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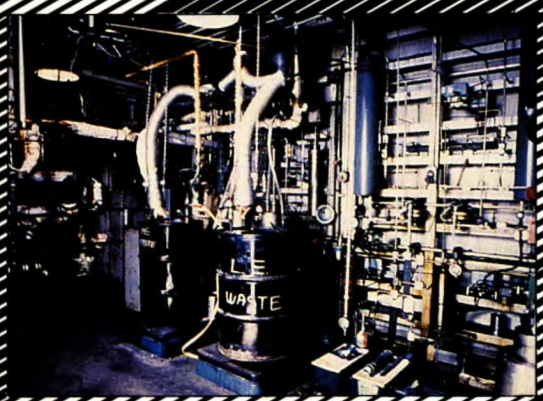
CANMET

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

CANMET REVIEW

1986-1987



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CANMET REVIEW 1986-1987

CANMET REPORT 87-8

Canada Centre for Mineral and Energy Technology
Energy, Mines and Resources Canada

Published under the authority of the
Minister of Energy, Mines and Resources

Cat. No. M38-13/87-8
ISBN 0-662-55930-4

FOREWORD

Economic growth within the minerals and energy sector continued to suffer from low mineral commodity prices, a further drop in international oil price, and contractual pressures to reduce both volumes and prices of coal sales. Offsetting these impacts, however, has been a substantial advance within both sectors towards decreasing operating or production costs.

Consistent with newly established federal Science and Technology policy, CANMET declared its intent during 1986-1987 to become a Government Technology Centre. As part of this strategic change towards increasing the relevance of CANMET's technology development activities to industrial client needs, the industrial advisory process has been strengthened. The newly created Minister's National Advisory Council to CANMET (MNACC) now includes within its mandate, advice on CANMET's business development objectives.

CANMET has continued its focus on consultation 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. A highlight was the presentation of the Canada Awards for Excellence 1986 Silver Award for Technology Transfer, to Almax Industries (1980) Ltd. and to CANMET and Queen's University. The award was for the successful development and well-managed transfer of technology used to manufacture efficiently high performance ceramics. After two years of successful foundry site visitations by CANMET's Mobile Foundry Laboratory, its continued operation was transferred to the Association of Provincial Research Organizations.

CANMET also initiated several major cooperative projects with governments and industry. Notable amongst these are the Reactive Acid Tailings program which is conducted jointly by CANMET and industry, and a joint project with the Alberta Oil Sands Technology and Research Authority and industry to study the viability of a novel method of recovering bitumen from the Athabaska reservoir by a shaft and tunnel access process using horizontal wells and gravity drainage.

Provision of technology support continued throughout the year for major demonstration projects. A significant emphasis was directed towards technologies including novel burners and advanced combustion systems designed to reduce the emission of acid rain precursors during thermal power generation.

CANMET also continued its role of administering the federal mineral technology components of the Federal-Provincial Mineral Development Sub-Agreements.

Federal-Provincial Mineral Development Sub-Agreements

Province	Resources Assigned ($000)	Expenditures ($000)		
		1984-85	1985-86	1986-87
Newfoundland	1,500	0	236.9	365.5
Nova Scotia	3,275	309	464.2	872.3
New Brunswick	3,000	215	341.2	580.0
Ontario	3,550	—	307.5	1,172.0
Manitoba	4,665	152	1,179.3	1,231.3
Saskatchewan	515	0	39	174.1

Under the guidance of MNACC and through both the in-house and contracted-out technology development and transfer activities, 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.

M.D. Everell
Assistant Deputy Minister
Mineral and Energy Technology

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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.***

The formation of CANMET as the Mines Branch in 1907 supported the part that the Federal Government played and continues to play: to complement the roles of industry, the provinces, the universities, and other sectors in the industrial, economic and regional development of Canada.

CANMET's R&D is divided among technologies for mining and processing of minerals, coal, and oil sands, and their utilization. Through these activities 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 latter's economic performance and productivity.

To fulfill these goals, CANMET's total resources of $73 million and 785 person years are distributed approximately 5-10 per cent to policy, 40-45 per cent to protection, and 50 per cent to productivity related programs. Important input and guidance on project selection and implementation is provided by industry and by advisory and user groups.

The transfer of technology to industry forms an integral part of all CANMET activities. To aid in the transfer of this technology, CANMET collaborates with industry in many ways, including dedicating nearly one-third of its budget to contracted work. CANMET also provides services to industry. Remuneration for these services, which are usually based on special expertise and equipment, is currently about $1.3 million per year.

ORGANIZATION

CANMET carries out its mandate with a staff of 785 employees, organized into five operational laboratories, the latter 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, preparation, transportation and carbonization at their regional facilities 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 and corrosion, and with the fabrication of metals and alloys.

The **Research Program Office** coordinates the planning, monitoring and evaluation of CANMET's research programs, administers the contracted-out activities, manages the Branch Management Information System, and provides the Secretariat for the Minister's National Advisory Council to CANMET.

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:

ADMINISTRATION OF THE CANADA EXPLOSIVES ACT

CANMET maintains Canada's national facility to confirm the safety and characteristics of all explosives submitted for authorization under the *Canada Explosives Act*. Responsibilities continue to increase because of technical advances in formulation and manufacture, heightened concern about the safety of transportation and storage of high-hazard fireworks and propellants, and added international responsibilities.

Dr. K.K. Feng (Research Scientist) operating the accelerating rate calorimeter, which is used for testing the thermal stability of explosives

Don Cox (technologist) tests a high explosive on a BAM friction machine

During 1986-87, CANMET examined 445 explosives for authorization under the Act and continued to explore factors that cause ammonium nitrate to detonate. The Canadian Explosives Research Laboratory continued its investigation into the thermal properties of explosives, in particular into the properties of trinitrotoluene (TNT). Several equations of state were evaluated to assess their impact on predicting detonation properties and fume compositions of a large variety of slurry and emulsion explosives. The contract on the propagation sensitivity of commercial explosives in 15 cm boreholes was completed and the initiating system, probably the detonator rather than the explosive or the primer, was identified as the cause of most cross-deck propagations in decked blasting. This is an important finding since premature detonation and misfiring cause safety problems as well as poor fragmentation, overbreakage, underbreakage, vibration damage, and bad muckpile position. These factors significantly increase drilling and blasting costs which, even under ideal circumstances, are a major factor in the cost of mining.

MINERAL AND ENERGY TECHNOLOGY

MINING

Historically, Canada has enjoyed her status as one of the world's foremost producers of metals and mineral concentrates while new discoveries of profitable grade abounded. But the depression in markets in the 1980's made it difficult for mining companies to remain competitive. As limits to measures such as staff-reductions and corporate cost-cutting were attained, the mining industry awoke to the need for greater effort in, and concern for, research and technology to ensure its own survival.

CANMET's Mining Research Program emphasizes projects designed to assist the Canadian mining industry in improving its methods. In addition, other projects address the measurement and control of health and safety hazards in mines and provide policy support. CANMET has developed and maintains a national information bank on current and developing mining technology in the Canadian mining industry and related organizations. Technology transfer is facilitated by close contacts maintained with the mining industry. The third annual edition of the *Index of Mining Technology Development* is now being produced. It has been very well received by the mining industry and is in great demand.

Mining Methods and Equipment

To assist the mining industry in increasing the efficiency of rock-breaking, loading and transportation operations, CANMET reviews, evaluates and promotes innovative concepts and developments in mining methods and equipment.

Advances in safety and productivity often result from improvements in mining equipment. During the year under review, a contractor studied the technical feasibility of drilling or breaking hard rock using a cavitating hydro impactor. The contractor's investigation resulted in the development of a new shock-resistant, high-pressure water seal. The development of accessories critical to the automation of down-the-hole drills has been successfully completed. The accessories, which were installed on a Continuous Mining System's CD-90 drill, were field tested at a research mine and will be commercialized by the contractor. All of these developments, if and when commercially implemented, will improve the efficiency and reduce the cost of drilling.

New concepts for material handling systems which improve productivity and safety are being developed for use in underground and open pit mines. Increased use of mathematical modeling and computer control can lead to optimal use of mine equipment. Successful automation and robotization of haulage trucks in large open pit mines could result in yearly savings of $150,000 to $200,000 per unit.

The current recovery rate for potash is 40 per cent and, although profitable, this represents a significant loss of resources as well as profits. Progress was made in an ongoing review of underground potash mining methods. The review was designed to lower mining costs and to achieve greater predictability of water inflow in Saskatchewan potash formations. Satisfactory progress was reported in efforts to establish the level of wall and roof support derived from backfilling.

A manual entitled *Estimating Preproduction and Operating Costs of Small Underground Deposits* was produced under contract. It was developed specifically for junior mining companies, prospectors, and independent entrepreneurs with limited financial resources. The manual enables the users to benefit indirectly from the knowledge and experience of a large consulting group when carrying out preliminary assessments of the economic viability of exploiting promising orebodies. CANMET intends to issue a series of such manuals and booklets as a companion to the *Pit Slope Manual*. The reception of the first volume on estimating preproduction costs has been excellent.

Rock Mechanics

A primary concern of rock mechanics research is ground control in mines. Investigations deal with the problems of mining in highly stressed ground, or of mining the large excavations which are needed for more economic excavation. Based on a novel concept, the development of a support design and evaluation system has been completed. The method allows the use of design drafts to determine effective and economic support systems in specific rock mass conditions. This technique will improve both the efficiency and the cost effectiveness of mine support systems.

Since 1982, rockburst activity has increased dramatically in Ontario mines. To address this concern, a tripartite research project funded equally by the federal and Ontario governments and the Ontario mining industry, was initiated. In 1986, a major emphasis of CANMET's rockburst research was on the design and installation of new seismic networks around rockburst-prone mines. Basic research centered on techniques to accurately locate the source of seismic events. CANMET's development of microseismic and macroseismic monitoring systems is associated with the $4.2 million Canada/Ontario/Industry Rockburst project, undertaken to help reduce fatalities, accidents, and damage to equipment in underground mines. Instrumentation and techniques to identify potential rockburst zones, and to locate and monitor existing ones, were developed. Technical information thus gathered will promote the understanding of this natural phenomenon. Another system developed by CANMET accurately monitors stress changes which occur in rock structures adjacent to stopes and headings which are being mined. Accurate monitoring of these changes will not only increase worker safety, but will also improve productivity and reduce operating costs because it leads to better stope and pillar recovery operations.

Specific mine structures, such as surface crown pillars, have special stability and support requirements. A specific surface crown pillar characterization system is needed which would provide an understanding of how the rock mass interacts with support systems such as backfill. Progress has been made towards developing a technology for rock mass characterization and the development of deterministic models to analyze the standard stability of surface crown pillars. Special surface crown pillar cases (laminated rock, intensively weathered rock) are being studied which, when combined with 24 completed case studies of Canadian surface crown pillars located in Manitoba, Ontario, Quebec and New Brunswick, will provide a cross-section of rock mass settings and characteristics.

Disposal of spent fuel rods will become a critical aspect of nuclear electricity generation. EMR's program is an integral part of the larger Atomic Energy of Canada Limited (AECL)-directed Canadian Nucleur Fuel Waste Management Program to find safe and effective methods of disposing of high level nuclear wastes. During the year under review, evaluation of the Barton-Bandis Joint Model continued with studies to investigate form testing scale effects on rock joint shear strength. Results of

index testing and characterization studies will eventually assist in relating laboratory-scale rock joint behavior to in situ rock mass conditions. Data on mechanical and thermomechanical rock properties determined for three areas were summarized and statistically analyzed.

Rand Jackson and Ah-Soo Wong (Physical Scientists) conduct stiff triaxial tests on a 300 000 lb. load frame and confining pressure panel

Towards the end of a mine's life when the workings become extensive, local instability can propagate into regional instability affecting the whole mine or a very large section of it. Multiple rockbursts and/or caving may result. The stability of the hanging wall above the rockburst area at the Quirke Mine at Elliot Lake, Ontario, was evaluated, and field stress measurements were taken at the Niobec Mine in Quebec and at the Campbell Red Lake Mine in Ontario, while pillar stress measurements were taken at the Denison Mine at Elliot Lake.

CANMET designs and develops instruments to meet some of industry's more pressing geotechnical needs. A small, side-looking borehole TV camera has been upgraded, making it suitable for use in the most harsh underground mine environments. After upgrading, the camera has seen repeated use in wet and brine-filled boreholes. It has proven to be an extremely reliable instrument in these operations. Six prototypes of a newly-developed vibrating wire strain-monitoring unit have been used to determine ground reaction during drift development in an operating mine.

Under the umbrella of Federal-Provincial Mineral Development Sub-Agreements, CANMET supports research to increase mine efficiency and productivity while maintaining or improving safety in the industry. The Ontario MDA focusses on increasing knowledge of fill and filling systems, new stoping methods for deep mines, and improved computer software for use in small mines. During the year under review:

- A contract to develop computer program specifications was completed.
- Investigations of the performance of dewatered tailings and the liquefaction potential of backfill continued.
- The effectiveness of consolidated fill in controlling violent pillar failure was studied.

The Manitoba MDA concentrates on rock mechanics research of particular concern to mines in northern Manitoba. During the year under review:

- Action was taken to procure a full-scale mine and shaft communuication system following a review of both voice and data transmission systems for isolated areas in mines.
- A review of cut-and-fill mining practices in Manitoba was completed.
- Avalanche control skills/projectiles which could be applied to hang up removal in ore passes were developed and tested.
- The data retrieval system for the geotechnical data base proved satisfactory.
- Geotechnical monitoring of test stopes in en echelon lensed ore bodies continued.
- After a review of available technology for its suitability to use in blast decisions for large open stope mining was completed, two test stopes were selected for field studies.

Mineral Reserves Assessment

CANMET produces a yearly report on Canada's economically mineable uranium reserves and inferred resources. Ore reserves of specified mineral deposits are

determined and new evaluation methods developed to improve assessment of mineral resources and related economic benefits.

Mine Environment

Dust affects both the comfort and the long-term health of workers in all mining operations. The origin, composition and size distribution of respirable dust are some of the factors which must be known in order to develop effective control measures and to guide and interpret epidemiological and medical studies. Blasting, crushing, and rockhandling were found to be major dust sources. Installing a wet scrubber in a crusher/conveyor belt area in an underground uranium mine effected a substantial difference in size distribution and a dramatic reduction in long-lived radioactive dust. Data obtained from a ventilation/radiation study in a bacterial leaching stope will be used to improve stope operating conditions. New instruments, developed to continuously monitor radon and thoron gas and their decay products, performed satisfactorily.

Equipment Safety Certification

CANMET is charged with providing a national service to certify equipment and materials suitable for use in Canadian underground mines, though mainly for use in coal mines where the presence of methane gas and coal dust presents a constant danger of explosion.

During the fiscal year, a total of 55 new certificates were issued for equipment and materials for use in underground mines. In addition, a total of 92 test series were performed for the Canadian Standards Association and 17 private companies. The tests were mainly tests of equipment for use in explosive atmospheres with some gas detection testing.

Oxygen index apparatus used in testing the flammability of conveyor belts

In the field of standards writing for which CANMET provides much of the input and the research and development, a new draft of the *Flameproof Diesel Code* was produced, a new edition of the Canadian Standards Association (CSA) standard for explosion-proof electrical enclosures was published, extensive revisions to the standard for hydraulic fluids were made, and the new CSA standard for flame-tested conveyor belting for underground mines was approved for publication. In addition, several other key standards were revised to reflect new technology.

