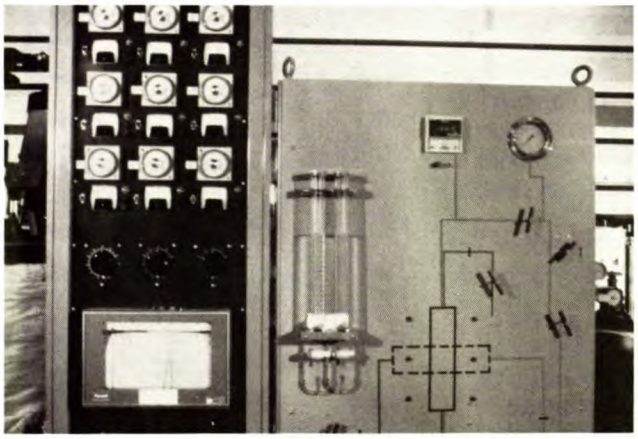
A new program was created to provide technical information so that the mining industry and governmental agencies can predict with some confidence the long-term management requirements of mine and mill tailings. The primary concern is that these wastes do not contribute an unacceptable hazard to the surrounding environment after the cessation of mining and processing activities at the site. The Reactive Acid Tailing Sulphides research program (RATS), a cooperative industry, provincial, and federal government program, is designed to study the degree and rate of acid generation from sulphide tailings of base metal processing operations and to develop environmentally sound abandonment schemes.

FUELS TECHNOLOGY

In Canada, a gap exists between the supply of liquid fossil fuels and demand. In response, CANMET is developing technologies to increase the supply through research programs related to the upgrading of oil sands, heavy oils, and synthetic crude production; coal combustion; coal gasification and liquefaction; and oil and gas domestic heating furnaces.

Recovery of Bitumen and Heavy Oils

A better process is needed to extract bitumen from mined oil sands if the recovery of oil sands by surface-mining methods is to be competitive with the stimulated in situ recovery of heavy oil and bitumen, enhanced recovery of conventional oil, and production of conventional oil from arctic and east coast offshore reservoirs. The Alberta Oil Sands Technology and Research Authority (AOSTRA), in concert with industry and EMR, developed the concept for an Oil Sands Demonstration Centre that will be used to demonstrate the Taciuk process for combined thermal extraction and partial upgrading of bitumen from mined oil. Technical and economic studies for the construction and operation of the centre have been completed.



Experimental unit used to study the recovery of bitumen from oil sands

Treatment of Bitumen-Oil Emulsions and Effluent Waters

Separating oil-in-water and water-in-oil emulsions formed during the in situ recovery of oil sands and enhancing recovery of heavy oils is desirable for environmental reasons and to maximize product yield. CANMET has developed a variety of flowsheet options that will be used to treat these emulsions in a 70-barrel-per-day mini-plant.

Upgrading Technologies for Bitumen, Heavy Oils, and Residuals

The utilization of Canada's large reserves of bitumen and heavy oil depends upon the development of commercially viable upgrading processes. EMR participated with Petro-Canada in the start-up of a recently constructed CANMET hydrocracking demonstration plant in Montreal and in assessing techniques to characterize additives that hold promise for use in the demonstration plant. To support commercialization of the CANMET hydrocracking process, CANMET optimized process conditions and characterized new feedstocks. Progress in developing hydrocracking technology included the identification of promising new and modified additives that would inhibit the formation of coke during hydrocracking. Continuing work on reactor modelling included a comparison of pitch conversions from pilot-plant experiments using a continuous stirred tank reactor and a tubular reactor; development of a model to predict solids concentration profiles in the hydrocracking reactor; and an assessment of the effect of backmixing on the hydrocracking process. Fundamental reactor studies completed this year included pilot-plant voidage measurements that will be used to predict voidages in commercial-scale hydrocracking reactors.

A deconvolution method was developed to interpret hydrodynamic data on flow regimes and bubble size. Contractors assessed liquid tracer techniques and pinpointed spin trapping as a viable means of identifying free radicals produced during thermal decomposition of heavy oils. Pyrolyzing heavy oil under hydrogen pressure produced a lower rate of coke formation than pyrolysis under nitrogen atmosphere.

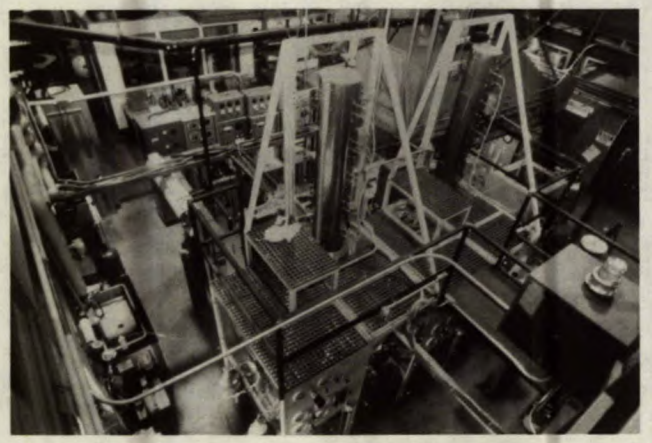
Catalytic Processes for Hydrocarbon Conversion and Distillate Upgrading

In-house and contracted-out catalyst studies centred on developing technology for the production of saleable liquid fuels, with particular emphasis on concepts that show promise for commercial application in Canada. Bench-scale studies were conducted on the primary conversion of bitumen, heavy oil, coal, oil/coal mixtures, natural gas, and their by-products and residues into suitable feedstocks for refinery operations. Secondary upgrading of all types of primary liquids derived from these processes focussed on the production of specification transportation fuels. Achievements include:

- Catalysts that reduce the viscosity of heavy oils sufficiently to meet interprovincial pipeline standards were formulated.
- Progress was made in converting heavy residual pitch materials to distillate liquids.
- A new approach to upgrade synthetic fuels to transportation fuels using highly active, low-cost supported metal catalysts was developed. These hydrogenation

catalysts work effectively at 240°C, allowing operation at hydrogen pressures of 3.5 MPa and achieving almost complete conversion of aromatics.

- Several coal-derived distillates were hydrotreated to evaluate the performance of a Ni-Mo/Al_2O_3 catalyst for heteroatom removal.
- Under contract, catalysts to convert hydrocarbons in synthetic distillates, and catalysts to remove nitrogen and oxygen compounds, were prepared and evaluated.



Dual-mode hydrotreater, consisting of two reactors, is used to test and develop catalysts

Last year, a number of additives prepared using coal and coal-derived materials were evaluated in a bench-scale facility for their performance in CANMET hydrocracking and related processes. In a different application, researchers found that hydroprocessing catalysts containing some metal-exchanged hydrous titanates produced more pentane-soluble oil and less gas than commercial hydrotreating catalysts.

Characterization of Liquid Fuels and Development of Separation Processes

The Canadian participants (EMR and the Saskatchewan Department of Energy and Mines) of a Canada/U.S. cooperative tar sands and heavy oil project are studying the effects of fire flooding on heavy oil properties. Work on heavy oil from a Saskatchewan reservoir is being complemented by studies on bitumen samples from Alberta.

CANMET researchers produced characterization data essential to understanding the impact that processing conditions have on the properties of products obtained from synthetic crudes, using existing commercial-scale coker operations and advanced hydroprocessing conversion technologies. Residue utilization studies resulted in a patent application for the use of processing residues in road and roofing asphalts.

Secondary upgrading of synthetic distillates focussed on research involving both sorption and membrane technologies. Zeolites and other sorbents were found to effectively remove unwanted heteroatoms from synthetic crude distillates.

Membranes show promise in applications related to the treatment of effluent streams from bitumen or heavy oil recovery operations. In processes involving the production of high-quality distillate streams, they successfully separated etherification products used to boost octane ratings from methanol streams. This separation cannot be achieved using conventional distillation techniques because azeotropes are formed. Some success was obtained in separating saturated and aromatic hydrocarbons by membrane technologies.