Explosive Atmospheres

CANMET participates in a Dust Explosion Control Program involving the mining industries of both Canada and the United States. The explosibility of two materials has been determined and an explosion investigation into the causes and prevention of ferro-silicon system hydrogen gas-initiated explosions completed. The diesel emissions program is well into the technology transfer phase. A cross-Canada "fingerprinting" of all underground diesel vehicles was completed. This fingerprinting will assist industry in choosing the appropriate filter option. Results from mines which have begun implementing this technology show that industry will realize substantial benefits from this project. In terms of health

Ken Judge (technologist) works on the Hartman apparatus

and safety a 100 per cent improvement in air quality is possible in underground mines; in terms of operating costs, a 50 per cent reduction in ventilation requirements is possible. However, most operators will probably opt for a mix to achieve a more widespread benefit.

COAL AND OIL SANDS MINING AND PREPARATION

CANMET is Canada's leading agency for fossil fuel research, development, demonstration and transfer of new technology to industry. Research at CANMET is carried out in response to or in anticipation of industry's needs and problems. Close links with industry are therefore both beneficial and essential. In this regard the Minister's National Advisory Council to CANMET (MNACC) plays an important role in CANMET's programs. The Council is a representative body formed by Order-in-Council to advise the Minister, EMR Canada, to whom it provides a national perspective on R&D needs. Council recommendations are taken into account when formulating both short- and long-term plans.

Although Canadian coal production levels remain high, the export arms of the industry are operating in a fiercely competitive international market where Canada is not the low cost producer. Thus the continuing development and demonstration of new technologies for mining coal and preparing it for the customer are becoming increasingly important to the industry.

CANMET is developing technology to assist the Canadian mining industry in improving its methods and in measuring and controlling health and safety hazards associated with mines. CANMET's annual publication of *Current Coal Research Development and Demonstration Projects in Canada* provides an index of current and recently completed projects and promotes technology transfer by making industry members aware of what others are doing.

Coal Reserves Assessment

Within EMR, the Institute of Sedimentary and Petroleum Geology (ISPG) of the Geological Survey of Canada has responsibility for coal resource assessment while CANMET is responsible for coal reserves, including commercial coal quality. ISPG and CANMET will collaborate on creating and maintaining a coal quality data file which will contain information on both resource quality and reserve/production coal quality. Supplement No. 6 of CANMET's *Analysis Directory of Canadian Commercial Coal*, which presents coal quality data based on a national sampling progam conducted in 1984, was released. For the first time, this report series included the trace elements fluorine and chlorine. Contractors are assessing current techniques to determine in situ coal density – a critical factor in establishing tonnages of coal reserves and resources.

Coal samples were analyzed for the Nova Scotia Department of Mines and Energy as part of the Joint Federal-Provincial Resource Development Agreement.

Underground Coal Mining

CANMET is dedicated to improving occupational health and safety, and to encouraging, by selective application, more productive mining methods in Canada's underground coal mining industry.

If coal is to be extracted safely without loss of productivity, gateroads must be supported. Under an EMR-IRAP grant, a contractor has completed the analysis of an extensive gateroad deformation database collected in the Sydney Coalfield. Another contract has resulted in a gateroad support system which is lighter and much easier to handle than the heavy H-section steel arches currently used. The research contract demonstrated that grout-filled steel tubes could provide a bending resistance equivalent to normal arch steel with a 37 per cent reduction in weight. The monolithic packing system installed by Cape Breton Development Corporation (CBDC) provides more effective gateroad support than conventional systems but is more expensive. Both CBDC and CANMET are investigating the use of materials indigenous to Nova Scotia as substitutes for the most expensive components of this system. One such substance being investigated is a fly ash/cement mix. When coupled with an underground mixing system and a fully mechanized packing system, considerable cost savings and improved efficiency should ensue.

Knowledge of the stability of the surrounding strata is imperative if both productivity and a safe working environment are to be maintained during excavation. A geotechnical program was initiated by CANMET to monitor strata behaviour in the vicinity of the tunnel-boring machine during drivage of Tunnel No. 3 to the Harbour seam and during the development of a 'bearing' crosscut to Tunnel No. 2 in the Sydney Coalfield.

The applicability of existing undersea subsidence guidelines to the Sydney Coalfield is uncertain since they were derived primarily from European land truthed data which have been extrapolated to undersea conditions rather than derived empirically from seabed truthed data. CANMET has therefore initiated a long-term program to measure actual seafloor subsidence development, produce effective predictive techniques, and establish safe working guidelines specifically for the Sydney Coalfield.

Investigation of the outburst phenomena experienced at No. 26 Colliery in Cape Breton has continued following closure of that colliery since other CBDC operations are expected to reach similar depths and geological environments within the next five years. A detailed series of in situ stress determinations were undertaken. A preliminary evaluation of minifracturing techniques in an

underground coal mine environment and an assessment of its performance in weak coal measures strata such as coal and mudstone was conducted.

The presence of methane gas and of dust in underground coal mines presents a hazard to the health and safety of workers. To contain the methane emission hazard, adequate quantities of air must be delivered to strategic zones in the mine workings and where necessary these must be supplemented with effective methane drainage. Thus, the ability to predict the volume of methane which will be emitted is a vital element in the ventilation planning process. A comprehensive and critical review of methane prediction techniques practised in a number of major coal producing countries was completed. In a joint research effort with the U.S. Bureau of Mines, methane liberation patterns were identified. During the year, studies were continued of air leakage through the gob. The use of monolithic packing increased the volumes of air reaching the bottom of the faces on the sidewalls and would permit mining to continue for a length of 2500 m of a longwall advancing panel without resort to a cundy. The performances of hollow shaft ventilators were described for three operating shearers at Lingan Colliery. Tracer gas techniques were used to describe the distribution and quantities of air flow around shearer drums produced by hollow shaft ventilators installed in their bases. The improved understanding of both ventilation and methane release contributes to better control of the underground mine environment.

Monitoring and developing measures to control airborne respirable dust levels in underground coal mines will reduce the risk to coal workers of developing pneumoconiosis and pulmonary disorders. Twelve face-time and nine portal-to-portal dust surveys were conducted.

Surface Coal and Oil Sands Mining

Changing markets and demand for coal over the past few years have dictated a redirection in research to improve the economics of surface mining operations and to emphasize thermal rather than metallurgical coal for foreign and domestic markets. During the year under review, six projects cooperatively funded with industry were initiated. External financial participation in these projects totalled $730,000 while CANMET's share was $475,000. CANMET promoted enhancement of existing technology and adaptation and acceptance of new technology by industry through the preparation of concise state-of-the-art reports on mining methods and equipment, organization of and participation in seminars and symposia, and the demonstration of blast casting technology.

The demonstration of blast casting techniques is being carried out as a jointly funded CANMET-industry research project at a surface coal mine in the mountain region of southeast British Columbia. This demonstration has shown a significant reduction in material handling costs. As typical mining conditions where this technique can be applied are identified, other mines in the region are beginning to consider it as an alternative to mechanical excavation.

Considerable effort continues to be directed toward surveying world-wide developments in surface mining production technology. In-house CANMET studies concentrated on optimizing production of loading and hauling units from continuous and discontinuous mining systems. The concept of match factor, that is, matching the load capacity to hauling at all times during the operation, was re-evaluated.

Spontaneous combustion continues to present industry with coal handleability problems since it poses a threat to the safety of workers and increases costs owing to lost productivity. Thus, CANMET is investigating the causes and means of controlling this phenomenon. Considerable progress was made in characterizing western Canadian coals with respect to their susceptibility to spontaneous combustion. Saturating stored coal with carbon dioxide shows promise as a means of reducing its liability to spontaneous combustion. In a study of spontaneous combustion reaction mechanisms, a contractor correlated thermal response with moisture content. In another study jointly funded by CANMET, Transport Canada, and CBDC, it was found that bacterial oxidation of methane to a non-flammable product is possible on a three tonne-scale.

CANMET's industry-oriented applied research program for surface coal and oil sands mining addresses the design, monitoring, and stabilization of geostructures to ensure safe working conditions. During the fiscal year under review:

- Field tests for a finite element computer model based on the stress-property-deformation-relation technique were carried out as a jointly-funded cooperative research project with industry.
- A contractor upgraded CANMET's tiltmeter/radiotelemetry monitoring system to accept slope inclinometers and transmit data over extended distances. The upgraded system is currently being used to monitor movements in the dragline working bench at the Syncrude mine site.
- Geotechnical data collected from the footwall of a mine located in southeastern B.C., was used in a contract study to investigate exploration techniques, monitoring and analytical de-

sign methods, operational constraints, and other factors affecting the stability of steeply dipping footwalls in mountain regions. The critical parameters for stable footwalls were identified and innovative methods of analysis developed, particularly with regard to the analysis of buckling failure of curved slabs.

— All seven coal producers in British Columbia, the B.C. Mining Association, and the Canada-British Columbia Mineral Development Agreement collectively funded an investigation of the stability of "live" waste dumps. This work documents and consolidates the current state-of-the-art of the behaviour of such dumps. CANMET provided the incremental funding necessary for comprehensive data analysis of the complete monitoring records of the "live" dumps maintained by the seven B.C. producers.

Coal industry leaders recognize that new technology and tighter control will be an absolute necessity if the industry is to compete in the world energy market. Computer modelling and simulation are effective methods for improving productivity and reducing costs. A steady state computer model of truck/shovel operation was developed jointly with the National Research Council of Canada and tested using data from eight surface coal mines in western Canada. A contract to validate an event-based model of the bucket wheel excavator-conveyor-bin system was completed. A dragline model to calculate range diagrams and to optimize various dragline methods was tested using data from an operating mine. A joint cooperative project with industry to develop a computer model of the "Easi-miner" resulted in a first version of the model simulating production of the "Easi-Miner" and hauling equipment. A jointly-funded demonstration and evaluation of an integrated truck management system commenced with a western Canadian coal mining company.

The condition of mine haulage roads has a strong influence on the productivity of fleets and hence the operating cost of the mine. Determining the most economical expenditure on haul road construction and maintenance requires detailed knowledge of haul road rolling resistances. An instrumented trailer that can measure rolling resistances when towed by a 3/4 ton truck equipped with an automated data acquisition system has been designed and constructed.

Coal Preparation

As it emerges from the mine, raw coal contains clay, rock, pyrite, and debris in various quantities. Coal preparation removes these impurities or non-combustibles to produce a uniformly high quality fuel. One of the components of these impurities is sulphur, which reacts with oxygen during combustion to form a harmful pollutant. By removing the impurities, coal preparation plants improve the economic and environmental worth of the product and reduce its transportation costs. An industry technology review involving visits to twelve coal preparation plants identified those areas where CANMET could best assist industry.

CANMET's Surface Mining Laboratory's rolling resistance trailer in the field at a western Canadian surface coal mine

The national evaluation of coal preparation process control was complemented by an international evaluation of new developments in the countries which are at the forefront of process control R&D. In off-line process control, work on coal blending provided graphical and numerical techniques to determine the optimum separation cutpoints.

Recent decreases in coal prices have encouraged operators to search for means to improve recovery of fine coal and in turn reduce costs. CANMET evaluated the feasibility of using spirals to improve the recovery of fine coal. Several advantages to using the spiral were indicated. However, the study also showed that, for certain coals, using cyclones or combinations of cyclones and spirals can help achieve the optimum recovery depending on the washability of the fine particles.

Based on the experience gained in evaluating spirals, a project to recover coal from refuse samples from a western Canadian coal preparation plant was carried out. It was found that the addition of spirals could improve the recovery of fine coal and produce refuse with an acceptable ash content.

In conjunction with CANMET's program to characterize Canadian magnetite resources for optimum utilization in coal heavy medium processes, a research contract to determine magnetite losses, magnetite sources, characteristics and costs was completed.

The Canada/Federal Republic of Germany Memorandum of Understanding on coal slurry systems supports four areas of cooperative activities: dense coal slurry systems; coarse coal slurry; short distance pipelining; and design of slurry pipelines.

The success of cooperative multi-disciplinary research in solving practical industry problems has attracted considerable industrial as well as national and international recognition. During the fiscal year, cost recovery activities comprised such areas as oxidation and weathering of stockpiled coal and related effects on flotation/beneficiation/coking properties, low rank coal upgrading, char evaluation, characterization of pitches, oil sands tailings, pond emulsions, demulsifier identification, modification and testing, and characterization of heavy oil natural surfactants.

Coal oxidation impacts on many aspects of both coal benefication and utilization, including froth flotation, coking properties, and coal dustiness. Some techniques used in an ongoing study of coal weathering/oxidation and low rank coal upgrading include scanning electron microscopy, mercury porosimetry, surface area meaurements and gas sorption/desorption ($\triangle P$) studies. The $\triangle P$ instrument developed at CANMET has been commercialized.

CANMET's mobile dewatering plants provide direct assistance to industry and allow researchers to conduct experiments under actual plant operating conditions. The mobile plants were field-tested at one washing plant. Fine adjustments were made to the operation of the belt filter press and the process conditions were optimized. Areas for improvements which would enhance machine operation and reduce chemical consumption were identified. During the year, CANMET's mobile water treatment plant was used at one washery to optimize flocculent application and to improve the performance of the water treatment circuit. The washery has requested CANMET's assistance in full scale plant trials using the flocculent selected during trials with the mobile plant.

Coal Desulphurization

CANMET research efforts directed towards economically upgrading high sulphur coals included: dry magnetic beneficiation, deep cleaning by progressive grinding, flotation, magnetic separation, preconcentration of coarse sizes using novel rare-earth permanent magnetic rolls, selective biodepression of pyrite from coal, and column flotation after ultrafine grinding. The Cape Breton Development Corporation has stated that sulphur removal (pyrite) remains their most serious technical problem. If these technologies can be shown to be effective and economic, pilot plant testing will proceed in cooperation with CBDC.

MINERAL PROCESSING

CANMET carries out in-house investigations and contract studies in support of the needs of the Canadian minerals industry. The program is developed in close consultation with industry and with the provinces through Mineral Development Agreements. The program is implemented in cooperation with industrial R&D performers, private research companies, provincial research organizations, and universities.

Major projects are under way in the processing of metallic ores, and industrial minerals, in the development and testing of improved construction materials, especially concretes, and in the preparation and treatment of ceramic products, both traditional and advanced. These activities are supported by a range of mineralogical investigations, particularly aimed at process design and optimization. CANMET develops new or improved processes to economically extract metals from concentrates and to recover ore values normally lost to the waste stream. The methods used include leaching and other chemical processes.

CANMET also provides a certified reference materials service for commercial analytical quality control, consistency and safety.

Minerals Evaluation

Development of Canadian mineral resources (including various large tonnage, low grade and complex deposits of metallic minerals and known industrial mineral occurrences) requires detailed assessment of mineralogy, valuable element distribution, and probable liberation characteristics. During the year under review:

- A study of the occurrence and recovery of gold in the copper and cobalt-bearing mineralization of the Windy Craggy deposit, northwest British Columbia, was completed.
- Initial batch-scale metallurgical investigations of difficult-to-process ores of the Anvil type indicated resistance to fine grinding and poor recoveries.
- A study of the occurrence and nature of the platinum-group minerals associated with chromite contained in the lower part of the Chromatiferous Zone in the Bird River Sill, southeast Manitoba, was initiated. The platinum-group minerals – sulphides, arsenides, tellurides – occurred mostly as inclusions in the silicate minerals, not in chromite.
- A study of the effect of arsenic substitution in the sulphur site of the jar-

osite crystallographic cell upon silver losses into jarosites continued.

— Detailed mineralogical investigations commenced of selected gold ores.

Beneficiation: Metallic

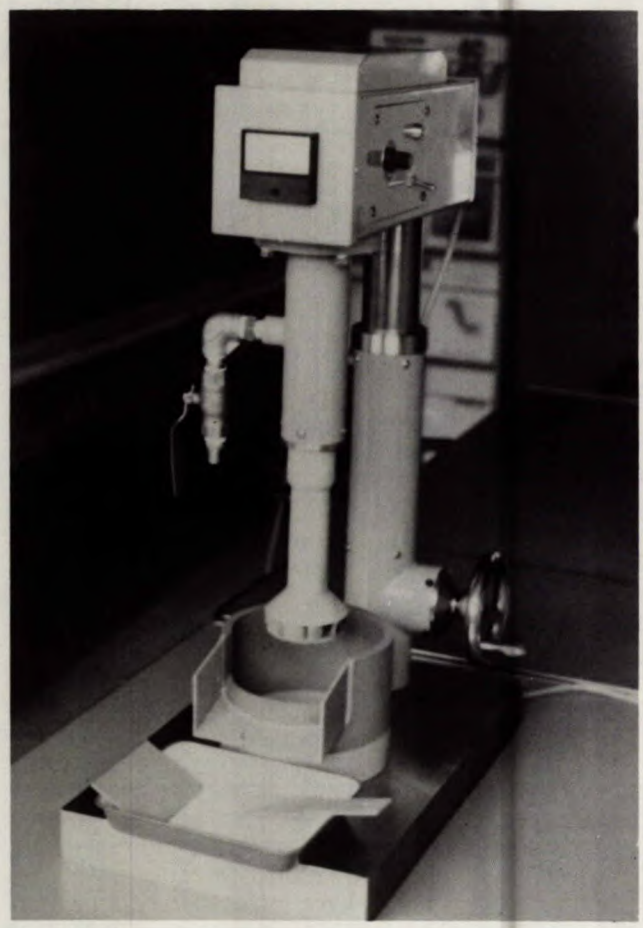
In ore dressing, usage of the Simulated Processing of Ore and Coal (SPOC) family of programs by Canadian industry increased dramatically following conversion of the software to the IBM PC system. The next generation of computer assisted mineral processing methods – expert systems – is now under development. Four projects are under way to develop and implement expert systems in Canadian mineral processing plants.

It has become increasingly apparent that the Canadian iron ore industry must improve efficiency, reduce energy costs and improve quality if it wishes to remain viable and competitive in today's buyer's market. During the year under review, experiments were completed with cold extruded pellets of Carol Lake iron ore concentrate using polymers and calcium carbonate as a plastisizer and binder. Thickener overflow water is used as make-up water in a concentrator, but, particularly during certain periods of the year, is of poor quality, creating problems throughout the circuits. After minerological examination, it was found that addition of ionic flocculants could enhance settling rates significantly and increase the amount of overflow water by up to 30 per cent.

Researchers continued to investigate methods to improve the recovery of fine mineral particles and to develop techniques to enhance tin reclamation from base metal sulphide flotation tailings. Tests were carried out on Kidd Creek, QIT – Fer et Titane Incorporated (QIT), and Rio Algom ores. In investigations to determine the fundamental properties affecting mineral liberation, it was found that the liberation of values from complex base metal ores can be inferred from the pyrite grain size distribution.

Beneficiation: Industrial Minerals

The industrial mineral sector spends more money on energy as a production input than any other industry, nearly four times the average for the manufacturing sector as a whole. In certain industries, such as cement, lime and gypsum, energy costs represent about one-half the production costs. Advances in energy conservation require improved equipment design, process modification, fuel switching, use of less energy intensive materials as supplements and the optimization of energy flows. All these require R&D to optimize processing conditions. CANMET's programs to investigate, at pilot-scale, the effect of grinding aids, use of high efficiency classifiers, various grinding mill/classifier configurations, etc. have indicated a potential 50 per cent reduction in unit energy consumption. The manufacture of



Nagaham flotation cell

cement is especially energy intensive. A project is being designed to evaluate energy savings attainable in a commercial cement plant by incorporating roller mills, high efficiency classifiers and on stream particle size analysis and control. In another program, the substitution of largely waste materials such as fly ash, condensed silica fume and ferrous and non-ferrous slags, for the cement in many concrete applications, is being investigated as a means of reducing costs. The development of perm roll high intensity magnetic separators resulted in spectacular improvement in CANMET's efforts to separate ash and pyrite from coal, clay from potash, and silica from iron ore.

Laboratory studies undertaken in connection with the Canada/Nova Scotia Mineral Development Agreement on samples of barite from Scotsville, Lake Ainslie, Pine Brook and Brookfield, demonstrated good potential for the recovery of mud-grade barite by gravity separation methods coupled, in the case of the Brookfield sample, with wet magnetic separation. Wet processing of asbestos tailings has led to the development of low fines content fibres for plastics and asbestos applications.

Treatment: Ceramics

Throughout the world, interest is growing in the use of ceramic materials for functional and structural applications. Some of the functional applications are in sensors of various kinds, NDT transducers, batteries, ion pumps and fuel cells. Structural applications are based on toughened, wear- and corrosion-resistant, high-temperature and strength ceramics for uses such as ultra-high-temperature gas turbines, internal engine parts, heat exchangers, cutting tools and contact bearings. Characterization of beta/beta" -aluminas prepared containing Li^+ and Mg^{2+} stabilizer and beta/beta" -alumina toughened by zirconia is underway. Development of ultrasonic techniques to lower the detection of fine defects in ceramics continued under contract. For its work in transferring advanced ceramics technology to Canadian industry, CANMET was awarded the 1986 Silver Medal in the Canada Awards for Excellence. CANMET shares the award with Almax Industries and Queen's University for the successful transfer of know-how and expertise related to the composition, preparation, and processing of piezoelectric ceramics for use in thermoelectric generators and sodium-sulphur batteries. A system has been assembled for the electrical characterization of materials as a function of temperature and frequency; another system has been assembled for the dc transient response analysis of electrochemical cells.

Work on semiconductor materials for photoelectrochemical and catalytic processes continued.

The corrosion resistance of direct-, tar-, and resin-bonded and carbon-containing dolomite refractories in contact with slags, showed that all have good corrosion resistance in contact with basic slag at temperatures below 1700°C.

Treatment: Industrial Minerals

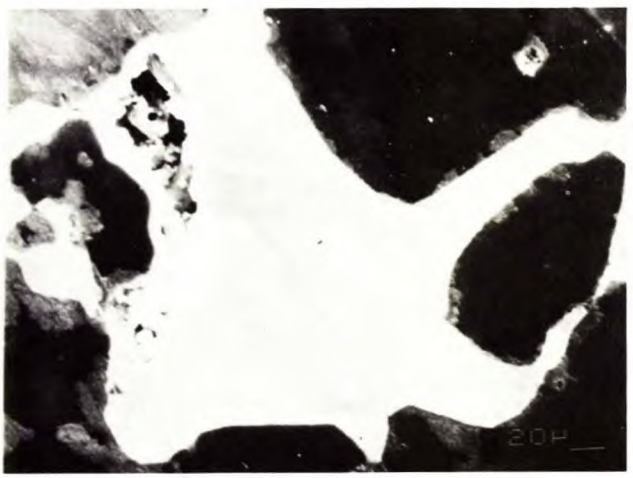
CANMET has produced a superplasticized concrete in which a much higher proportion of the portland cement has been replaced by fly ash than previously thought practicable. This concrete has had more than half its cement replaced by fly ash, yet it exhibits higher strength and higher modulus than control concrete. Another major advantage is that very large sections can be placed without internal cracks owing to thermally induced stresses, since it has a much lower heat of hydration. Replacing the cement with fly ash will help industry utilize a mineral waste product while reducing the cost of concrete by 15 to 20 per cent.

During the lifetime of structures, widespread detoriation results from the reaction of alkali in cements with certain types of silicas present in aggregates. Using a combination of in-house and contract work, CANMET is collecting information on the extent of the problem, identifying certain regional sources of aggregate which exhibit reactivity, and developing the use of supplementary cementing materials to control the above reactions.

The use of ground, granulated blast furnace slag from a northern Ontario plant (using technology developed by and under contract to CANMET) is saving millions of dollars per year as a replacement for cement in mine backfill applications.

Biotechnology

Biotechnology has been identified as one of the emerging technologies. There is ample evidence that biological species interact with mineral systems. The BIOMINET network has been instrumental in improving communications between the many disciplines related to this field. In-house research has been effective in identifying heterotropic bacteria which selectively leach nickel. Work in collaboration with contractors and industrial clients is showing significant advances in biosorption of metals, and biodestruction of hydrocarbons and cyanide. A process to recover selenium from a waste stream is being evaluated for its commercial use in the mining industry. The success at Denison Mines in bioleaching of uranium is being evaluated in terms of secondary recovery of zinc and copper in Manitoba.



The pitting resulting from the microbial oxidation of sphalerite. Mag 20 000X

Extraction: Common Metals

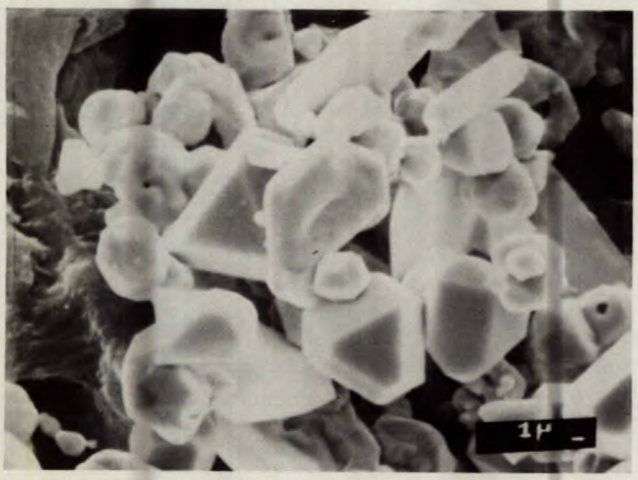
The high level of interest in gold has been reflected in ongoing research. A number of alternative pretreatment and leaching systems have been identified, tested, and compared to the cyanide process. The recovery of gold from solution using a new ion exchange system has yielded encouraging results. Work continued on perfecting the acidification-volatilization-reneutralization (AVR) approach, evaluating reverse osmosis, and assessing

ion exchange techniques as methods to recover cyanide from barren solutions. Activity on gold was extended into separation of platinum group metals.

The search for processes to improve metal recoveries and reduce the environmental impact in sulphide ore treatment has lead to the development of a ferric chloride leach technique. Significant improvements have been made in the cementation and solution purification stages of this process. These flowsheet changes may provide industry with an economical and attractive route to high recoveries from complex sulphide ore deposits.

Plasma technology has the potential, in many instances, to substitute electrical energy for fossil fuel energy. Plasma technology has been developed to the state where applications on an industrial scale are being considered, are planned, or are a reality. To assist in the development of applications, CANMET has accepted the lead agency role within the Federal government. Several shakedown trials have been conducted on a 100 kVA plasma reactor.

Electrochemical research has been instrumental in improving the control and efficiency of electrolytic process plants. A major cooperative study of copper refining has advanced the understanding of processes by the Canadian industry. A comprehensive study of aqueous and fused salt lead electrolysis was completed under contract.



High purity gold crystals

Extraction: Rarer Metals

The Canadian uranium industry is well established and prosperous. However, as new ores are discovered and environmental concerns increase, the limitations of the conventional sulphuric acid leaching process become more evident. CANMET's systematic review of the conventional process identified many areas where new technology could be applied using chloride metallurgy. Spinoff from this work has led to improvements in existing uranium technology and in the recovery of other rare earths, gallium, nickel, gold, and platinum group metals.

Standards and Specifications

Through the Canadian Certified Reference Materials Project (CCRMP), CANMET provides Canadian industry with compositional reference materials that are characteristic of samples at Canadian mining and metallurgical sites. Revenue from the sale of CCRMP products increased approximately 10 per cent last year. Three gold ores, two vegetative materials for radionuclides and a uranium ore were certified and offered for sale. Certification of a uranium concentrate (yellowcake), a copper concentrate, a suite of seven zinc-aluminum alloys, and a rare earth britholite are under way. CCRMP facilities continued to serve as a resource centre for reference material preparation for four projects by industry and other agencies.

Research in and development of analytical methods continued. One example is the application of high-performance liquid chromatography to the determination of rare earths in steels, alloys and advanced materials, and of low molecular weight organic acids and of inorganic anions for the characterization of environmental samples. An analytical manual, *Assay Methods Used in CANMET for the Determination of Precious Metals*, was issued.

Participation continued in international committee work for the International Standards Organization (ISO), the American Society for Testing Materials and the International Atomic Energy Agency. Examples of such participation are:

— ISO/REMCO, Council Committee on Reference Materials;

— ISO/Technical Committee 102 on Iron Ore Standards; and

— ISO/Technical Committee 183 for Standard Methods for the Chemical Analysis of Copper, Lead, and Zinc.

An International Conference on Fly Ash, in Madrid, and an International Workshop on Concrete for Offshore Structures, in St. John's, Newfoundland, were successful.

By-Product Recovery

Canadian zinc ores contain a considerable amount of silver. However, an estimated $13 million in silver is lost annually. CANMET, in cooperation with industry, is studying the mechanisms by which silver is lost and is investigating and evaluating technological changes to improve its recovery.

Most concentrates of copper, nickel, and lead sulphide ores are treated by pyrometallurgical smelting. Many of the concentrates sent for smelting contain minor amounts of valuable metals (for example cobalt, precious metals, molybdenum and zinc, some of which may be lost to the slag). Methods for decreasing such losses or recovering metals from the slag before it is discarded would help conserve Canadian mineral resources. Pyrometallurgical research at CANMET has shown that using a high iron sulphide matte has potential for improving non-ferrous slag cleaning and increasing revenues for Canadian smelters.

Environmental Controls

Increased interest in effective tailings management and abandonment technologies has strengthened the level of cooperation between industry and the research community. Work continued on more fully elucidating the physical, chemical and biological mechanisms in acid drainage production. Cover materials including deep water proved effective in reducing acidic drainage.

Under the Reactive Acid Tailings (RATS) program, hydrogeochemical investigations of highly reactive acid tailings are being conducted at the Waite Amulet tailing site near Noranda, Quebec.

FUELS TECHNOLOGY

Synthetic fuels produced from Canadian low-grade energy resources such as coal, bitumen, heavy oils and refinery residues are gaining increasing importance as world reserves of conventional crude diminish. During 1986-87, CANMET continued its lead role in R&D activities related to the production of synthetic fuels suitable for transportation and residential heating. These in-house activities were complemented by cooperative projects with industry, universities, provincial agencies and the U.S. Department of Energy.