Conversion of Natural Gas to Liquid Fuels

The Natural Gas Conversion Program is designed to develop technologies that will allow better utilization of natural gas in refineries. A twofold strategy is pursued. The conversion of synthesis gas to a high cetane diesel fuel, which constitutes the first area, involves the design and testing of new catalysts and processes to selectively produce diesel fuel from synthesis gas. The experimental research is complemented by economic evaluations of the various options made through consultation with the private sector and the use of economic feasibility models for alternate fuel technologies.

The second part of the program concerns the development of new technologies for producing blending components to improve fuel quality. Several processes, both catalytic and non-catalytic, are under investigation. In one process, natural gas is converted to acetylene using an electric arc process. In-house research focusses on the design of catalysts to convert acetylene into high-octane blending components such as benzene, toluene, and xylenes. In another process, natural gas is polymerized into higher hydrocarbons using a hollow cathode.

Direct Liquefaction and Pyrolysis of Canadian Coals

CANMET's program in direct liquefaction and pyrolysis is carried out through fully and partially funded contracts with provincial research organizations, industry, and universities. Both fundamental and processing aspects of coal liquefaction are addressed. Projects include:

— flash pyrolysis of eastern Canadian coals;

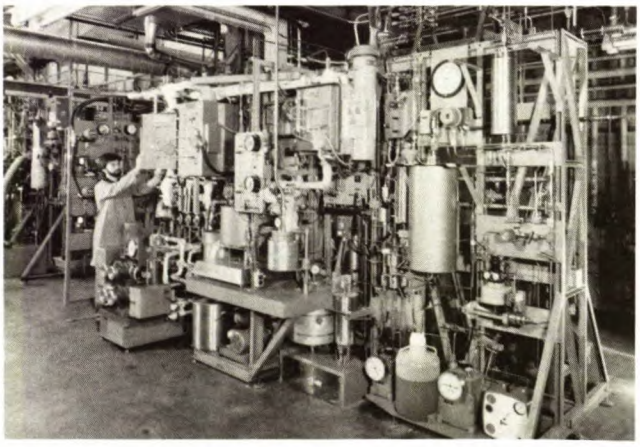
— single- and two-stage liquefaction of Nova Scotia coals;

— upstream agglomeration of high-ash coals;

— a techno-economic comparison of the Sandwell Centrax solid separation process with the Kerr-McGee critical solvent deashing process.

Coprocessing of Coal and Heavy Oil-Bitumen

CANMET is investigating the concept of simultaneously processing slurries of coal and bitumen or heavy oils. In eastern Canada, the combination of Nova Scotia coals with conventional crude residuals or imported heavy oils has potential for large-scale applications. In western Canada, the low-rank plains coals of Alberta or lignites from Saskatchewan are prime feedstocks in combination with tar sand bitumen or heavy oil.



Alex Agnew, technologist, adjusts valve on continuous flow coprocessing unit

The in-house program, which includes both batch and continuous-flow bench-scale experiments, resulted in the demonstration of the feasibility of using various heavy oils and petroleum residues as coprocessing media for a large number of low-rank Canadian coals. Research projects include:

— a study of the effect reacting gas has on coprocessing by using carbon monoxide or hydrogen sulphide in addition to hydrogen;

— a test of the feasibility of two-stage coprocessing;

— the coprocessing behaviour of eastern Canadian bituminous coals;

— use of a novel design for a catalytic reactor to improve product quality;

— a study of coal-heavy oil compatibility;

— full characterization of distillate and residue products;

— determination of the thermodynamic properties of coprocessing residues.

The contract program addresses fundamental and processing features. Examples of projects undertaken by the fully funded program are:

— petrographic characterization of residues;

— the feasibility of residue flash pyrolysis;

— mathematical modelling of coprocessing kinetics;

— a techno-economic study of CANMET coprocessing;

— upstream and downstream deashing by spherical agglomeration.

Gasification and Pyrolysis

CANMET is developing in-house expertise in characterizing contaminants present in gasification products; CANMET is also developing low-cost adsorbents to remove acidic species from the products generated when coal is gasified at high temperatures. Researchers found that the ash produced when lignite is burned is a promising potential catalyst for gasification. The reactivities of Suncor and Syncrude coke during gasification in fixed, fluidized, and entrained beds were estimated.

Laboratory work on hydrogen retorting of New Brunswick oil shales, which forms part of a program to assess the potential to produce liquids from Canadian oil shales, was completed.

Carbonization

Canadian exports of metallurgical coal depend significantly on CANMET's internationally recognized test facilities. Conventional international test methods for assessing coking characteristics underestimate the quality of western Canadian coals, which are facing increasing competition because of soft international markets. CANMET's facilities, operated cooperatively with industry through the Canadian Carbonization Research Association, are used to assess the coking qualities of Canadian coals. During the fiscal year:

- Pilot-scale tests of blending non-coking coal with the coke oven charge showed that a 10 per cent non-coking blend produced weakly bonded coke.

- Coke oven tests of two western Canadian coals using the Carbolite oven determined that the effects of storage time and temperature on thermal, rheological, and coking parameters were not significant.

- A method to predict coke strength, based on a reflectogram of all coal macerals, was developed.
- Work performed at CANMET and under contract has shown that existing thermal rheological models using dilatation and fluidity cannot be used reliably to predict the quality of coke from western Canadian coals.
- Coke microscopy is being used to investigate the coking behaviour of various macerals and components of coking coals or blends.
- A better understanding was gained of the physical process of coking in a slot-type oven; also, better prediction capabilities were developed for coke quality and gas pressures in both pilot and industrial coke ovens from the combined effects of coal type, bulk density, static loading, and plastic layer area.
- Inexpensive materials, such as decant oil and primary tar collected from the centre of a coking charge, were tested as additives to improve the coke quality of highly inert coals.
- Tests were carried out to determine the effect on coke quality of increasing the bulk density of the coal in coke ovens by increasing the charging height. Preliminary results show a negative effect on coke quality.

Conventional Coal Combustion

Conventional coal combustion research focusses on the combustion performance, heat transfer, and emission characteristics of Canadian coals and coal rejects for conventional power generation and industrial use, both in Canada and in support of the export market. The combustion, slagging, and fouling properties of these coals were evaluated and means of minimizing emissions from conventional coal combustion furnaces by control of flame properties through burner and furnace design, chemical additives, flue gas clean-up, and coal feed comminution were developed. During 1985, 32 coal combustion trials were performed in the pilot-scale utility boiler:

— 6 were cost-shared evaluations of an eastern Canadian coal;

— 8 were in-house studies on the effect of comminution and residence time on coal combustion properties;

— 18 were undertaken to support the IEA Coal Cleanability and Combustion Characterization project instituted to generate a database for quantifying fuel performance benefits associated with coal cleaning.

To facilitate the use of coal in place of oil in industrial combustion systems, data that compare the combustion and heat transfer characteristics of coal with those of fuel oil under similar aerodynamic conditions must be obtained. CANMET researchers conducted 14 combustion trials in CANMET's tunnel furnace to generate data for a furnace-modelling contract. A contractor has improved and extended to low-volatile coals an existing computer model that predicts the combustion performance of Canadian coals burning in the tunnel furnace. Researchers continued to develop non-intrusive diagnostic techniques to measure flame temperatures and species concentrations without disturbing the flame.

Chris Hughes, technician, studies flame with laser Schlieren

To better understand the reaction history of individual burning coal particles, CANMET has built a controlled mixing history reactor. This provides a rapid, yet simple method of evaluating the burning characteristics of different coals.

Fluidized-Bed Combustion

CANMET is contributing to the utilization of high-sulphur and low-grade fuels by expediting the application of fluidized-bed combustion. The primary application is in the environmentally benign utilization of high-sulphur coal and petroleum cokes. Other applications include co-firing of coal and wood waste from the pulp and paper industry, utilization of coal washery rejects, and combustion of liquid or solid residues from heavy oil upgraders. Since most of these applications are site-specific, implementation of the technology by commercial forces alone is not feasible.

In the past year, combustion evaluations carried out in CANMET's bubbling FBC pilot plant to determine the sulphur capture potential of natural mineral matter in the fuel included:

— bituminous coal washery rejects

— low-sulphur lignites

— biomass materials

— preliminary work on pitch residues from heavy oil upgrading.

Contractors continued research on mathematical models for fluidized-bed combustion.