In 1986-87, CANMET's reputation was enhanced as a centre of expertise for the primary and secondary upgrading of Canada's hydrocarbon resources. Research activities focussed on developing improved processes for the production of liquid fuels, particularly technologies showing promise for commercial application in Canada. Primary conversion concentrated on developing catalysts for upgrading bitumen, heavy oil, coal, coal/oil mixtures, natural gas, and their by-products and residues to suitable feedstocks for refinery operations. Secondary upgrading studies involved the design and evaluation of catalysts for the production of specification transportation fuels from both conventional and advanced primary conversion processes. These activities were complemented by shared cost and collaborative research with industry. Also, fundamental studies, carried out in concert with universities, were expedited by the commisioning of several advanced facilities for hydrocarbon processing and catalyst characterization.

Recovery of Bitumen and Heavy Oils

One of the world's largest oil sands deposits, the Athabasca reservoir, constitutes 75 per cent of the oil sands reserves in Alberta. CANMET is contributing to the development of new technologies for bitumen recovery (i.e. extraction from mined oil sands and in situ production) by supporting, under a Canada/United States Memorandum of Understanding, contracts to develop a program to study the use of non-condensible gas additives with steam for recovery of both bitumen and heavy oil. CANMET is also cooperating with the Alberta Oil Sands Technology Research Authority (AOSTRA) and industry in the development and field trials of novel concepts of horizontal well in situ steam recovery technology at the AOSTRA Underground Test Facility in the Fort McMurray area of the Athabasca deposit. This three-year pre-pilot program utilizing horizontal wells should also be of particular relevance to in situ recovery from the thin heavy oil reservoirs of Saskatchewan. Horizontal wells may be the only way to achieve major commercial in situ recovery from the Athabasca deposit or marginal heavy oil reservoirs as only seven per cent of the Athabasca reservoir is potentially amenable to surface mining.

CANMET also contributes to research conducted or subcontracted by the Petroleum Division of Saskatchewan Research Council (SRC). This contribution, via the Management Committee of the Saskatchewan Heavy Oil Fossil Fuel Agreement, includes consultation, scientific and technical advice, evaluation and direction for research conducted or subcontracted by the Petroleum Division of the SRC. CANMET provided similar support to contracts by Saskatchewan Energy and Mines, to industry, to research and to field testing/demonstration programs.

Bitumen/Oil Emulsions, Effluent Waters and Tailings

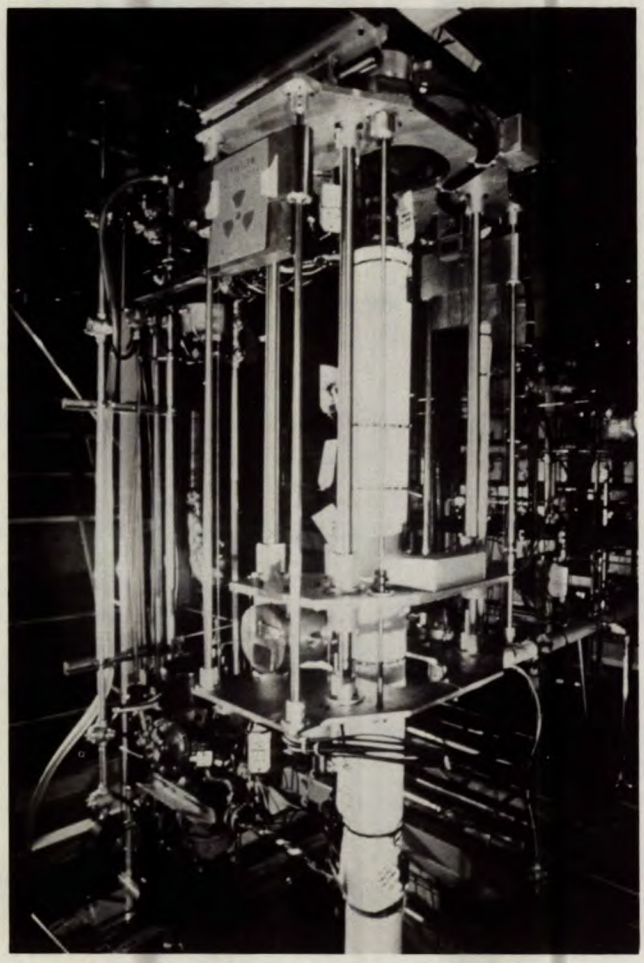
CANMET is prepared to assist in the development of the vast mineable Athabasca oil sands through participation with AOSTRA and industry in advanced technologies to extract and possibly to partially upgrade bitumen from the mined oil sands. Because of the present slump in the world price of oil, negotiations to attract industrial participation in these technologies were not successful. However, CANMET is continuing smaller-scale projects to utilize this technology to extract bitumen from sludges, residues, and oily wastes.

A review of laboratory programs in bitumen/oil emulsion characterization provided opportunities to develop collaborative research programs with industrial enterprises. These programs are continuing through joint laboratory and plant activities in which CANMET staff provide the scientific expertise and company engineers the operational skills and experience. Based on results of an in-house fundamental study, a long outstanding

problem associated with monitoring the quality of bitumen processing streams was resolved. This permits on-line monitoring and drastically reduces the time required for off-line analysis compared to existing practice. Potential benefits include hundreds of thousands of dollars saved in time and cost of sampling and analysis, and improvement in plant operation. The feasibility of using novel techniques to separate water and bitumen emulsions has been proven on laboratory and bench scales. Industry is now planning to test this technology using CANMET's pilot scale facilities. This method has the potential to fundamentally change existing practice and may result in millions of dollars saved in the cost of bitumen processing.

Upgrading Bitumen, Heavy Oils and Residuals

Fundamental research has enhanced CANMET's expertise in slurry hydrocracking. A novel dual-energy densitometer, developed jointly with Atomic Energy of Canada, Limited (AECL), rapidly determines ash levels.



A view of CANMET's hydrocracking pilot plant No. 1 with the travelling gamma densitometer in place

This instrument has considerable potential for commercial application in the petroleum industry. The CANMET Hydrocracking Demonstration Plant in Petro-Canada's Montreal refinery continued operations, achieving high conversions at design throughputs. CANMET supported the demonstration activities by troubleshooting operating problems and monitoring reactor performance. This included advising and assisting Petro-Canada on reactor behaviour, hydrodynamics of multiphase flow, solids microscopy, analysis and sampling. CANMET's advances in simplifying additive preparation, made the process more commercially attractive.

Several significant outputs were achieved in primary processing. The optimal catalyst pore-size diameter was identified for viscosity reduction of bitumen and heavy oil to meet pipeline specifications. A fluidized bed technique employing a microbalance reactor was developed to investigate the catalytic pyrolysis of refractory pitches to produce saleable liquids. Viscosity changes in the hydrocracked product and the relative activities for asphaltene conversion and hydro-desulphurization (HDS) were found to correlate with pore diameters in the 3 to 200 nm range.

Work supported by CANMET will provide a database for designing catalysts which retain their activities over longer periods. The catalysts are used for upgrading bitumen to transportation and other fuels. Work on catalytic hydrocracking of heavy oils in a layered fixed bed will provide experimental evaluation of a new approach to primary upgrading and will add fundamental information on microwave enhancement of catalytic hydrogenation and hydro-desulphurization.

Upgrading of Synthetic Crude Distillates and Utilization of Residues

Advanced primary upgrading processes are expected to increase the supply of synthetic crudes. Industry thus requires improved catalytic processes and separation techniques to produce transportation fuels from these crudes.

A techno-economic feasibility study was initiated of a low-severity process to produce specification fuel from synthetic crude middle distillate, to determine near commercial applications of the technology. Research was expanded to include the production of specification jet fuel from synthetic crude middle distillate. The objective of this aspect of the program is to develop catalysts which will selectively convert fuel components which could pose problems of soot formation in jet turbines. Progress on these studies was substantially augmented by the commissioning of an automated micro-reactor which allows hydroprocessing studies on small quantities of liquids for extensive times on stream and the development of advanced surface spectroscopic capabilities which permit in situ catalyst testing and characterization. New concepts for upgrading synthetic

crudes, such as polymer supports and metal cluster hydrotreating catalysts, were explored.

Work continued in-house and by contract on developing thin film Co-Mo-Al oxides supported on Al metal for use as hydro-desulphurization (HDS) catalysts. The HDS activity of the thin films greatly exceeds commercial catalysts per square metre of surface area. This technology has the potential to produce catalysts with significantly improved activity for removing sulphur from light petroleum feedstocks.

Work continued on the use of a microactivity test unit to experimentally evaluate and predict the performance of synthetic crude gas oils versus conventional gas oils for fluid catalytic cracking operations in Canadian refineries. The data from these experiments will be used to identify and correct problems which may be encountered in refining synthetic gas oils.

Conversion of Natural Gas to Liquid Fuels

During 1986-87, the emphasis of CANMET's natural gas to liquid fuels conversion program was shifted to the investigation of direct conversion routes, which are expected to be more efficient than indirect ones. A review of existing and potential conversion routes is in progress and forms part of a program to evaluate their suitability for Canada. One area with great potential is the conversion of natural gas using plasmas generated with renewable off-peak electricity. This technology could have a substantial economic impact and may be feasible for provinces having hydroelectric power such as Quebec, Manitoba, Newfoundland, and British Columbia. As plasma technologies are ideal for producing petrochemicals from natural gas, the potential for spinoff technologies is high. The primary objective of the research on plasma conversion of natural gas is the production of premium fuels such as high cetane diesel or high octane gasoline.

Other studies are being carried out in-house and under contract on the catalytic conversion of methane to premium fuels. The objective is to develop technologies that could be integrated into existing plants. Blending stocks produced would help the refiner of both conventional and synthetic crudes to meet specifications. These technologies would add flexibility in the plant and would help refiners to remain competitive while using available Canadian resources.

The experimental research programs were complemented by discussions with various private-sector organizations concerning the establishment of cooperative research programs. Negotiations were opened with the Gas Research Institute concerning CANMET's participation in a cofunding agreement involving several international participants. Since the total program value is worth more than $1.25 million per year, CANMET's $50,000 contribution will provide a high leverage ratio.

Negotiations were opened with various Canadian companies to establish a consortium to finance and manage research on the development of natural gas conversion technologies. This consortium would provide leverage to each participant and would bring together developers, financiers and end users of these technologies, thus increasing the chance for commercial success while facilitating technology transfer.

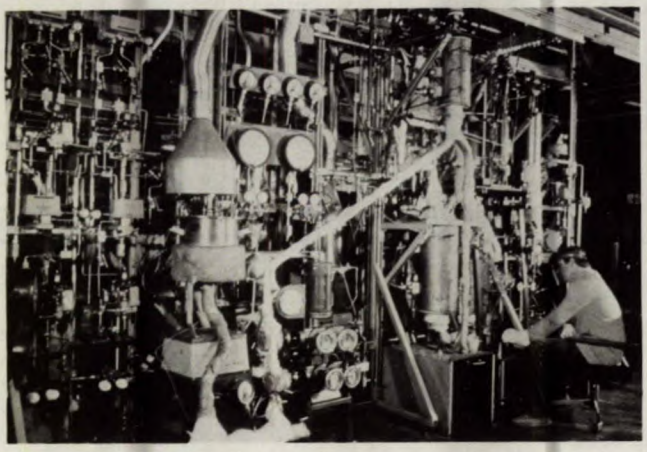
Coprocessing and Coal Conversion

In eastern Canada, the combination of Maritime bituminous coals with conventional crude residues or imported heavy oils offers potential for coprocessing (the simultaneous processing of slurries of coal and vacuum bottoms/heavy oils) applications. In western Canada, the process allows upgrading of low-rank plains coals with indigenous tar sands residues or heavy oils. CANMET has initiated a program to develop a potentially marketable Canadian process. During the year under review:

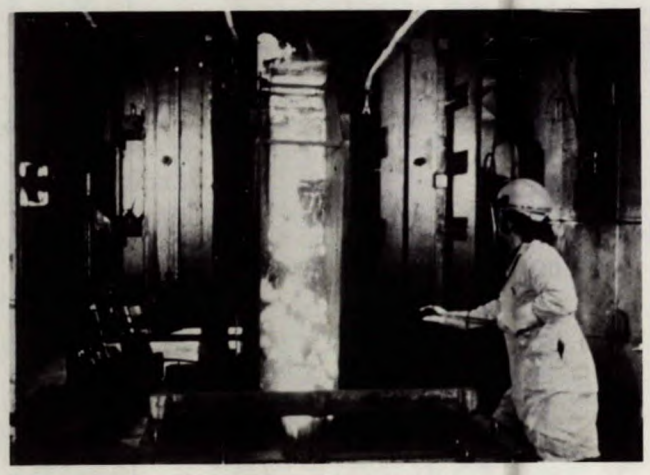
- The performance of eastern Canadian high-volatile bituminous coal when coprocessed with bitumen/heavy oil was examined. The thermo-physical properties of the bituminous coking coals made them more difficult to process than western Canadian subbituminous coals.
- A techno-economic study comparing CANMET hydrocracking with coprocessing showed that coprocessing was always slightly less economical.
- Coprocessing was studied using two different catalysts in a well-mixed reactor. Compared to catalysts supported on alumina, a series of bimetallic catalysts based on hydrous titanates improved oil yield, coal conversion, and hetroatom removal.
- Other factors studied included the effect of solvent/coal combination on process performance and yield, the effect of coal concentration on product distribution, the effect of temperature distribution in a single stage coprocessing reactor, rheology of coprocessing fluids, thermodynamic properties of coprocessing distillates, and the effect of additive level and distribution.

Novel or advanced coal liquefaction approaches are being investigated through fully-funded and shared-cost contracts. Modified direct coal liquefaction technology and advanced pyrolysis processes could reduce synthetic fuel costs and meet future Canadian energy needs. Under the Canada/Japan Science and Tech-

nology Consultation Agreement, a large number of Canadian coals have been tested. The test results for five low-rank coals were presented at a Canada/Japan joint technical meeting in Japan.



CANMET's continuous flow coprocessing unit



Metallurgical coke produced in CANMET's 310-mm-wide pilot scale oven

Gasification

Throughout the world, gasification processes are being considered as candidates for the clean use of coal. CANMET research in this area focusses on evaluation and optimization of technologies which can accommodate low-grade and non-reactive fuels and reduce emissions of deleterious species including acid rain precursors and particulates. In cooperation with industry CANMET has been participating in demonstration trials to evaluate western Canadian low rank coals for power generation via integrated gasification-combined cycle. The removal of acidic components from the gasification products at high temperatures would significantly improve the thermal efficiency of the combined cycle power generation process. Several low cost waste solids from metallurgical and aluminum industries have been successfully tested for their ability to remove acidic components at high temperatures.

Entrained bed gasification reactors are part of the integrated gasification combined-cycle commercial process which produces electricity from coal with very low acidic emissions. The detailed design of a bench scale entrained bed gasification unit has been completed. This system will be used to characterize non-reactive feedstocks under conditions used in the most advanced gasification processes. As part of this project the evaluation continued of gasification reactivities of Canadian coals.

Carbonization

Canadian exports of metallurgical coal depend significantly on CANMET's internationally-recognized test facilities while conventional international test methods for assessing and predicting coking characteristics underestimate the quality of western Canadian coals. These facilities are operated cooperatively with industry through the Canadian Carbonization Research Association. CANMET's facilities are also used to improve the coking quality of lower grade coals, and to formulate blends of Canadian coals, thus extending resources.