Early work on sulphur capture in FBC showed that limestones and dolomites vary greatly in their ability to achieve a given level of sulphur capture. CANMET is developing a database of the sulphation capacities of the Canadian limestones likely to be used in FBC applications. Thirty Canadian limestones were evaluated and the results verified against full-scale conditions. Researchers found that ash constituents of coal can either enhance or retard the sulphation capacity of the limestones, whereas iron compounds were found to have a negative effect. Additional tests were carried out in support of the AOSTRA-CANMET-Industry Upgrading Residue Utilization Project, in collaboration with scientists from Norway and Sweden. Circulating FBC provides more efficient sulphur capture and increased ability to cope with unreactive fuels. Therefore, this second-generation FBC concept will likely be employed in most large-scale FBC applications in Canada. A contractor has completed the design for a pilot-scale plant for CANMET.

Circulating FBC is perceived as the most promising technology for the utilization of residues such as coke and pitch from the upgrading of tar sands and heavy oil. Because the relatively high concentrations of alkali and vanadium may cause boiler tube corrosion, CANMET is investigating the deposition of vanadium, sulphur, and alkali; the corrosion caused by them; and methods to capture and stabilize them. Syncrude coke was successfully combusted using a limestone sorbent capturing an average of 90 per cent SO_2 and 95 per cent vanadium. Contractors are conducting pilot-scale circulating FBC studies of Syncrude coke using limestone from Fort McMurray to adsorb the sulphur.

Coal-Liquid Mixture Fuels

Coal-liquid mixture fuels could partially or completely replace oil or natural gas in existing boilers and industrial combustors while avoiding the capital costs of burner retrofit and on-site facilities for coal storage, handling, and preparation required for conventional pulverized coal technology. Because much of the ash and inorganic sulphur are removed from the coal during preparation of the coal-liquid mixtures, atomizer wear, boiler tube erosion, and environmental pollutant emissions are reduced. Work at CANMET is now directed towards coal-water fuels. CANMET is providing technical support for the coal-water fuel demonstration being sponsored by EMR's Coal Division at the Maritime Electric Generating Station, Charlottetown, P.E.I.

CANMET and the National Research Council of Canada contributed to the development of wear-resistant ceramic atomizers used by Canada Cement Lafarge in the successful conversion of its wet process cement kiln to on-site prepared coal-water fuel, thereby replacing natural gas economically. The Iron Ore Company of Canada demonstrated firing an industrial furnace using CBDC's coal-water fuel (CWF) and is evaluating the results with CANMET's assistance. Under contract, a high ash CWF was burned in the tangentially fired unit at Chatham using a new burner developed by the boiler manufacturer. The new burner provided better combustion and boiler performance than the one used previously.

Combustion Technologies for Pollution Abatement

CANMET is working to develop and demonstrate technology to minimize the emissions of acid rain precursors (SOx and NOx) from conventional thermal power stations, industrial boilers, and process heating furnaces. One potentially low-cost alternative to stack gas scrubbers for pulverized coal-fired boilers involves simultaneously inhibiting the formation of NOx and enhancing the capture of SOx during combustion, using either dry ash or wet ash (slagging) burner systems. CANMET's efforts are directed toward in-furnace control strategies, with most of the work performed under contract. Two retrofit pulverized coal burners incorporating staged combustion and limestone injection for simultaneous reduction of NOx and SOx emissions were installed in a 17 MWt hot water boiler at CFB Gagetown. Under contract:

- The burners were designed to reduce acid-rain emissions by 50 per cent when a coal containing 3 per cent sulphur is burned.

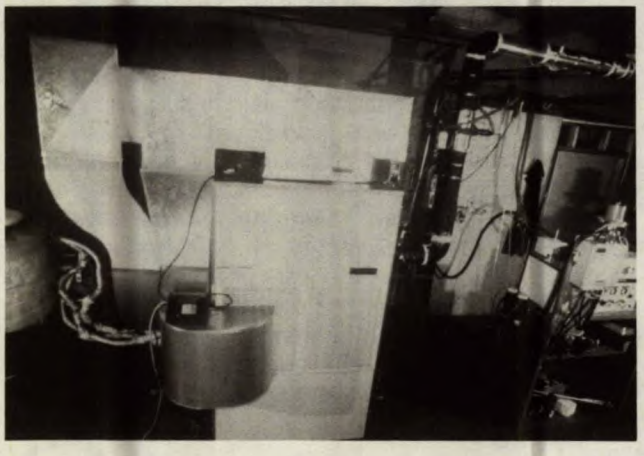
- The combustion and NOx/SOx emission characteristics of coal from the newly opened Shand deposit were evaluated. This project is part of the first Canadian demonstration of upper-furnace sorbent injection for SOx control in a lignite-fired boiler.

- A prototype burner, whose use will result in SOx being absorbed in the molten ash and the NOx controlled by staged combustion, is being designed.

Conservation in Residential and Industrial Systems

CANMET is working to reduce consumption of oil and gas used for space and service water heating through improved combustion technology. Experimental procedures for seasonal performance are being developed and new designs produced. Retrofit technologies are being developed to improve efficiency and safety in airtight housing, and the effects of degrading fuel quality are being examined. The results are transmitted to standards writing agencies, testing laboratories, manufacturers, and government agencies.

The Industrial Fuel Efficiency Program is concerned with increasing the efficiency of utilization and reducing the consumption of oil and gas in industrial processes. Much of the existing industrial equipment, particularly if more than ten years old, may not be operating or even operable at maximum efficiency. The program supports a limited number of specific studies in a variety of industrial regions and sectors of Canada. During the past year six pre-engineering studies, including on-site testing, were carried out in the following industries: structural clay products, dairy processing, pipes foundry, brewery, and two steelmaking plants.



Experimental rig used to evaluate the effects of fuel quality on oil burner performance

Two potential industrial sites for a retrofit flue gas condensing system on a gas-fired unit have been identified in a meat-packing plant and at a pulp and paper boiler. Contractors are analyzing the application of this technology, which provided major efficiency gains, in the residential sector.

Biomass Combustion

Since 1980, CANMET has provided substantial scientific support to federal and private sector programs related to the combustion of biomass in industrial boilers and processes. This support has included the evaluation of proposals, advice on new initiatives, the formulation of project tasks, and contract management.

METALS AND MATERIALS

CANMET's research related to metals and materials centres on the control and prevention of corrosion; the properties of materials; the development of casting and welding processes; materials failure analysis; certification and structural integrity; metalworking technology; and advanced instrumentation.

CANMET's projects deal with the microstructure-sensitive properties of steels, the control of microstructure by composition and processing, and the characterization of microstructure. The ultimate objective of each project is to develop predictive models of the microstructure-property interaction, which can be used to design improved materials.

Casting Processes

The recent economic recession has meant that, in general, only those foundries producing smaller castings on automatic moulding machines, mainly for the automotive industry, have been able to maintain their business. Other foundries with a more diverse range of products and production methods have been forced to cut back. These realities have prompted a new emphasis on technology transfer, the development of improved moulding techniques, and the application of statistical quality control. CANMET research included:

- — efforts to shorten the curing time for citric/gluconic acid-limestone and citric/malic acid-limestone bonded moulds;
- — casting trials for the zinc-aluminum alloy series Zn-8 Al, Zn-12 Al, and Zn-27 Al using both "cup" and "wheel" dies. Defect-free castings were produced in the 27 per cent Al alloy and acceptable castings in the 12 per cent Al alloy;
- — refinement of a disposable mould process for aluminum-based automotive castings sufficient to produce acceptable castings with both coated and uncoated polystyrene patterns;

— modification of a ladle system designed and fabricated in the foundry to simulate the characteristics of a low-pressure furnace for producing grey iron castings by the disposable mould process;

— a joint study with Cominco Research Laboratories of the effect of strontium, calcium, and sodium modification on the corrosion of Zn-27 Al;

— continuation of thermal fatigue tests on candidate permanent mould cast irons.

CANMET's Mobile Foundry Laboratory visited an additional 24 foundries last year, bringing the total number visited across Canada to 76. A consultant found that technological improvements suggested during the visits had resulted in $793 000 in savings and projected that $5.2 million in additional savings would be generated over the next five years.