Many blast furnace operators are now recognizing the CSR (coke strength after reaction) test results rather than the ambient temperature coke strength tests (e.g. ASTM stability) as the best method for determining coke quality. Tests with cokes having the same ASTM stability show that CSR properties vary considerably. Differences in indices were found to be related mainly to the basic components in the coke ash. High CSR values of most Canadian coals should be advantageous in marketing them.

Results from carbonizing a typical blend from a Canadian steel company at different coking rates and times, indicated that cokes having higher CSR indices were produced by faster coking rates to 9OO°C at the centre of the oven and by extending gross coking times to produce higher temperature coke.

Sampling by means of cages in a coke oven battery indicated that the coal in the bottom of the oven carbonized faster than that at the top, resulting in cokes with higher densities and strength. Sole (bottom) heated oven experiments on coal blends indicated that the apparent specific gravity of coke is primarily a function of the load under which it is produced. Canada's steelmakers have used the results of this study to decrease temperature differences along the height of their coke oven flues to improve coke quality and coking pressures.

Combustion

In Canada and internationally, the use of liquid fuels in utility and industrial processes is declining. CANMET's coal combustion research program reflects the increasing importance of coal in our domestic energy requirements and also supports Canadian coal exporters in their drive to secure a reasonable share of the world market. An industry/government collaborative program has been established in which the utilities and coal suppliers participate, while CANMET's in-house program has been established to increase fundamental knowledge and provide expertise in coal combustion.

Pulverized Coal Combustion

Industry needs reliable data on the combustion characteristics and performance of coals from new deposits or from mines which have been inactive for many years. To address the demand for data on the combustion performance of coals, CANMET initiated a comprehensive collaborative program with industry.

CANMET's conventional coal combustion research encompasses studies of 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.

During 1986-87, twenty-five coal burns were performed in CANMET's pilot-scale utility boiler on behalf of a Canadian coal company, the IEA, and as part of an in-house program. The heat transfer characteristics of coals were investigated using CANMET's tunnel furnace and then compared with fuel oil burned under similar aerodynamic conditions. Results obtained from firing with No. 2 and No. 6 fuel oil will aid in the experimental development of a pilot-scale burner/swirl generator, which could be used to fire a coal-water fuel in the pilot-scale utility boiler and provide industry with reliable data on coal-water fuel combustion characteristics.

Fluidized-Bed Combustion (FBC)

In Canada, fluidized-bed combustion could potentially be used to generate electricity and process steam from high sulphur coal. Additional applications include co-firing of coal and wood waste in the forest products industry, utilization of coal washery rejects and unreactive fuels, incineration of various organic wastes and combustion of liquid or solid residues from oil sands/heavy oil upgraders.

The wide range of coals available in Canada, which may ultimately find application in FBC systems, makes it highly desirable to be able to obtain quickly and economically some measure of their relative reactivity and combustion performance. Accordingly, CANMET developed a bench-scale FBC and an empirical procedure for ranking the reactivity of coals and other fuels. Reactivity tests have been conducted on four samples of eastern Canadian coals and on an oxidized coal.

CANMET's bubbling bed fluidized bed combustor was used to explore the combustion of heavy liquid fuels such as pitch residues from heavy oil upgrading. Baseline combustion performance data were obtained using residual oil, and combustion trials with Athabasca bitumen were carried out. A contractor continued fundamental studies of the combustion of large particles. A three-dimensional model of atmospheric FBC (AFBC) was developed. Pilot-scale research and mathematical modelling showed that coals of similar rank can burn according to substantially different mechanisms.

Although circulating FBC is perceived to be the most promising technology for utilizing residues such as coke and pitch from the upgrading of tar sands and heavy oils, the high concentrations of alkali and vanadium contained in these materials may cause boiler tube corrosion. Pilot-scale tests performed under contract showed that a circulating FBC can burn Syncrude coke with combustion efficiencies of 98 to 99 per cent, that 90 per cent sulphur capture is possible using Fort McMurray limestone at a Ca/S ratio of 1.7, and that potentially corrosive vanadium and nickel in the coke are, for the most part, trapped in the solid residues.

CANMET is a member of the Management Committee and chairs the Technical Committee which is responsible for the construction of a 22 MWe circulating FBC utility boiler at the Chatham generating station of the New Brunswick Power Commission. This demonstration project is partially funded by EMR's Coal Division, Mineral Policy Sector. Besides being the largest FBC boiler to be built in Canada, and the first to operate at the high steam pressure and temperature conditions required of utility boilers, this unit will be unique in that it will be co-fired with New Brunswick high sulphur coal and oil shale. This will be the first industrially-sized circulating boiler to be built in Canada.

New Coal-Based Fuels

The clean use of coal for electricity generation and process steam has been designated as a high priority for combustion research, development and demonstration in both Canada and the United States because of a mutual interest in reducing transboundary flows of industrial stack gases. In addition, European concerns regarding the long-distance transport of acid rain have resulted in collaborative projects to suppress both SOx and NOx emissions from pulverized coal-fired boilers under two International Energy Agency agreements. The use of coals to replace premium fuels such as gas and oil has been inhibited by the inconvenience of handling solid fuels and by the attendant environmental implications. The development and commercialization of fuels made from coal-liquid mixtures, involves easy and economical coal handling and minimal environmental impact.

Canadian industry, which accounts for less than 15 per cent of the total United States/Canada acid rain inventory, is actively pursuing economical and technically reliable technology options for burning coal cleanly in existing combustion facilities. The use of retrofit technology, although more difficult to apply than newly-designed systems, will impact immediately and positively on long-term targets for controlling deleterious emissions and for disposal of the neutralized products.

A study, carried out under contract, demonstrated that coal-water fuel (CWF) ash deposits on heat transfer surfaces were benign and could be removed by soot blowing with no long-term detrimental effects on heat transfer or erosion of the surfaces. The project was funded by the Canada/Nova Scotia Oil Substitution Agreement with technical direction from CANMET and the Nova Scotia Power Corporation. The atomization characteristics of CWF and the performance of generic CWF atomizers were evaluated under the same agreement by a contractor.

Pollution Abatement Technology

Two novel staged-pulverized-coal burners installed at the central heating plant of Canadian Forces Base Gagetown (NB) were modified to improve their combustion performance. The performance of the retrofitted burners is now comparable to that of conventional burners but has the added advantage of a higher boiler efficiency with significantly reduced emissions of SOx and NOx.

The slagging burner concept is being strongly promoted by a western Canadian utility which is heading a consortium to develop and demonstrate application of the Rockwell burner for utility boilers. CANMET provided substantial scientific support in assessing research results to evaluate NOx/SOx reduction using this slagging burner with both low-sulphur, high-alkali western coals and high-sulphur, low-alkali eastern coals.

CANMET also co-funded a full-scale demonstration of in-furnace NOx and SOx reduction in a lignite-fired 150 MWe boiler at Boundary Dam Generating Station. Other participants were Saskatchewan Power Corporation, EMR Coal Division, CE Canada Limited, Canadian Electrical Association and the Saskatchewan Heavy Oil and Lignite Agreement.

Conservation: Residential, Commercial and Industrial

To reduce the consumption of fuels for space and service water heating, CANMET has directed research efforts towards improving combustion technology and optimizing operating conditions while recognizing the need for safe operating conditions and minimal impingement on the environment.

A retrofit furnace developed by CANMET and Clare Brothers is 20 to 30 per cent more efficient as well as being safer than existing unmodified gas furnaces. Clare Brothers has placed the unit on the market in both Canada and the United States.

CANMET support of a limited number of specific studies of retrofit combustion systems in a variety of industrial sectors and regions of Canada will allow the performers to fully document their capability for energy conservation. This will enable them to offer such service subsequently and privately to industry in general. Other activities include advanced systems to condense flue gas products in industrial processes, to gain latent heat energy and increase efficiency.

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 intiatives, the formulation of project tasks, and the management of contracts.

Wood stoves have been shown to be an efficient and often cheap way to heat a house. However, significant amounts of incomplete combustion products can often be generated, resulting in a potential fire hazard if these products are deposited in the chimney in the form of creosote, or in severe air pollution problems in areas of poor fumigation. CANMET research is directed toward changing the design of these appliances to improve combustion performance and to generate techniques by which it can be effectively measured.

METALS AND MATERIALS

In many ways, the results of CANMET research have gone towards enhancing Canada's capability to produce and fabricate metals and materials into competitive, reliable, and safe products.

Operation of CANMET's mobile foundry laboratory was transferred to the Association of Provincial Research Organizations to continue, with the support of the National Research Council's Industrial Research Assistance Program (NRC/IRAP), the on-site productivity improvement campaign which during the past two years CANMET successfully pioneered across the country.

Acting on evidence that the cutting and drilling performance of hard metals used in the mining industry could be significantly improved, CANMET is funding an industrial research contract. It is anticipated that technological advances in this area could lead to the production in Canada of cutting materials which are now imported.

Casting Processes

In its program on casting technology, CANMET operates an experimental foundry equipped to produce cast

metals and alloys by a variety of commercial methods, and develops improved processes and quality control techniques for Canada's $1.2 billion foundry industry.

During the year under review, the CANMETCOAT process for producing surface modified castings was transferred to a commercial foundry to enable it to supply digger tooth castings to Syncrude. Initial field trials have shown an increase in life of CANMETCOAT teeth over the conventionally hard-faced product. In other process developments, CANMET's low pressure disposable mould casting technique was successfully demonstrated to a number of potential clients in the automotive industry. The emphasis was specifically on aluminum alloy parts. Continued development work has resulted in procedures for casting commercial shapes in copper-base alloys and cast iron. CANMET's electro-slag casting facility, one of the few such units in North America, was used to produce ultra-low sulphur steel melting stock for industry-driven projects on near net shape production technology and line pipe steel evaluation. At the request of the U.S. Department of Energy, a number of nickel-aluminide electro-slag cast billets were produced with modified compositions and structures yielding very high levels of cold formability.

In a cooperative program with Ontario Hydro on the costs of electric furnace melting of cast iron, investigations at six Ontario foundries resulted in the identification of operational changes offering savings of up to $25 per ton. The scope of this study will be repeated in Quebec with the cooperation of the Centre de recherche industrielle du Québec and Hydro Québec. The general assessment methodology has been transferred to computer software as one item in a range of quality and cost control computer programs being made available by CANMET to the Canadian foundry industry.

As mentioned above, the Mobile Foundry Laboratory is now operated under CANMET supervision by provincial research organizations across Canada. This successful mode of technology transfer was complemented by regional workshops for foundaries in Quebec, Manitoba, Alberta, and British Columbia on the "Gating and Risering of Castings".

Metal-Working Technologies

CANMET metal working research is directed towards improving Canadian capability and competitiveness in industrial production of flat-rolled and shaped steels, non-ferrous products and advanced metallic and composite materials.

Research in rolling processing technology is focussed to give steel plate, strip and bar producers an insight into development and control of rolling processes. Accomplishments in the past year include:

- Adapting mathematical models and evaluating them for force, torque and grain refinement predictions in rolling processing of plain carbon and microalloyed steels. The results are of potential use in on-line control of rolling pass reduction and prediction of metallurgical behaviour of the rolled product.
- Initiation of experimental process development for high strength, notch-tough, weldable plates using the pilot-scale on-line accelerated cooling (OLAC) system. The system is being applied initially to demonstrate the potential benefits of the OLAC technology to Canadian steel producers.
- Simulation of hot-strip rolling of plain carbon and microalloyed steels successfully both in cam plastometer and in pilot-reversing mill tests. This capability was developed in preparation for a new industry-cooperative project on modelling of a Canadian hot-strip mill, and for new cost-recovery projects requiring flow stress data for hot-strip processes. A committee of the American Iron and Steel Institute has selected the CANMET cam plastometer, on a cost-recovery basis, for its development of base flow stress data for steel bar and strip rolling process control.

The CANMET pilot-scale rolling mill was used to process experimental steels for other developmental projects on automotive, rail, marine and energy recovery projects, and steel billets for share-funded industrial developments of automotive spring and tire-bead wire steels.

Research in the formability and processing of sheet steels included completion of the study on the influence of the thermal cycle in a Sendzimir galvanizing line on the properties of aluminum-killed drawing-quality (AKDQ) steel. High coiling temperatures following the recrystallization thermal cycle produced good drawability. The results solve problems identified by the Canadian steel sheet producers. Tests of six different grades of steel sheet supplied by the Canadian producers validated a computer program developed to determine r-values from sheet tensile tests for in-plant quality control of formability. Completed contract research identified the frictional effects of the galvanized coating of steel sheet on forming behaviour. The final report has been issued to the galvanized sheet producers.

In near net shape forming research, development of the thermal- mechanical-coupled finite element code was advanced to be capable of modelling plastic flow and heat transfer in hot-rolling processes. Proposed applications of the code are directed initially toward analyses of

process improvements required in an industrial hot-strip mill and in an industrial Steckel mill. In a contracted study of new forgeability criteria, the fiducial grating method of microstrain measurement was found effective for analysis of internal crack formation in forgeability tests. The new criteria will be useful for defining the limiting conditions for industrial forging processes. CANMET organized and held an international symposium on "Computer modelling of fabrication processes and constitutive behaviour of metals".

Existing facilities are being modified to compact and extrude experimental quantities of materials such as rapidly solidified alloys and metal-matrix composites. This fabrication capability will be integrated with industry-related projects on advanced materials development.

Welding Technology

CANMET's welding technology program is directed toward those Canadian industries and Federal government departments concerned with the fabrication and safe operation of welded engineering structures such as pressure vessels, offshore structures, and pipelines.

CANMET organized a shared-cost national program to develop the technology needed for the prevention of disbonding of the stainless steel weld overlay in petrochemical reactor vessels. Twelve organizations from industry, research institutes, and universities are involved in this cooperative venture. The experimental part of Phase I has identified cooling rate from operational temperature as the significant factor in disbonding.

Welding procedures are being evaluated and the strength and notch toughness properties of steel weldments for Arctic ships and naval submarines are being documented for regulatory purposes. In the past year most of the work has been concerned with an evaluation of the weldability of various high-strength steel weldments for submarine fabrication. This work, which is partially funded by the Department of National Defence, directly supports Canada's program for the acquisition of a submarine fleet.

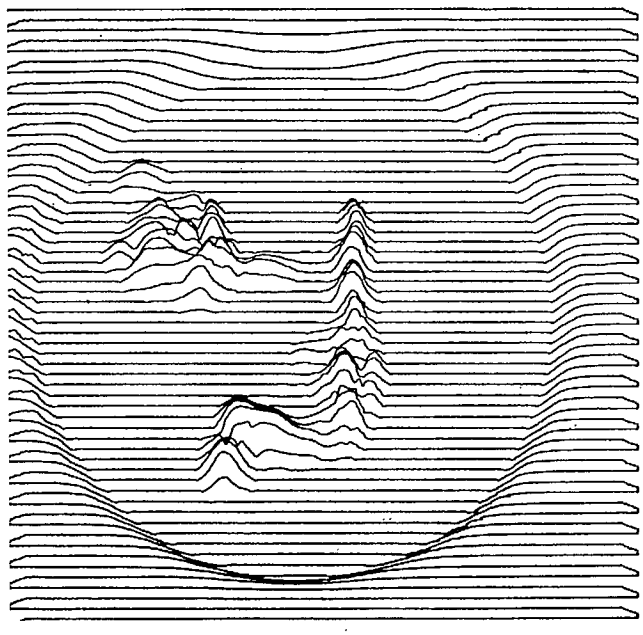
CANMET's program to relate the crack-tip opening displacement (CTOD) properties and the Charpy V Notch (CVN) fracture properties of welds made from flux-cored, shielded-metal-arc and submerged-arc processes has been completed. Data gathered will assist steel suppliers and fabricators to qualify their products for regulatory specifications which require a minimum level of crack initiation toughness. In related work, an industrial task force has steered work on the development of weld consumables with fracture toughness characteristics appropriate to Arctic design temperatures. This contract research is targetted to simultaneously provide the Canadian Coast Guard, Canada Oil and Gas Lands Administration, and Canadian Standards Association with relevant toughness data; and to enable Canadian consumables manufacturers to develop products for use in this country.

In the area of modelling, a cooperative program with steelmakers has detailed the high temperature ductility of continuous cast grades, assisting the producers in relating defect incidence to high temperature properties. Emperical equations have been published relating operational welding parameters for submerged- and gas-metal-arc processes to penetration, bead size, and melting rate.

Finally, procedures have been developed in-house for welding thick section 2-25 Cr/Mo steel by narrow gap submerged-arc technology. The data and technologies are being transferred, through contract work, to energy companies involved in the design and fabrication of high temperature reactor vessels.

Nondestructive Testing (NDT)

In Canada, a national concern for public safety has been reflected in a strong growth in nondestructive testing. This results from the need for structural integrity of engineering structures, product quality and liability, conservation of resources, and increasing productivity. CANMET's NDT activities encompass both the administration of a national program to certify NDT personnel in Canada and the development of NDT technology.



An ultrasonic image showing hydrogen disbonding in a weld overlay surface layer of a petrochemical reactor vessel

Thrusts in the development of NDT technology were defect detection and characterization, on-line process monitoring, and materials property assessment. Work continued in the area of ultrasonic inspection and characterization using optical methods. This technology will enable samples to be inspected at elevated temperatures and will be amenable to the inspection of awkward shapes. Ongoing work aims at making the technology sufficiently sensitive for laboratory and industrial applications. Two receiver systems are being developed, one based on heterodyning and the other on the confocal Fabry-Perot interferometer. Technology transfer and commercialization of these two technologies will be pursued by a Canadian company.

Microstructures and Properties of Engineering Materials

Materials technology is undergoing momentous change. Traditional materials such as steel and nonferrous alloys now compete with non-metallic materials, notably polymers, and with each other.

To meet increasing property requirements, advanced alloy-design concepts are being exploited in microalloyed steels, aluminum-lithium alloys, and spinodally-hardened copper alloys. Equally significant is the extensive development of "engineered materials" which are a synthesis of metallic and non-metallic components, produced by novel processes. These materials achieve properties which exceed those of traditional ones. Examples are rapidly solidified materials, surface-engineered alloys, composite materials, and advanced structural ceramics.

Melt-spun iron-neodymium-boron alloys have exceptionally high magnetic field strengths and are candidate materials for compact permanent magnets suitable for space vehicles, robots and small engines. Melt-spun flakes of these alloys were prepared and their magnetic properties characterized. During the year under review, amorphous coatings were produced which are expected to exhibit exceptional corrosion resistance. In collaboration with the University of Waterloo, the production and properties of composites reinforced with metallic glass ribbons were investigated. In collaboration with the Department of National Defence, enhanced solid solubility of iron in melt-spun Fe-Al bronzes and their superior corrosion resistance compared with conventionally-processed materials has been demonstrated. Research carried out in conjunction with Noranda and the National Research Council showed that rapid solidification eliminates macrosegregation and significantly reduces microsegregation in Cu-Ni-Sn strip produced by direct casting.

Research on inclusion-engineered steels has emphasized the control of inclusions in medium-carbon steels to improve their machinability.

Corrosion and Erosion

In cooperation with the private sector, CANMET has developed methodologies for analyzing, preventing, controlling, monitoring, and evaluating degradation by corrosion and erosion. During the year under review:

- Nineteen linepipe steels supplied by several companies were evaluated for resistance to hydrogen-induced damage. This project was 50-50 share-funded with the Canadian Standards Association Sour Service Task Force.
- The cracking susceptibility of welds of electro-resistant welded linepipes were investigated. Cracking was not observed.
- The relative performance of ferritic and austenitic alloys used for in-bed combusters burning high-sulphur coal in a fluidized-bed pilot-plant operated by Nova Scotia Power Corporation were determined in different temperature ranges. T91 was the only ferritic alloy to exhibit promising performance and then only at temperatures below 550°C. Types 304H, 310 and 347H stainless steels were acceptable in most regions of the combuster at temperatures up to 700°C. Samples located closer to the top of the combuster exhibited higher erosion rates.
- In a study conducted in cooperation with the Canadian Coast Guard, data related specifically to weld repair confirmed that a number of shielded metal-arc-welding consumables can be chosen to minimize or eliminate weld-metal corrosion, whereas the problem of heat-affected-zone attack can best be controlled through modification of the steel plate chemistry.
- The evaluation of corrosion properties of iron-aluminum bronzes demonstrated a significant improvement in the corrosion rate of rapidly solidified alloys containing 3 to 8 weight per cent Fe.
- Research was carried out under contract to determine the effectiveness of ion implantation and ion-beam mixing techniques to improve the high-temperature oxidation resistance of Fe-based alloys by increasing the aluminum concentration near the surface.

The ion treatments improved oxidation resistance more effectively than aluminum implantation.

— The effect of laser surface melting and alloying of commercial Fe-based alloys on high-temperature oxidation was investigated in collaboration with NRC.

Materials Failure Control and Analysis

CANMET participates with industry and universities in projects to determine the mechanical behaviour of metals and is thus constantly developing competence in new test methods while broadening understanding of the factors controlling mechanical behaviour. Examples are the effects of thickness and temperature on fracture toughness and corrosion fatigue, and of metallurgical microstructure on mechanical properties.

Stress analysis allows the proper interpretation of the effects of specimen geometry and processing history on mechanical behaviour. Stresses in single-pass weldments were measured and compared favourably with predictions of residual stress patterns made from finite element analysis performed under contract.

CANMET contributes to the prevention of structural failures by performing failure analyses, by contributing to the writing of national codes and standards, and by testing structures containing known defects. Electric resistance wire (ERW) pipe contalning artificial and production defects was tested and the reduction in strength caused by ERW weld imperfections was measured. The dynamic fracture toughness of austempered ductile iron was evaluated in collaboration with a Quebec foundry.

Work has continued on the evaluation of the corrosion fatigue behaviour of welded joints as part of CANMET's project on offshore steel structures. Studies of the effect of section thickness on fatigue life of welded T-joints under constant amplitude loading in air and seawater have been completed. At constant hot-spot stress, both initiation and propagation lives are reduced as thickness increases. An exhaustive review of worldwide data for tests on plate and tubular joints supported evidence that the latter show no benefits from cathodic protection even after long usage.

Advanced Instrumentation

A commercial prototype of the CANMET portable X-ray stress diffractometer has undergone successful field trials at Ontario Hydro and the Defence Research Establishment Atlantic (DREA).

Electron energy-loss spectrometry and X-ray microanalysis were used to characterize precipitates extracted from the heat affected zone of weldments in Ti- and Nb-bearing steels for offshore structures. The microstructure of seamless tubing from a Canadian manufacturer, identified by transmission electron microscopy, pinpointed the cause of inadequate toughness properties. Subsequently, the heat treatment was modified to alleviate the problem.

TECHNOLOGY TRANSFER

During 1986-1987, the Office of Technology Transfer (OTT) enhanced its activities and participation in the Industrial Research Assistance Program (IRAP) for financially assisting the demonstration and commercialization of technologies developed or sponsored by CANMET. OTT worked with CANMET's laboratories to plan and execute numerous technology transfer activities; assisted with patenting and licensing procedures by acting as a liaison with Canadian Patents and Development Limited (CPDL) and by retaining patent agents under contract; advised Branch management and scientists on intellectual property matters arising from in-house research and R&D contracts; and continued to report significant events within the Branch.

TECHNOLOGY EVALUATION

OTT provided engineering and economic evaluations for a number of projects, including: a comparison and update of the sulphation roast and the pressure acid leach processes for Zn/Pb/Ag recovery from complex sulphide ores; biorecovery of selenium from base metal processing effluents; coal coprocessing to produce liquid fuels; and the CANMET ferric chloride leach process for recovering base and precious metals from complex sulphide bulk concentrates. The evaluation of the selenium recovery process has encouraged a major mining company to seriously consider investing in the process.

PROJECT REVIEW

Evaluation of the residential heating research at CANMET was initiated through a contract to determine the impact of the transfer of CANMET technology on manufacturers, energy suppliers, and consumers.

A review of the 50/50 energy conversion program was initiated. The contractor will be selected and work will begin in the next fiscal year. The contractor is to evaluate the technical and economic impact of the Program research, and also to determine what research or industrial use has been made of the contract outputs.

TECHNOLOGY TRANSFER ACTIVITIES

CANMET has 15 active projects under the IRAP program, with a total budget of $9.3 million, of which the companies contributed $5.7 million and NRC the remainder. Seven new projects were started during the fiscal year and up to four new projects are under development for commencement in the next fiscal year.

OTT assisted CPDL with patenting and provided guidance on the licensing of the following technologies developed at CANMET or under contract:

- Patenting action for the Delta P Index Measuring Instrument was begun under the START program and a potential manufacturer was assisted with the display of the instrument at the Tenth World Coal Preparation Congress in Edmonton.
- OTT has arranged for a patentability assessment and is now negotiating a licence to the manufacturing rights for the Radon Dosimeter, which will be marketed primarily in the United States.
- The CANMET-developed technology for the Hardfacing of Steels was registered under the trademark CANMET-coat, and discussions on the exploitation of the technology have begun with a commercial manufacturer.
- The Catalyst Reactor Unit has been licensed to a Canadian company to manufacture and market the units. Patent protection is being sought in Canada and the United States.

In order to develop proper technology transfer strategies, OTT conducted or assisted with numerous marketing and commercialization assessments of CANMET technologies, including Hydrogen conducting Ceramic (Hyceram), Oxidation of Natural Gas to Methanol, and the Low Severity Hydrotreating Process. In addition, a campaign was initiated to promote an in-house publication, *The Gold Assay Methods Manual*; as a result, over 150 copies have been sold to date throughout North America.

TECHNOLOGY INFORMATION

Provision was made for a comprehensive collection of literature in mineral and energy technology documentation, i.e. indexing and abstracting of relevant literature for inclusion in appropriate computer-based data files. Publication and distribution of report literature incorporating the results of research by CANMET scientists and contractors, and provision of reliable and timely technical information required in the course of research by CANMET scientists or other researchers and operating personnel across Canada, are the principal concerns of the Technology Information Division. During the year under review, these activities were pursued with vigour notwithstanding the distractions caused by the move of operating staff to alternate quarters.

LIBRARY SERVICES

Nearly 4,500 new books, reports, periodical volumes, dissertations and conference proceedings were added to the collections. The number of subscriptions to serials and periodicals stood at 2,640 at year's end. Over 80,000 separate loan transactions to CANMET staff have been registered during the year. Through technical information resource-sharing arrangements, just under 4,000 items were loaned to other libraries, whereas some 2,000 items were borrowed from other institutions for the use of CANMET staff.

TECHNICAL DOCUMENTATION

The implementing agreement has been signed for cooperative production of an energy technology database among member countries of the International Energy Agency. Under the agreement, each participating country indexes and abstracts its own energy technology literature to be combined in a single on-line access database for use by researchers and operating personnel of all contributors. The agreement represents a major step forward in our ability to share energy technology information originating in any of the member countries almost as soon as published. In other related activities the technology information staff added nearly 9,000 new records to the five CANMET databases – MINTEC, MINPROC, COAL, COALPRO and CANPUB. All but one of these -CANPUB- are accessible to the Canadian public either through the CAN/OLE network of the National Research Council, or through the private sector database utility, QL Systems. Use of the four publicly accessible CANMET databases exceeded 8,000 searches. CANPUB is an in-house database, under construction, containing records of all extant publications by staff members of CANMET and its predecessors, going back to the establishment of the Branch in 1907.

PUBLICATIONS PRODUCTION

During the year there have been a total of 792 reports published. Of those, 37 were major reports, distributed widely throughout Canada and to several hundred exchange partners in foreign lands. The remainder, 755, were divisional reports, intended essentially for internal distribution; however, copies of these were made available on demand to external clients requesting them. Increased use of the two official languages is reflected by the nearly 20 per cent increase in translations; a total of 900 pages were translated into one or the other of the Official Languages.

TECHNICAL INQUIRIES AND REFERRAL SERVICE

The number of requests for information received in the Division was just over 2,600. Eight per cent of these were referred to other, more appropriate agencies; the rest were handled by CANMET information officers, with occasional assistance with specialized, unpublished information by CANMET research staff. An estimated 15,000 pieces of literature were mailed out in response to these inquiries.

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

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Mineral processing	(613) 995-4069
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APPENDIX A

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CANMET PROFESSIONAL STAFF

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R.R. Poirier; DEC (Cégep l'Outaouais); General Technology Information Officer

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Publications

M. Close; B.A. (Toronto); B.A. (Hons) (Ottawa)

D. Davidson; B.A. (Hons); M.A. (Carleton); Editor (English)

E. Blackburn; B.A. spéc. en traduction, LL.L. Licence en droit civil (Ottawa); Editor (French)

M.P. Desrosiers; B.A. conc. en litt. française; B.A. spéc. en traduction (Ottawa); Editor (French)

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B.W. Konda; B.Eng. (Uyderabad), Ph.D. (Nottingham), P.Eng.; Phys. Sci.

D.J. Kennedy; B.Sc. (Windsor); Phys. Sci.

G.W. Klinowski; M.Sc. (Silesian Tech.); Engineer

Coal Testing

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

Surface Mining Laboratory

Geotechnical Engineering

B.M. Das; B.Sc., A.I.S.M. (India School of Mines); Ph.D. (Tech. U. of Mines, Ostrava, Czechoslovakia), P.Eng.; Res. Sci

A.W. Stokes; B.Sc., Ph.D. (Nottingham); Res. Sci.

Environmental Control

R.N. Chakravorty; B.Ch.E. (Jadavpur), Ph.D. (Nottingham); Res. Sci.

N.J. Stuart; B.Sc., Ph.D. (Nottingham); Res. Sci.

R.J. Kolada; B.Sc., Ph.D. (Nottingham); Res. Sci.

J. Szymanski; M.Sc., Ph.D. (Wroclaw); Res. Sci.

V. Srajer; M.Sc. (Univ. Appl. Sci., Kosice), P.Eng.; Engineer

Coal Reserve Assessment

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Advanced Technology

R.K. Singhal; B.Sc. (Nottingham), Ph.D. (Newcastle-on-Tyne), C.Eng., P.Eng.; Phys. Sci.

H.G. Naidu; B.Sc., A.I.S.M. (India School of Mines); P.Eng.; Engineer

Fuel Processing Research Laboratory

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N.E. Anderson; B.Sc. (Alberta); Phys. Sci.

Carbonization

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R. Zrobok; B.Sc. (Alberta); Phys. Sci.

Fossil-Fuel Science and Applications

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D. Axelson; B.Sc., Ph.D (Toronto); Res. Sci.