Metal-Working Technologies

CANMET is developing facilities and processing techniques to identify, promote, and support advances in the technological capabilities of Canada's primary and secondary metal-working industries:

- Forging techniques that reduce material and energy usage are being developed. A fully coupled thermal/mechanical finite element code has been completed and is now being validated.
- Contractors redesigned a 500 ton press to permit temperature and rate-controlled forging processes, and developed a technique to relate fracture criteria to local strain measurements.

CANMET is assisting the Canadian steel and metal-forming industries in producing and processing high-quality steels. In-house, the effect that recrystallization of the base metal has on the galvanizing line was studied, while contractors investigated the forming behaviour of galvanized steel.

Rolling mill processes for modern high-quality steel plate, strip, and sheet are being developed. CANMET researchers:

— continued cam plastometer and rolling experiments designed to determine the effects of total strain, strain per pass, and final pass temperature on austenite and ferrite grain refinement in Ti-N-V steels;

— used base data on the high-temperature stresses of Nb,Ti,V, and Ti-N steels at strain rates equivalent to strip rolling to simulate and develop strip-rolling schedules;

— made significant progress in the mathematical modelling of rolling processes.

Welding Processes

CANMET welding programs are aimed at assisting Canadian fabricators in developing advanced welding technologies, which will allow them to remain competitive with offshore fabricators in the manufacture of structures such as heavy-wall reactor vessels, arctic ships, and offshore platforms. In-house and contracted-out programs include studies of weld-overlay surfacing, narrow-gap welding of pressure-vessel steels, development of a gas-metal-arc/submerged-arc combination process, repair welding, laser welding, and mathematical modelling of gas-metal-arc and submerged-arc welding processes.

The modelling or simulation of metallurgical processes such as continuous casting, as well as the microstructure and mechanical properties of the weld heat-affected zone (HAZ), are being carried out in cooperation with the primary metal industries. The output of this work can be used to determine the effects of changes in process-operating parameters. The Gleeble thermal mechanical simulator has been used to assess the hot ductility of continuous steel compositions, and the effect of heat input on the weld HAZ structure and mechanical properties. Contractors are working on finite element analysis modelling of weld thermal cycles, grain growth, and precipitate dissolution in the HAZ.

Welding procedures are being developed, and mechanical properties in Arctic ship steel welds as well as high-strength steel weldments for submarine application, are being evaluated.

It is necessary to ensure adequate fracture resistance in welded joints for application in the harsh, low-temperature environments found in offshore applications. Evaluation of fracture toughness and microstructure of currently available welding consumables for the shielded-metal arc, flux-cored arc, and submerged-arc welding processes is nearing completion. Researchers are studying the effects of post-weld heat treatment, used to relieve residual stresses, on the toughness of shielded-metal arc weld metals.

Nondestructive Testing

Rapid growth in nondestructive testing reflects national concerns for the structural integrity of engineering structures, product quality, resource conservation, and increased productivity. The certification of qualified nondestructive testing personnel must be strictly controlled and must not be affected by adverse influences or pressures. CANMET certifies nondestructive testing personnel on a national basis.

The technological sophistication and the range of applications of conventional nondestructive testing methods are growing. An acoustic emission monitoring prototype, developed at CANMET, successfully classified defects in three-inch steel plates. The effects of stress on the initial magnetization curve of pipeline steel were measured. Work continues in the area of ultrasonic inspection and characterization using optics and lasers.

Besides corrosion, the other major offshore problem is fatigue damage caused by stress range and crack size. In collaboration with industry, a method to reconstruct a flaw in three-dimensional space has been developed.

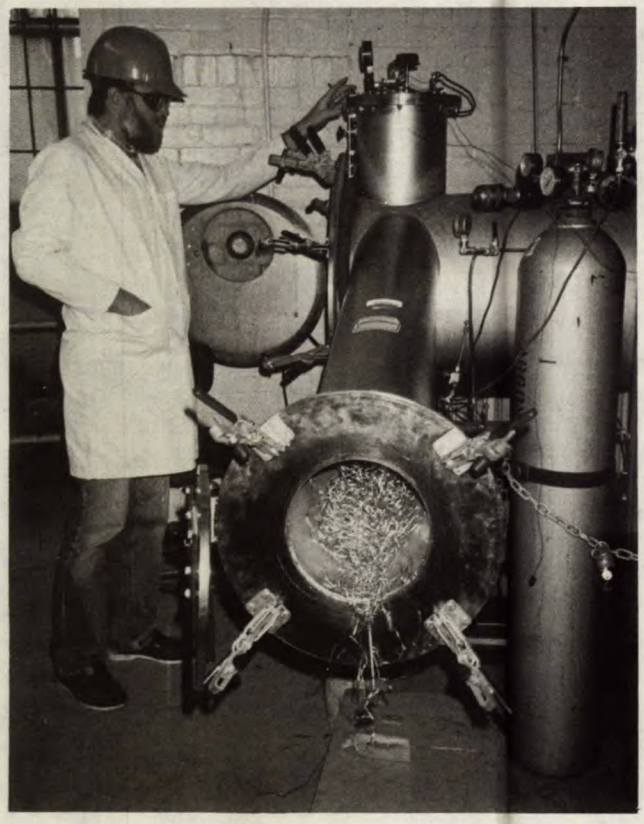
Microstructures and Properties of Engineering Materials

The knowledge gained from characterizing the microstructure of engineering materials is used to design and modify production processes and to improve service properties. CANMET research encompasses a broad span of materials and disciplines such as property optimization, fundamental mechanisms of phase transformations, deformation, and fracture.

Procedures are being developed to characterize particle-spacing distributions using automatic image analysis and a microcomputer. As part of an international effort, quantification factors for electron energy loss spectroscopy (EELS) were determined for the microanalysis of light elements in metals, alloys, and ceramic materials.

The effects of alloying, deformation, and cooling rate on austenite transformation behaviour and microstructure in steels are being studied. A method developed for rapidly determining the thickness, at any location, in a thin foil specimen enabled the identification of a new transformation product that strongly influences fracture properties of microalloyed steels. In related work, through-thickness fracture properties were determined for 25-mm thick plate of a Ti-V microalloyed steel processed by different thermomechanical schedules. The properties of the steel have been related to the microstructure features. Work on ultra-low-carbon bainitic steels indicates that requirements for high strength, in combination with low-temperature fracture toughness, can be met in boron steels containing 0.04 ppm C and 60 ppm N and should be achievable in commercial steelmaking.

The effects of inclusions and microstructure on the gauge-face, adhesive wear of rail steels were investigated using the National Research Council's laboratory rail-wheel simulator. Manganese sulphide inclusions strongly promote this type of wear, while oxide inclusions have little effect. As part of a program to develop improved free-machining steels, a thermodynamic database is being developed for steelmaking processes involving Ca treatment to ensure the presence of soft inclusion phases that promote long tool life.



Technologist Jim Barry using a melt spinning apparatus to produce ribbon from experimental aluminum bronze alloy by rapid solidification (10^6°C/second) from the molten state

A remedial heat treatment that doubles the impact toughness of Mn-Ni-Al bronze propeller castings, with no decrease in strength, has been developed. Rapidly solidified Fe-Al bronze, containing up to seven weight per cent Fe, has demonstrated superior corrosion resistance compared with sand cast alloys. Rapid solidification of materials results in microstructure refinement and improved chemical homogeneity.

Corrosion and Erosion

CANMET carries out basic and applied research on corrosion of pipelines, oil country tubular goods, marine materials, and coal combustion equipment. Achievements include:

- using inhibitor formulations consisting of molybdate or tungstate, in combination with reagents such as phosphate or nitrate, to achieve corrosion inhibition of greater than 95 per cent with coal water slurries containing chloride and sulphate;
- tempering samples of Algoma sour service C-90 seamless tubing at six temperatures from 610 to 780°C and measuring the sulphide stress-cracking resistance of the tempered steels;
- eliminating or minimizing weld metal corrosion by choosing the appropriate shielded-metal arc or submerged-arc welding consumables;
- modifying the steel plate chemistry to control the heat-affected zone attack;
- evaluating the effects of simulated fluidized combustion on the stress-rupture properties of materials for heat exchanger tubes and in-bed hardware. Definite interplay between corrosion and deformation or rupture was not found;
- reducing the isothermal oxidation rate slightly and improving resistance by the addition of Ca to Fe 10 Al alloy;
- significantly improving corrosion resistance of several rapidly solidified Fe-Al bronzes;
- implanting Al in pure Fe and dilute Fe-Al alloys to provide a modest improvement in oxidation resistance.