C.W. Angle; B.Sc. (Alberta); Phys. Sci.

R. Mikula, B.Sc. (Saskatchewan), Ph.D. (British Columbia); Phys. Sci.

S. Twa; B.Sc. (British Columbia); Phys. Sci.

Y. Theriault; B.Sc., M.Sc., Ph.D. (Alberta); Res. Sci.

X. Shu; Ph.D. (Imperial College); PDF

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W.I. Friesen; B.Sc. (Brock), Ph.D. (British Columbia); Res. Sci.

A.W.F. Mo; B.Sc. (Alberta); Phys. Sci.

R. Ansari; Ph.D. (Western Ontario); PDF

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A.I. Salama; B.Sc. (Alexandria), Ph.D. (Alberta); Res. Sci.

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

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APPENDIX B

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CANMET REPRESENTATION ON TECHNICAL COMMITTEES 1986-1987

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MRL	Mining Research Laboratories	TID	Technology Information Division
MSL	Mineral Sciences Laboratories	NUTPO	National Uranium Tailings Program Office
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Technical Committee for "Flameproof Diesel-Powered Vehicles for use in Gassy Underground Mines" M424 (chairperson)	E.D. Dainty (MRL)
Technical Committee on Acoustics and Noise Control (Construction & Mining Machines – Task Force on Occupational Noise) (member)	M. Savich
Technical Committee on Fire Resistant Conveyor Belting, no. M4.22 (member)	K.J. Mintz
CANADIAN SOCIETY OF CIVIL ENGINEERING Technical Activities Committee (member)	V.M. Malhotra (MSL)
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CANADIAN SYMPOSIUM ON SURFACE SCIENCE (FOURTEENTH) Surface Canada 88 (session organizer and co-chairman)	J.R. Brown (ERL)
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Analytical Subcommittee (treasurer)	J.L. Dalton (MSL)
Metallurgical Committee (secretary)	G.M. Ritcey (MSL)
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Ottawa Section Professional Affairs Committee (member)	J.C. Hole (MSL)
Ottawa Section Executive (treasurer)	M.E. Leaver (MSL)
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Surface Science Division (member)	J.R. Brown (ERL)
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Coal Beneficiation Working Group (member)	M.W. Mikhail (CRL)
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COMMITTEE ON COPPER CASTINGS FOR THE CANADIAN STEEL INDUSTRY COMMITTEE (chairman)	R.K. Buhr (PMRL)
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COMMISSION TO IMPLEMENT A NEW COURSE IN PHYSICAL TECHNOLOGY BETWEEN CEGEP AND INDUSTRY (member)	J.P. Monchalin (PMRL)
CSIRA (ex-officio member)	J.D. Boyd (PMRL)

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(chairman executive council)	R.W. Revie (PMRL)
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Technical Committee (member)	C.J. Adams (ERL)
HOUSING AND URBAN DEVELOPMENT ASSOCIATION OF CANADA (HUDAC)	
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Comité des Sciences naturelles et génie	N. Billette (MRL)
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As of March 31, 1987/au 31 mars 1987

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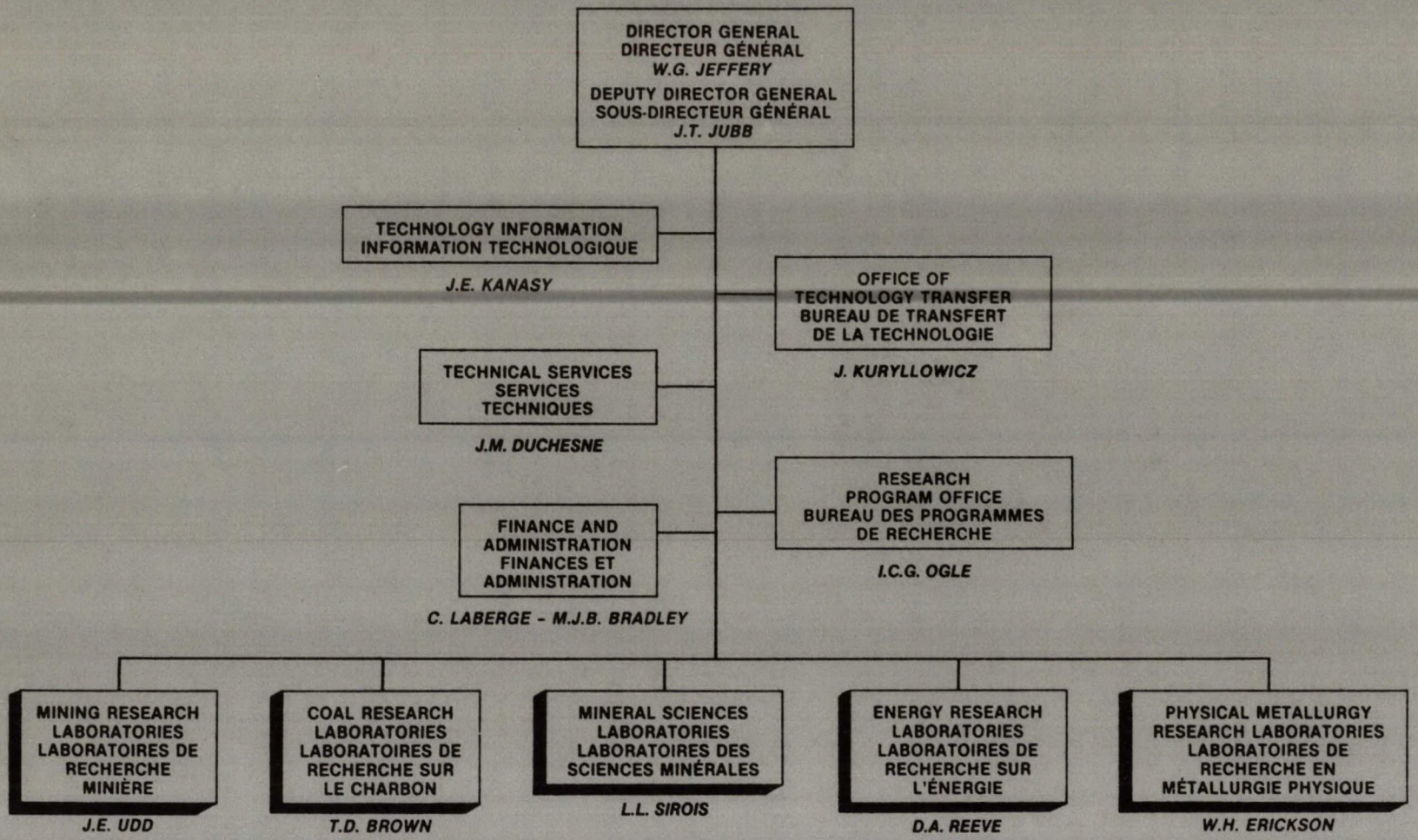
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W.H. ERICKSON

PARTIAL LIST OF CONTACTS WITH CANADIAN CORPORATIONS AND INTERNATIONAL ORGANIZATIONS DURING FISCAL YEAR 1986-1987

LISTE PARTIELLE DES CONTACTS AVEC LES SOCIÉTÉS CANADIENNES ET ORGANISMES INTERNATIONAUX AU COURS DE L'ANNÉE FINANCIÈRE 1986-1987

INDUSTRY: FOREIGN / INDUSTRIE: À L'EXTÉRIEUR DU CANADA

Abex Corporation, Mawa, New Jersey
Alpha Cast Inc., Whitewater, Wis.
Amax, Michigan, Conn.
Amax, Golden, Co.
ARCO, South Louisiana
Aurora Metals Division, Montgomery, Ill.

Battelle Laboratories, Columbus, Ohio
Bethleham Steel Corp., Pittsburgh, Pa
Bethleham Steel Corp., Bethleham, Pa
BHP Iron and Steel, Wollongong, Australia
Blaw-Knox, Chicago, Ill.
British Steel Corp., Middlesborough, U.K.
Brom Machine & Foundary Co. Ltd., Winona, Minnesota
Buffalo Weaving and Belting, Buffalo, N.Y.

Carborundam Corp., Bethleham, Pa
CBI Industries, Oak Brook, Ill.
Centre for Research on Sulphur in Coal, Champaign, Ill.
CERCHAR, Paris, France
Chevron Corp., Richmond, Ca.
Chevron Incorporated, New Orleans, Louisiana
Chinese National Non-ferrous Metals Company,
Climax Molybdenum Co., Golden, Co.
Commercial Testing and Engineering Co., Lombard, Ill.
Conoco Coal Research, Pennsylvania
Cool Water Demonstration, Barstow, Ca.
Croda Limited, United Kingdom
Creusot-Loire, France

Dano International Services, New York, USA
Dayton Malleable Iron Co., Dayton, Ohio
Detector Electronics Corporation, Minneapolis, Minn.
Deutz Engineering, Atlanta, Georgia
Dosco Overseas Engineering Co., Nottingshire, U.K.
Duffers Associates, Troy, N.Y.

EER Corporation, Irvino, Ca.
Eimco/Jarvis Clark, Utah, USA
Elkem Als, Norway
Elkraft, Denmark
Elkem Inc., Niagara Falls, N.Y.
Energy Development Corp., Pittsburg, Penn.
Engenharia, SA, Sao Paulo, Brazil

Engineers India Ltd., New Delhi, India
Englehard Corp., Edison, N.J.
ERA Technology, Leatherhead, England
ESAB, Sweden
ESAB, Norway
Esco Corp., Portland, Oregon
Exxon Production Research Co., Houston, Tx.

Falcon Research, Johannesburg, S.A.
Factory Mutual Research, Norwood, Mass.
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Foote Mineral Corp., Chicago, Ill.
Ford Motor Co., Deerburn, MI

General Casting Corp., Milwaukee, Wis.
General Monitors, Costa Nesa, Ca.
Grecian Magnesite, S.A.

Highveld Steel and Vanadium Corp. Ltd., London, England
Houston Lighting and Power Co., Texas

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Idemitsu Kosan, KK, Calgary
Imperial Chemical Industries, U.K.
Impro Corporation,. Virginia, U.S.A.
International Harvester, Chicago, Ill.

Japanese Metal Producing Companies
Jones Fortier Advisors Ltd., Pittsburg,PA
J-P Associates, Dallas, Texas

Kashima Steel Works, Kashima, Japan
Kawasaki Steel Corp., Chiba, Japan
KCERL , Lexington, Kentucky
Kelly Foundry and Machinery, Elkins, Va
Kulp Foundry, Stroudsburg, PA

Little, A.D. and Associates, Cambridge, Mass.
Lloyd's Registry, London, U.K.
Lusjhe Chain Co., Sweden

Marex Welding Products Ltd., Walthem Cross, U.K.
Metallurgical Consultants Inc., Houston, Tx
Mineral Industries Computing Limited, U.K.
Minnegasco, Minneapolis, Minnesota
Mitre Corporation, Virginia

Mitsubishi Heavy Industries, Tokyo
Mobil Research and Development Corporation, New Jersey
Mobil Oil, USA
Modern Castings, Des Plaines, Ill.

Nippon Oil and Fats Co., Japan
Nippon Steel Corporation, Kitayusha, Japan
NIOSH, USA
Nuclear Assurance Company, Grand Junction, Colorado

Odebrecht Construction, Aracaja, Brazil
Odebrecht-Harrison, Salvador, Brazil
Olan Industries, Lake Stevens, Wa
Ortec Corp., Oakridge, Ten.

Packer Engineering, Napier, ILL
Petrobas Mining, Aracajan, Brazil
Pfizer International, New York, N.Y.
Phibro Energy Inc., Conn.

Reynolds Aluminum, Richmond, Va.
Ridge Foundry, San Leandro, Ca.
Rockwell Burner Development, Canoga Park, California
Rockwell International, Troy, MI.
Round-up Powder Company, Montana, U.S.A.

S. Agumber, Croda, U.K.
Scandura Mining Products
Scharf Company, Pittsburg, Pennsylvania
Siemans AG, Karlsruhe, West Germany
South California Edison
SRI International, Menlo, California
Stainless Foundry & Engineering Corp., Milwaukee, Wis.
Studsvik Emergiteknik, Sweden
Sumitomo Steel Co., Houston, Tx
Sumitomo Metals, Japan

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Tonawanda Coke Corp., Tonawanda, N.Y.
Tri State Testing, Ashland, Kentucky
TRW Inc., Redondo Beach, California
Tuula Kyraes, Luleaa, Sweden

Union Carbide, Charleston, West Virginia
United States Steel Corp., Monroeville, Pa.
U.S. Wood Heating Alliance

Vicinary Chain Co., Spain

Westfalia-Lunen Company, West Germany
Westinghouse Research and Development Centre, Pittsburg, Pa
Wicke Gmblt & Company, Wuppertal, West Germany
Wyoming Analytical Laboratories, Arvada, Colorado.

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ACG Technology Ltd., Mississauga, Ontario
Adjeleian Allen Rubeli, Toronto, Ontario
AIMCO, St. Catharines, Ontario
Air Liquide Canada Limitée
Alberta Lazer Institute
Alberta Rockwell Corp., Calgary, Alberta
Algoma Steel Corp., Sault Ste. Marie, Ontario
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Altimag Consultants
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AMCA International, Ottawa, Ontario
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Amok Limited
Ancast, Winnipeg, Man.
Appleton Electric Ltd., Cambridge, Ontario
Arctec Canada Ltd., Kanata, Ontario
Ardiem Inc. Corp., Vancouver, British Columbia
Associated Foundry, Surrey, British Columbia
Atlas Copco Canada, Canadian Corporations, Dorval, Québec

Atlas Steel, Welland, Ontario
Atlas Steel, Varennes, Québec
Armstrong Monitors Corporation, Nepean, Ontario
Aston Pyrotechnics Canada Ltd., Guelph, Ontario
Astro Canada, Guelph, Ontario

BBT Geochemical Consultants
BP Canada Inc., Calgary, Alberta
BH Levelton and Associates
Babcock & Wilcox, Cambridge, Ontario
Badene, L. Associates, Willowdale, Ontario
Bailey Hoogovens, Canada Inc.
Bay Bronze, Winnipeg, Manitoba
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Beaver Construction, Montréal, Québec
Beaver Delta Machinery, Guelph, Ontario
Belgen Foundry, Drummondville, Québec
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Black Box Canada Incorporated, Norval, Ontario
Blanchard Foundry, Saskatoon, Saskatchewan
Bow Valley Industries, Calgary, Alberta
Bow Valley Offshore Limited Partnership, Halifax, Nova Scotia
Breton Engineered Projects, Sydney, Nova Scotia
Brunswick Mine, Bathurst, New Brunswick