Materials Failure

CANMET is evaluating the fatigue life of welded joints representative of those in steel offshore structures. A fracture mechanics model for predicting the fatigue life of welded joints, developed in cooperation with contractors, correctly predicts the deleterious effects of increasing plate thickness. Fatigue crack growth in welded plate T-joints of 26 and 78 mm thickness is greater in sea water than in air, reducing fatigue life by a factor of two to three.

CANMET has been characterizing clean steel plate for offshore applications by crack-opening displacement and J integral techniques. The effect of microstructure on the low-temperature toughness of microalloy steels, and the quantitative relation between inclusion distribution and resistance to tearing fracture, are being evaluated. An extensive series of tests to establish the variation of cleavage toughness with thickness led to the development of a statistical model to interpret the results.

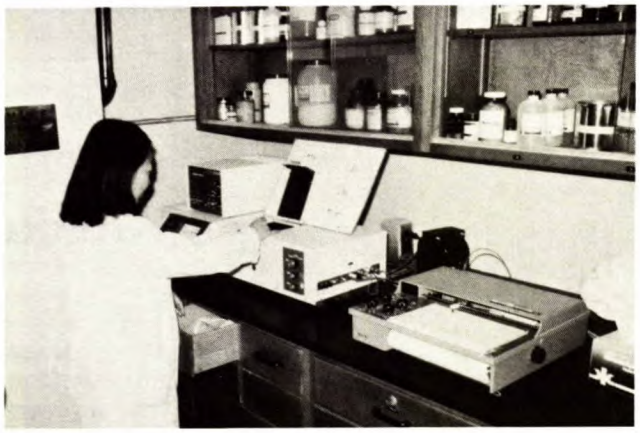
Advanced Instrumentation

Progress has been made in commercializing the CANMET portable X-ray stress diffractometer. A model has been developed with Chalk River Nuclear Laboratories to predict intergranular stresses in polycrystalline metals.

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

During 1985-86, CANMET examined 351 explosives for authorization under the Canada Explosives Act. Technical advice was provided on explosives, including an evaluation of a technician's protection suit to determine its response to attack by incendiary-type devices. A draft standard for fireworks was also completed — the first time such a standard has been prepared in Canada.

CANMET continued investigating the thermal properties of explosives, in particular, the thermal properties of tetryl and ammonium nitrate. The evaluation of test procedures under the United Nations Classification System has been completed and their procedures for routine testing of explosives implemented. A contractor is conducting field tests to verify a computerized model of high-velocity impact. The method sheds light on impact sensitivity and permits quantification of the phenomena for use in hazard studies.



Use of sophisticated analytical equipment to determine the chemical decomposition of explosives

TECHNOLOGY TRANSFER

During 1985-86, the Office of Technology Transfer (OTT) expanded its technology transfer activities and increased participation in the Program for Industry/Laboratory Projects (PILP) that demonstrates and commercializes technologies developed or sponsored by CANMET. OTT worked with CANMET's laboratories to plan and effect technology transfer activities; assisted with patenting procedures by acting as a liaison with Canadian Patents and Development Ltd. (CPDL) and by retaining patent agents under contract; advised Branch management and scientists on intellectual property matters arising from R&D contracts; continued to report significant events within the Branch; and responded to urgent issues such as the Nielson Task Forces.

TECHNOLOGY EVALUATION

OTT continued to provide engineering and economic evaluations for a number of projects, including:

- major evaluations of the ferric chloride leach process, the foundry vacuum-cured degradable sand-binding system, and the coprocessing method for production of syncrudes;
- more routine evaluations of the sulphation roast and the pressure acid leach processes, the in-place bioleaching process, potential manganese recovery from an iron ore mine, and gold recovery from tailings;
- reviews of operating and capital cost estimates for a medium-tonnage underground mine;
- modifications to the O'Hara-derived software package for determining the costs of mining and milling projects, in collaboration with consultants.

PROJECT REVIEW

An economic evaluation of the mobile foundry laboratory (MFL), completed on contract, was very favorable. Negotiations were completed to transfer the MFL to the Centre de Recherches Industrielles de Québec (CRIQ) and the Ontario Research Foundation (ORF) on a trial basis, with technical support from CANMET.

TECHNOLOGY TRANSFER ACTIVITIES

CANMET has 13 active PILP/IRAP projects with a total budget of $10.2 million, of which the companies are contributing $5.8 million and NRC the remainder. The following new projects were started during the fiscal year:

- development of wet processing of asbestos fibre from tailings, diesel exhaust filters, column flotation for mineral beneficiation, low permeability fibrous concrete, a rockburst-monitoring system, and a direct current plasma arc furnace for metallurgical applications;
- abatement of noise level of Canadian diamond drills;
- market study and development of the automated ultrasonic flaw-imaging system.

An internal review of the START program was completed, with a policy paper on the program drafted for review by senior management. Discussions were initiated with various companies for demonstrating various technologies.

TECHNOLOGY INFORMATION

Providing access to up-to-date information on mineral and energy technology to CANMET's own research staff, as well as to other researchers across Canada who have come to depend upon CANMET as a source of information, continued to be the principal objective of the Technology Information Division.

LIBRARY SERVICES

The number of periodicals received on subscription or on exchange has reached 2600. In addition, 3000 volumes of books, dissertations, and proceedings have been acquired and added to the collections. Loans to

CANMET staff exceeded 68 000, while loans to external borrowers were just over 4000.

TECHNICAL INQUIRY SERVICE

Information officers responded to 2700 requests for information; of these 45 per cent were from industry, 35 per cent from governments, with the remainder from researchers and students in universities and the Canadian public at large.

In the course of responding to these inquiries, and in fulfilling publications exchange obligations, some 16 000 separate publications were mailed out to addressees throughout Canada and in many other countries in the world.

DOCUMENTATION OF TECHNICAL LITERATURE

Indexing and abstracting of mining, mineral processing, and coal technology literature continued at a brisk pace. A total of 6000 new items were added to the five databases produced by CANMET — COAL, COALPRO, MINTEC, MINPROC, and CANPUB. The first four are publicly accessible through the CAN/OLE network or through QL Systems. Public use of these databases during 1985-86 exceeded 11 000 searches.

PUBLICATIONS PRODUCTION

A total of 505 reports prepared by CANMET staff have been produced and printed through the centralized production unit, including over 100 scientific papers that were published in professional journals around the world. Reports published in both English and French numbered 23; the total number of pages translated into one or other of Canada's official languages exceeded 4300.

For further details about the information products and services available from CANMET, or about the work of CANMET's operating divisions, please contact:

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APPENDIX A

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CANMET PROFESSIONAL STAFF

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K. Tait; B.Sc., M.Sc. (London) (Interchange Canada); Res. Sci.

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*Retired effective Oct. 1, 1986.
**Appointed effective Feb. 1, 1986.

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Ores and Fire Assay

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D.L. Curley; B.Sc. (Carleton); Chemist

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Mineral Processing Laboratory

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Metallic Minerals

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J.M. Lamothe; B.Eng. (École Polytechnique Montreal); Res. Eng.

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Carbonization

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Process Control and Computer Applications

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Coal Preparation (Pilot Plant)

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I.S. Parsons; B.Sc. (Western Ontario); Phys. Sci.

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Engineering and Field Demonstration

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APPENDIX B

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CANMET REPRESENTATION ON TECHNICAL COMMITTEES 1985-1986

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Subcommittee 31A (member)	G. Lobay (MRL)
Subcommittee 31 (member)	K.J. Mintz (MRL)
CO-OPERATIVE AGREEMENT ON COAL SLURRY PIPELINE WITH WEST GERMANY	
(coordinator)	T.D. Brown (CRL)
(project leader/contact)	M.W. Mikhail (CRL)
EIGHTH INTERNATIONAL STRATA CONTROL CONFERENCE ORGANIZING COMMITTEE	
(Canadian representative)	D.B. Stewart (CRL)
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INSTITUTION OF MINING AND METALLURGY (U.K.)	
Mining Industry Editorial Advisory Board	R.K. Singhal (CRL)
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(member)	J.J.M. Too (PMRL)
INTERNATIONAL COMMITTEE ON APPLIED MINERALOGY IN THE MINERAL INDUSTRY	
(Canadian representative)	W. Petruk (MSL)
(liaison representative)	W. Petruk (MSL)

AFFILIATION KEY:

DGO	Director General's Office	CRL	Coal Research Laboratories
ERL	Energy Research Laboratories	RPO	Research Program Office
MRL	Mining Research Laboratories	TID	Technology Information Division
MSL	Mineral Sciences Laboratories	NUTPO	National Uranium Tailings Program Office
PMRL	Physical Metallurgy Research Laboratories	OTT	Office of Technology Transfer

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Petrography of Organic Sediments (member)	B.N. Nandi (ERL)
Subcommittee on Industrial Application of Coal Petrography (member)	B.N. Nandi (ERL)
INTERNATIONAL COMMITTEE ON COAL RESEARCH (member)	D.A. Reeve (ERL)
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Organizing Committee (chairman)	J.D. Boyd (PMRL)
INTERNATIONAL CONFERENCE ON SOLUTE DEFECT INTERACTIONS: THEORY AND EXPERIMENT	
Organizing Committee (member)	J.D. Boyd (PMRL)
INTERNATIONAL CONFERENCE ON THE STRENGTH OF METALS AND ALLOYS (ICSMA-7)	
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INTERNATIONAL JOURNAL OF MINE WATER
- Canadian editor ..... T.R.C. Aston (CRL)

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Committee on Wood-Fired Appliances (member)	R.W. Braaten (ERL)
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Subcommittee on CSA Standard C.22.2, No. 174: Cables to be Used in Hazardous Locations (member)	G. Lobay (MRL)
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(As of March 31, 1986/au 31 mars 1986)

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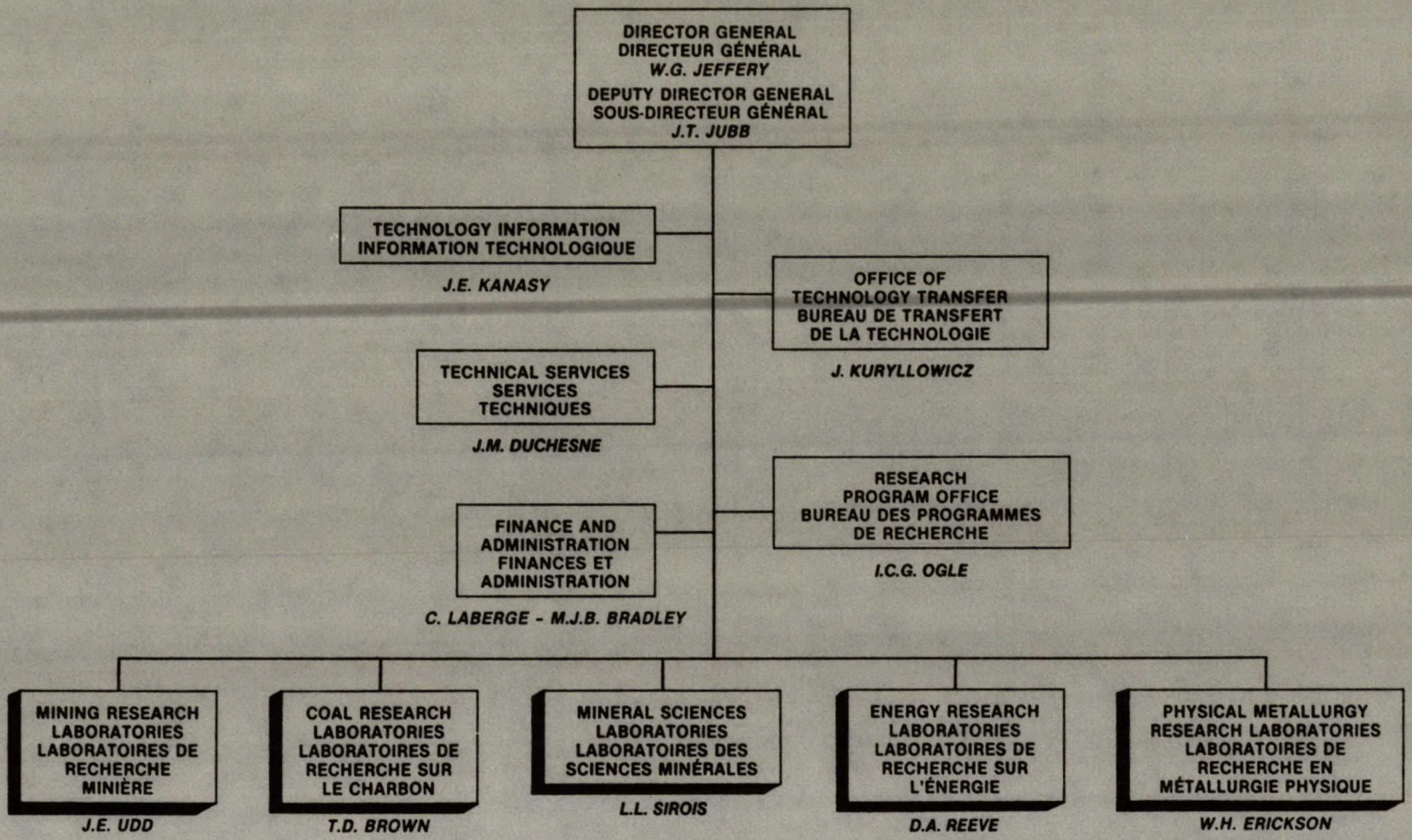
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PARTIAL LIST OF CONTACTS WITH CANADIAN CORPORATIONS AND INTERNATIONAL ORGANIZATIONS DURING FISCAL YEAR 1985-1986

LISTE PARTIELLE DES CONTACTS AVEC LES SOCIÉTÉS CANADIENNES ET ORGANISMES INTERNATIONAUX AU COURS DE L'ANNÉE FINANCIÈRE 1985-1986

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ACAOZ Inc., Montréal, Québec
Alberta Energy Company, Calgary, Alberta
Alberta Rockwool Corp., Calgary, Alberta
Alcan Canada, Kingston, Ontario
Alchem, Hinton, Alberta
AGRA Industries, Saskatchewan
Algoma Steel Corp., Sault Ste. Marie, Ontario
Alkaril Chemicals Ltd., Mississauga, Ontario
Alloy Foundry, Merrickville, Ontario
AMCA International, Montréal, Québec; Ottawa, Ontario
Ancast, Winnipeg, Manitoba
Archer Cathro Ltd., British Columbia
Asbestos Institute, Montréal, Québec
Associated Foundry, Surrey, British Columbia
Atlantic Analytical Services, New Brunswick
Atlas Steel, Welland, Ontario
Babcock and Wilcox Canada, Cambridge, Ontario
Bailey Hoogovens Canada Inc., Burlington, Ontario
Bayer Canada, Montréal, Québec
Beaumart Ltée., Contrecoeur, Québec
B.C. Hydro
B.C. Research, Vancouver, British Columbia
Belgen Foundry, Drummondville, Québec
Bell Northern Research, Ottawa, Ontario
Bevex Ceramic Tile, Edmonton, Alberta
Blanchard Foundry, Saskatoon, Saskatchewan
Bomen Construction Company, Calgary, Alberta
Bow Valley Industries, Calgary, Alberta
B.P. Canada Inc., Calgary, Alberta
Brampton Brick Co. Ltd., Ontario
Campbell Red Lake Mines Ltd., Balmertown, Ontario
Canada Cement Lafarge, Montréal, Québec
Canadian Arsenals, Montréal, Québec
Canadian Boiler Society, Toronto, Ontario
Canadian Carbonization Research Association, Toronto, Ontario
Canadian Coal Liquefaction Corporation, Alberta
Canadian Electrical Association, Montréal, Québec
Canadian Gas Association, Toronto, Ontario
Canadian Industries Ltd., Montréal, Québec
Canadian Liquid Air Ltd., Montréal, Québec
Canadian Standards Association, Toronto, Ontario
Canadian Stone Marine Ltd., Iberville, Québec
Canertech Inc., Winnipeg, Manitoba
Canron Foundry, Hamilton, Ontario
CANSTAR Oil Sands Ltd., Calgary, Alberta
Canterra Energy Ltd., Calgary, Alberta
Cape Breton Development Corporation, Nova Scotia
Caproco Ltd., Edmonton, Alberta
Cardinal River Coals Ltd., Alberta
Cassiar Mining Corporation, British Columbia
Catco, Montréal, Québec
Central Canada Potash, Colonsay, Saskatchewan
Centre de Recherche Noranda, Pointe-Claire, Québec
CIM, Montréal, Québec
Coastech Ltd., North Vancouver, British Columbia
Combustion Engineering Canada, Ontario
Cominco Ltd., Kimberly, British Columbia
Constable Consulting Inc., Sudbury, Ontario
Consolidated Silver Standard Mines, Vancouver, British Columbia
Crows Nest Resources, Calgary, Alberta
Davie Shipbuilding, Lauzon, Québec
Davis Engineering, Ottawa, Ontario
Daytona Walther Foundry, Guelph, Ontario
Denison Mines, Vancouver, Elliot Lake
Dome Mines Ltd., South Porcupine, Ontario
Dominion Bridge, Ottawa, Ontario, Edmonton, Alberta
Dominion Engineering Works, Montréal, Québec
Domtar Chemicals, Toronto, Ontario
Dow Chemicals, Fort Saskatchewan, Saskatchewan
Durham Resources, New Brunswick
Dynawest Projects Ltd., Calgary, Alberta
Eastern Steel Castings, Hawkesbury, Ontario
Eastview Engineering, Hull, Québec
Eaton-Yale, Chatham, Ontario
Electromec, Québec, Québec
Enterprise Foundry, Sackville, New Brunswick
Envirotech Corporation
ESAB, Sweden, Norway, Montréal, Québec
Esso Resources, Calgary, Alberta
Exeltar Ltd., Bedford, Québec
Falconbridge Ltd., Falconbridge, Ontario
Fenco Engineering, Toronto, Ontario
Fer et Titane du Québec Inc.
Fluor Canada, Calgary, Alberta

Fonderie Antique, Arthabaska, Québec
Fonderie Industriel, La foro, Québec, Québec
Fonderie Poitras, L'Islettville, Québec
Fonderie Romuald, St-Romuald, Québec
Fonderie Saguenay, Chicoutimi, Québec
Fording Coal Ltd.
Foster Wheeler Canada, St. Catherines, Ontario
Fuller Construction Co., Ottawa, Ontario
GAEL Tech Incorporated, Nova Scotia
Gemini Biochemical Research Ltd., Calgary, Alberta
Gemite Ltd., Toronto, Ontario
General Motors, St. Catherines, Ontario
Genstar Cement, Manitoba
Geosearch Ltd., Calgary, Alberta
Global Canatom, Cambridge, Ontario
Global Thermo Electric, Calgary, Alberta
G.T. Page Consulting Ltd., Calgary, Alberta
Gulf Canada Ltd., Mississauga, Ontario; Calgary, Alberta
Haider Mirza Catalyst Services, Point Edward, Ontario
Hamero International, Ottawa, Ontario
Hamilton Foundry, Hamilton, Ontario
Hands Fireworks, Papineauville, Québec
Hardy Associates, Vancouver, British Columbia
Harrison Saturn Joint Venture (SMC) Ltd., Edmonton, Alberta
Hatch Associates, Toronto, Ontario
Hayes Stuart Inc., Montréal, Québec
HDRK Research, Sudbury, Ontario
Heuristic Engineering Incorporated, Vancouver, British Columbia
Highwood Resources, NWT
Holmes Foundry, Sarnia, Ontario
Husky Oil, Calgary, Alberta; Lloydminster, British Columbia
Idea Corporation, Toronto, Ontario
IMP Foundry Ltd., Dartmouth, Nova Scotia
INCO Metals, Toronto, Sudbury, Ontario
Industrial Ceramics, Mississauga, Ontario
Industrial Membrane Research Corporation, Nepean, Ontario
Ingersoll-Rand Canada Ltd., Cambridge, Ontario
Inproheat Ltd., Vancouver, British Columbia
International Harvester, Hamilton, Ontario
Interprovincial Steel and Pipe Corp. Ltd., Regina, Saskatchewan
Iron Ore Company, Newfoundland
J.M. Asbestos, Asbestos, Québec
Key Lake Mining Corporation, Saskatoon, Saskatchewan
Kidd Creek Mines, Toronto, Ontario
Kilborn Engineering, Saskatoon, Saskatchewan
Koba Consultants Inc., Montréal, Québec
Krupp Canada
Krupp-Quakertown, Cambridge, Ontario
Lab-Elite, Montréal, Québec
Lac Minerals, Toronto, Ontario
Les Mines Selbaie, Joutel, Québec
Lethbridge Ironworks, Lethbridge, Alberta
Levelton, B.H. and Associates, Vancouver, British Columbia
Lumonics Inc., Ottawa, Ontario
Luscar Ltd., Edmonton, Alberta
Magdalen Silica, Montréal, Québec
Manalta Coal Ltd., Calgary, Alberta
Maritime Steel Foundry, New Glasgow, Nova Scotia
McIntyre Mines, Calgary, Alberta
McTarr Petroleum, Vancouver, British Columbia
Memteck, Nepean, Ontario
METAB, Montréal, Québec
Metals and Alloys Inc., Toronto, Ontario
Mitel Corp., Kanata, Ontario
Mobil Oil, Halifax, Nova Scotia
Mueller Industries, St-Jérome, Québec
Murphy Oil, Calgary, Alberta
New Brunswick Electric Power Commission
Nickel Development Institute, Toronto, Ontario
Niobec, St-Nonoie, Québec
Nonferrous Alloy Castings Ltd., Mississauga, Ontario
Noranda Inc., Pointe-Claire, Québec; Toronto, Ontario
Noranda Mines Ltd., Murdockville, Québec
Nordco, St. John's, Newfoundland
Northern Reactor Gasification, Calgary, Alberta
Northern Telecom, Montréal, Québec
Norwest Resources Consultants, Calgary, Alberta
Norwood Foundry, Regina, Saskatchewan
Nova Corporation, Halifax, Nova Scotia
Nova Scotia Power Corporation, Halifax, Nova Scotia
Nova Pb Ltd., Montréal, Québec
Nyes Foundry, Vancouver, British Columbia
Obed Mining Company, Hinton, Alberta
OCL Industrial Materials, Vancouver, British Columbia
ODC/OILFAB, St. John's, Newfoundland
Ontario Hydro
Ontario Natural Gas Association
Ontario Research Foundation, Toronto, Ontario
Pacific Enercon, Grandforks, British Columbia
Pentum Company, Springhill, Nova Scotia
Petro-Canada, Montréal, Québec; Toronto, Ontario
Pfizer, Montréal, Québec
Polar Resources Ltd., Calgary, Alberta
Porritts and Spencer Filtration Inc., British Columbia
Potash Corp., Saskatoon, Saskatchewan
Proto Manufacturing, Windsor, Ontario
Pyro Tech., Ontario
Quintette Coal, British Columbia
Rahn Metals, North Bay, Ontario
Ramsey Engineering, Toronto, Ontario
Reiss Lime Company of Canada Ltd., Blind River, Ontario
Renzy Mines
Resorption Canada Ltd., Ottawa, Ontario
Retom Geo-Research & Engineering, Calgary, Alberta
Rio Algoma, Nova Scotia
Robar Industry, Surrey, British Columbia
Rolls Royce Canada Ltd., Montréal, Québec

Sandwell Beak Research Group, Mississauga, Ontario
Saskatchewan Power Corporation, Saskatchewan
Saskoil, Saskatchewan
SDS Drilling, St. John's, Newfoundland
Seabright Resources
Servimet Inc., Tracy, Québec
Shawinigan Integ, Vancouver, British Columbia
Shell Canada, Calgary, Alberta
Sidbec-Dosco, Contrecoeur, Québec
SKW Canada, Montréal, Québec
Smoky River Coal, Alberta
SNC Inc., Montréal, Québec
SOQUEM, Bagotville, Québec
Spar Aerospace, Toronto, Ontario
Stabil Mix, Montréal, Québec
Staketech, Oakville, Ontario
Steel Bros., Manitoba
Stelco Inc., Toronto, Burlington, Ontario
Stone Webster Canada, Toronto, Ontario
Suncor Ltd., Alberta, Sarnia, Ontario
Sydney Steel Corporation (SYSCO), N. Sydney, Nova Scotia
Syncrude, Edmonton, Fort McMurry, Alberta
Tantalum Mining Corporation, Manitoba
Teck Mining Company, Toronto, Ontario
Texaco, Calgary, Alberta
TransAlta Utilities Corporation, Alberta
TransCanada Pipelines, Toronto, Ontario
Transportation Development Centre, Montréal, Québec
Transyt Canada Inc., Toronto, Ontario
UMATAC
Union Carbide, Montréal, Québec; Toronto, Ontario
Union Gas, Chatham, Ontario
Union Oil
Union Screen Plate, Lennoxville, Québec
United Keno Mines, Yukon
Versatile Vickers, Montréal, Québec
Vickers Canada, Montréal, Québec
Victoria Machinins Depot, Victoria, British Columbia
Volcano Inc., St-Hyacinthe, Québec
Wabush Mines, Newfoundland
Wellington Foundry, Wellington, Ontario
Wells Foundry, London, Ontario
West Coast Transmission, Vancouver, British Columbia
Westar Mining Ltd., Sparwood, B.C.
Wotherspoon Foundry, Oakville, Ontario
Zenon Environmental Inc., Burlington, Ontario

INTERNATIONAL ORGANIZATIONS / ORGANISMES INTERNATIONAUX

Air Products and Chemicals, Inc., Allentown, PA., U.S.A.
Amax Coal Co. Ltd., Evansville, Indiana, U.S.A.
American Society for Testing and Materials
Argonne National Laboratory, Illinois
Armco Steel, Ohio
Armor Chemicals, Chicago
Armtec Controls, New Hamshire, U.S.A.
Atlantic Richfield, California, U.S.A.
Austrian Trade Commission, Montréal, Canada
Australian Atomic Energy Commission
Babcock Power, London, England
Battelle Columbus Laboratories, Columbus, Ohio, U.S.A.
Beijing Research Institute of Coal Chemistry, China
Bharat Gold Mines, Gov't of India
Brazilian Potash Mining Company, Brazil
B.R.G.M., Orléans, France
Callaham Mining Corporation, Michigan, U.S.A.
Cement Aids Europe Ltd., U.K.
Century Oils, Ltd., London, U.K.
CETEM, Brazil
Chercher Explosives Research, France
Chamber of Mines, South Africa
Coalition of Northeast Governors, U.S.A.
Coal Mining Research Institute, Essen, West Germany
Commonwealth Scientific and Industrial Research Organization, Australia
Conzinc Mine, Broken Hill, Australia
Core Laboratories, Denver, Colorado, U.S.A.
Corning Glass Works, New York, U.S.A.
CRA Research, Australia
CSIRO, Australia
EBARA Corporation, Tokyo, Japan
Ebon Research Systems, Washington, D.C.
Egyptian Iron and Steel Corporation, Cairo, Egypt
Electric Power Research Inst. Palo Alto, California, U.S.A.
E.Z. Co Ltd., Australia
Eickhoff Corp., Pittsburgh, U.S.A.
Elkraft Power Co., Copenhagen, Denmark
Elkem als, Kristiansand, Norway
Essence et Lubrifiant Français (ELF), France
Federal Institute for Geosciences and Natural Resources, West Germany
Foster Wheeler, U.S.A.
Gaz de France, France
General Monitors Corp., Costa Mesa, California
Hanna Mining Co., Ohio, U.S.A.
Henan Xinmi Coal Mining, People's Republic of China
Hunan Coal Preparation Research Institute, China
IEC Central Office, Geneva, Switzerland
Imperial Smelting Processes (RTZ Metals), U.K.
Indian Bureau of Mines, India
Institute of Gas Technology, Chicago, Illinois
International Atomic Energy Agency, Vienna, Austria

International Energy Agency
ISO Central Secretariat, Geneva, Switzerland
Jamaican Geological Survey, Jamaica
Japanese National Institute for Research in Inorganic Materials, Japan
Japan Iron and Steel (NKK), Kawasaki, Japan
Japan Organo Co. Ltd., Japan
J.H. Fenner & Co. Ltd., Marfleet, Hull, U.K.
Koch Carbon International Ltd., Boston, U.S.A.
Korean Trade Missions
Lurgi, Germany
Michigan Technical University, Lasing, MI. U.S.A.
Mines de Potasse D'Alsace, France
Mining Resources Centre, Minnesota, U.S.A.
Ministry of Coal Industry, People's Republic of China
Ministry of Geology and Mineral Resources, People's Republic of China
Ministry of Nuclear Industry, People's Republic of China
Mobil Oil, U.S.A.
MSHA, Triadelphia, W. Virginia, U.S.A.
National Research Institute for Pollution Resources, Japan
Nippon Steel Corporation, Japan
Oklahoma University, Oklahoma, U.S.A.
Penn State University, Pack, PA. U.S.A.
Proctor and Gamble Company, Ohio, U.S.A.
Rand Mines, South Africa
Reliance Electric Ltd., Cleveland, Ohio, U.S.A.
Rockwell Corporation, Los Angeles, California
Scandura, U.S.A.
Science and Technology Commission of Shanvi Province, People's Republic of China
Selco, London, U.K.
SKW Trolberg, Germany
Southern Research Institute, Birmingham, Alabama
Standard Laboratories, West Virginia
Steven Winter Associates, New York
Sun Oil Company, Philadelphia
Tara Mines Ltd., Knockumber, Ireland
Tata Iron and Steel Company, India
Technical Research Centre, Finland
Tokyo Gas Co., Tokyo
UNIDO, United Nations
Union Carbide, Zimbabwe
U.S. Army Corps of Engineers
U.S. Bureau of Mines, Pittsburgh, U.S.A.
U.S. Department of Energy
U.S. Environmental Protection Agency
U.S. Mine Safety Health Administration
U.S. National Energy Laboratories
Wajax Ltd., U.K.
Warren Spring Laboratory, U.K.
Westfalia, Lunen, West Germany
Woodlawn Mines, Australia
Wyoming Analytical Laboratories, Denver, Colorado
ZN Inc., Sharon, Connecticut

DISTRIBUTION OF RESOURCES

1985-1986

	CAPITAL FUNDS $ 000	OPERATING FUNDS $ 000	PERSON YEARS
MINERAL AND ENERGY TECHNOLOGY			
Mining	3 669	5 432	70
Coal Mining and Preparation	894	5 613	62
Mineral Processing	922	14 837	168
Fuels Technology	3 126	18 387	185
Metals and Materials	703	9 886	145
Technology Information	49	2 971	46
Technical Services	58	3 133	68
Management and Support (Branch HQ Only)	149	3 647	40
ADMINISTRATION OF THE CANADA EXPLOSIVES ACT			
Explosives Testing and Research	55	807	12
TOTAL	9 625	64 713	796

DISTRIBUTION DES RESSOURCES

1985-1986

	FONDS D'IMMOBILISATION 000 $	FONDS D'EXPLOITATION 000 $	ANNÉES-PERSONNES
TECHNOLOGIE DES MINÉRAUX ET DE L'ÉNERGIE			
Exploitation minière	3 669	5 432	70
Exploitation et préparation du charbon	894	5 613	62
Traitement des minéraux	922	14 837	168
Technologie des combustibles	3 126	18 387	185
Métaux et matériaux	703	9 886	145
Information technologique	49	2 971	46
Services techniques	58	3 133	68
Gestion et soutien (Administration centrale de la Direction seulement)	149	3 647	40
APPLICATION DE LA LOI CANADIENNE SUR LES EXPLOSIFS			
Mise à l'essai et recherche en matière d'explosifs	55	807	12
TOTAL	9 625	64 713	796