Brunswick Mining and Smelting, New Brunswick

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Camax Engineering
Cambrian Engineering Group Limited
Canada Brick Ltd.
Canadian Bronze Co., Winnipeg, Manitoba
Canada Cement Lafarge, Saint-Constant, Québec
Canada Wire and Cable Limited
Canadian General Electric, Peterborough, Ontario
Canadian Hunter Exploration Limited
Canadian Industries Limited (CIL), Montréal, Québec
Canadian Liquid Air Limited, Montréal, Québec
Canadian Natural Gas Systems, Toronto, Ontario
Canadian Pacific Railways, Montréal, Québec
Canadian Pacific Research Labs, Montréal, Québec
Canadian Stone Marine Ltd., Iberville, Québec
Canadian Tungsten, Vancouver, British Columbia
Canertech Inc., Winnipeg, Manitoba
Canam Resource Parts, Edmonton, Alberta
Canterra Engineering Ltd., Calgary, Alberta
Caproco Ltd., Edmonton, Alberta
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Central Canada Potash, Colonsay, Saskatchewan
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Chadrien Ltd., Ottawa, Ontario
Chemex Labs Ltd., British Columbia
Chemlab Inc.
Chinook Fuel Innovations Ltd., Calgary, Alberta
Chromasco Ltd., Haley, Ontario
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Computing Devices Canada Ltd., Nepean, Ontario
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Cominco, Sheridan Park, Ontario
Combustion Engineering-Superheater Ltd., Ottawa, Ontario
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Concorde Scientific Corporation, Toronto, Ontario
Consultec Limited, Toronto, Ontario
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Consolidated Silver Standard Mines
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Corrosion Service Co., Toronto, Ontario
Crane Ltd., Medicine Hat, Alberta
Crothers Equipment, Toronto, Ontario
Crown Oil Sands Corporation, Winterburn, Alberta
Crows Nest Resources, Calgary, Alberta
Cyanamid Canada, Niagara Falls, Ontario

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Davie Shipbuilding, Lauzon, Québec
Davis Engineering, Ottawa, Ontario
Dayton-Walther Foundry, Guelph, Ontario
Degussa Corporation, Burlington, Ontario
Delfab-Hallteck, Halifax, Nova Scotia
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Denison Potacan Potash Company, Sussex, New Brunswick
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Detour Lake Mine
Devel Tech., Saskatoon, Saskatchewan
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Dobrocky Seatech, Victoria, British Columbia
Dofasco, Hamilton, Ontario
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Dome Petroleum, Calgary, Alberta
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Dominion Bridge, Edmonton, Alberta
Dominion Engineering Works, Montréal, Québec
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EBA Engineering
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Eldorado Nuclear Ltd.
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Fondremy, Chambly, Québec
Front End Resources, Grand Forks, British Columbia

Galtaco, Guelph, Ontario
Gamma Foundries Ltd., Richmond Hill, Ontario
Garrand Homes, Ottawa, Ontario
Garson, Garcy Enterprises
Gemite Unique Productions Inc.
General Motors of Canada, St. Catharines, Ontario
Geosearch Limited
Geotechnical Resources Ltd., Calgary, Alberta
Genian Construction Limited, Montréal, Québec
Gibraltar Mines Ltd., Vancouver, British Columbia
Global Thermoelectric Power Systems Limited
Golder Associates, Calgary, Alberta
Great Central Mines
Gregg River Mine, Hinton, Alberta
Guelph Chemical Laboratory Ltd.
Gulf Canada Ltd., Sheridon Park, Ontario
Gulf Canada Ltd., Calgary, Alberta
Gulf Canada Resources Co. Ltd., Calgary, Alberta
A. Gutulov, Metallurgical Consultant

Habitation Nordique, Québec, Québec
Haley Industries, Haley Junction, Ontario
Hall and Stavert Ltd., Charlottetown, P.E.I.
Hamilton Foundry, Hamilton, Ontario
Hands Fireworks Incorporated, Edwardburgh
Hanna Mining Company
E.H. Hanson & Associates, Delta, British Columbia
Hanson Material Engineering, Edmonton, Alberta
Harris N.D. Consultant
Harvey W. Consultant
Hatch Associates
Hawk Ridge Mineral Enterprises
Hearne Taurus
Heath and Sherwood, Toronto, Ontario
Hayes Stuart Inc., Montréal, Québec
Heuristic Engineering Inc., New Westminster, British Columbia
Heritage Foundry, Winkler, Manitoba
Hiex International Corporation
Highwood Resources
Holmes Foundry, Sarnia, Ontario
Howmet Thermatech, Boucherville, Québec
Hudson Bay Mining and Smelting Company
Husky Oil, Calgary, Alberta
Husky Oil, Lloydminster, Alberta

IMP Foundry, Dartmouth, Nova Scotia
Imperial Oil Ltd., Toronto, Ontario
Imperial Toy Canada Limited, Mississauga, Ontario
Inco, Toronto, Ontario
Inco Mines Limited, Thompson, Manitoba
Industrial Ceramics Limited
Industries USP, Lennoxville, Québec
Ingersol-Rand Canada Ltd., Cambridge, Ontario
Inproheat Ltd., Vancouver, British Columbia
Instantel, Kanata, Ontario
Interact Limited, Victoria, British Columbia
International Corona, Toronto, Ontario
International Malleable Ltd., Guelph, Ontario
International Mineral and Chemical Company
International Paint Co., Montréal, Québec
International Steel and Pipe Corp. Ltd., Regina, Saskatchewan
Interuranium Canada Limited
Irving Oil Refinery, St. John, New Brunswick
Iron Ore Company
ITT Barton Manufacturing Limited
IRDC
Ivaco, L'Original, Ontario

Jacques Whitford and Associates Ltd.
Jamaica Manufacturing Co. Ltd., Prescott, Ontario
Jenkins Canada Ltd., Lachine, Québec
J.M. Asbestos Ltd., Asbestos, Québec
Johnson-Matthey, Brantford, Ontario

Kaiser Aluminum
Kanmet Foundry, Cambridge, Ontario
Kidd Creek Mines, Timmins, Ontario
Kilborn Engineering
Knight and Resold
KSK Associates
KVA Electronics, Toronto, Ontario
Kwicki, Calgary, Alberta

Lacana Mines Limited
Lac Minerals-Macassa Division, Kirkland Lake, Ontario
La Fonderie Thetford, Thetford Mines, Québec
Lake Asbestos
Lakefield Research
Lake Ontario Steel Corp., Whitby, Ontario
Lavalin
Les Fonderies MAC Inc., Boucherville, Québec
Lethbridge Iron Works, Lethbridge, Alberta
Limpact Industries Limited, Cobourg, Ontario
Linatex Canada
LL&E Canada Ltd., Calgary, Alta
Lodestone Limited
Luscar Ltd., Edmonton, Alberta

Machinery & Equipment Manufacturing Association, Ottawa, Ontario
Maclaren Plansearch
Madeleine Mines Ltd.
Magaloy Foundry, Stratford, Ontario
Magdalen Silica, Montréal, Québec
Maghemite Incorporated
Magstone Limited

Mainland Manufacturing, Vancouver, British Columbia
Maritime Steel Foundry, New Glasgow, Nova Scotia
Martin McCubbin Associates
Masterloy Products Ltd.
Masdon Corp., Calgary, Alberta
McLean Foundry, Brantford, Ontario
Membrane Technology Consultants, Nepean, Ontario
Metals and Mines Limited
Metal Recovery Industries
Minesco Limited, Kirkland, Québec
Minexpert Inc., Montréal, Québec
Mining Resource Engineering Ltd., Kingston, Ontario
Mitel, Ottawa, Ontario
Mobil Oil, Halifax, Nova Scotia
Monarch Industries Ltd., Winkler, Manitoba
Mueller Industries, Saint Jérome, Québec
Murphy Oil, Calgary, Alberta
Muscocho Exploration, Monaubani, Québec

National Uranium Mining Company
Newmont Mines
Niagara Bronze, Niagara Falls, Ontario
Niobec Mine, Chicoutimi, Québec
Nodeni Consulting
Nolan, Davis and Associates
Noranda Mines Limited
Nordco Limited, St. John's, Nfld.
Norwest Resource Consultants Ltd., Calgary, Alberta
Norwood Foundry, Regina, Saskatchewan
Nova Scotia Research
Nova – An Alberta Corp., Calgary, Alberta
Nova/Husky Research Corporation, Calgary, Alberta
Nyes Foundry, Vancouver, British Columbia

OCL Industrial Materials, Vancouver, British Columbia
ODC/OILFAB, St. John's, Nfld.
Oilfab Haltech Ltd., Dartmouth, Nova Scotia
Omark Ltd., Cambridge, Ontario

Pacific Enercan, Grandforks, British Columbia
Pamour Porcupine Mines
Pan-Canadian Petroleum Limited, Calgary, Alberta
Partec-Lavalin, Toronto, Ontario
Penny Mines
Pétro-Canada, Montréal, Québec
PetroCan Products Ltd., Toronto, Ontario
Petrosar Ltd., Coronna, Ontario
Pfizer, Montréal, Québec
Pickands Mather
Philips Cales Limited, Brockville, Ontario
Pigment and Chemical Company
Pirelli Cables Limited, Saint Jean, Québec
Plant Adjustment Bureau Ltd., Moncton, New Brunswick
Polar Resources Limited
Polymath Energy Consultants Ltd.
Potash Company of America, Saskatoon, Saskatchewan
Potash Corporation of Saskatchewan
Pratt and Whitney Canada Ltd., Longueuil, Québec
Price Waterhouse, Toronto, Ontario
Prospectors & Developers Association, Toronto, Ontario
Prudential Steel Ltd., Edmonton, Alberta
Pyroban Corporation, Aurora, Ontario
Pyrolysis Systems Limited, Kingston, Ontario

Quarm, T.A. Consultant
Quatic Chemicals, Cambridge, Ontario
QIT-Fer et Titane Inc., Sorel, Québec
Quebec Metal Powders, Sorel, Québec

Rahn Metals, North Bay, Ontario
J.S. Redpath Limited
Reichold Ltd.
Reiss Lime Company of Canada
Renzy Mines Ltd.
Rio Algom Ltd.
Robar Industry, Surrey, British Columbia
Robertson Nickerson Ltd., Ottawa, Ontario
Roche Ltd.
Rockwell International
Rolls Royce Canada Ltd., Montréal, Québec
Rosco and Postole, Toronto, Ontario
Rossing Uranium
Russel and Co., Ottawa, Ontario

Safety Supply Canada, Toronto, Ontario
Sandwell Swan Wooster Inc., Vancouver, British Columbia
Saskatchewan Research Council
Seabright Resources
Seargeant Hoskins and Beckwith
Senes Consultants
Shaw-Almex Industries
Shell Canada Research Centre, Oakville, Ontario
Sheridan Technical Association, Mississauga, Ontario
Sherritt Gordon Mines Ltd., Fort Saskatchewan, Alberta
Sidbec-Dosco, Contrecoeur, Québec
Siemens Electric Limited, Pointe-Claire, Québec
Sifto Salt, Goderich, Ontario
Sinteris Canada Inc., Blenheim, Ontario
Smokey River Coal Company, Grande Cache, Alberta
SNC Inc., Montréal, Québec
Sonco Steel Tubing, Brampton, Ontario
Spar Aerosapce, Toronto, Ontario
St. John Foundry, St. John, New Brunswick
St. John Shipbuilding on Dry Dock Co., St. John, New Brunswick
St. John's Marine, St. John's, Nfld.
Standard Induction Casting, Windsor, Ontario
Stanton Foundry, St. Hubert, Québec
Stanton Pipes Ltd., Hamilton, Ontario
Stearns Catalytic
Steel Company of Canada (Stelco), Hamilton, Ontario

Steel Engine Products Ltd., Liverpool, Nova Scotia
Steel Flow Inc., Okotoks, Alberta
Steep Rock Resources
Steffen Robertson & Kirsten
Stone and Webster Consultants, Toronto, Ontario
Strathcona Minerals
Suncor, Sarnia, Ontario
Sydney Steel Corporation (SYSCO), N. Sydney, Nova Scotia
Syncrude Canada, Fort McMurray, Alberta
Syntech, Calgary, Alberta

Tallman Bronze, Burlington, Ontario
Tech Corporation, Chetwynd, British Columbia
Teck Mining Co.
Tektrend Int'l Ltd., Lachute, Québec
Tekrad, Québec, Québec
Terminal City Foundry, Vancouver, British Columbia
Thomson and Neilson
Three Island Steel
Thyssen Mining, Regina, Saskatchewan
Timminco-Chromasco
Tonolli Canada
Total Erickson Resources, Vancouver, British Columbia
TransAlta Utilities, Calgary, Alberta
TransCanada Pipelines, Toronto, Ontario
Transportation Development Centre, Montréal, Québec
Trow Limited

Union Carbide, Montréal, Québec
Union Gas, Toronto, Ontario
Union Screen Plate, Lennoxville, Québec

Vada Industries Ltd., Okotoks, Alberta
Vadeko International, Mississauga, Ontario
Versatile Vickers, Montréal, Québec
Via Rail Canada Inc., Montréal, Québec
ViaTek Ltd., Calgary, Alberta
Vickers Canada, Montréal, Québec
Victoria Machining Depot, Victoria, British Columbia

Wabush Mining
Wajax Industries, Edmonton, Alberta
Wellington Foundry, Wellington, Ontario
Wells Foundry, London, Ontario
West Coast Transmission, Vancouver, British Columbia
Westar Mining, Sparwood, British Columbia
Westech Industrial Ltd.
Westmin Resources Ltd.
Western Foundry, Wingham, Ontario
Witteck Development Inc.
Wotherspoon Foundry, Oakville, Ontario

York Barbell Co. Ltd., Oakville, Ont

Zalev Bros, Windsor, Ont
Zas Technology Inc., Montréal, Que
Zenon Environmental, Burlington, Ontario

UNIVERSITIES AND OTHER ORGANIZATIONS / UNIVERSITÉS ET AUTRES ORGANISATIONS

Agency of Industrial Science and Technology, Tokyo, Japan
Alberta Office of Coal Research and Technology
Alberta Oil Sands Technology Authority (AOSTRA)
Alberta Power Corporation
Alberta Research Council
Alberta, University of, Edmonton, Alberta
Algonquin College, Ottawa, Ontario
American Foundrymen's Society, Buffalo, N.Y.
American Foundrymen's Society, Des Plaines, Illinois
American Foundrymen's Society, Trois-Rivières, Québec
American Hot Dip Galvanizing Assoc., New York, N.Y.
American Iron and Steel Institute (AISI), Bethlehem, Pennsylvania
American Society for Metals, Metals Park, Ohio
American Society for Metals, St. Louis, Missouri
American Society for Testing Materials, Philadelphia, Pennsylvania
American Welding Society, Miami, Florida
Amsterdam University, Netherlands
Arizona State Univ., Tempe, Arizona
Argentina Commercial Secretary for Mineral Industry
Argonne National Laboratory, Chicago, Illinois
Asbestos Institute, Montréal, Québec
Association des mines de métaux du Québec, Québec, Québec
Association of Southeast Asian Nations
Atlantic Coal Research Institute, Sydney, Nova Scotia
Atlantic Institute of Biotechnology
Atomic Energy of Canada Ltd
Atomic Energy Commission, U.S.A.
Atomic Energy Control Board of Canada
Atomic Energy Licensing Board, Malaysia
Auburn Univ., Auburn, Alabama
Australian Technical Cooperation Program

B.C. Hydro, Vancouver, British Columbia
B.C. Ministry of Mines and Petroleum Resources

B.C. Ministry of the Environment
B.C. Ministry of Industry and Small Business
B.C. Research Council, Vancouver, British Columbia
Bedford Institute, Halifax, Nova Scotia
British Columbia, University of, Vancouver, British Columbia
Brigham Young Univ., Provo, Utah
Bureau de recherches géologiques et Minières, Paris, France
Bureau national d'études et de recherches aérospatiales, Paris, France

CAD/CAM, Cambridge, Ontario
Cambridge, University of, Cambridge, U.K.
Cambrian College
Canadian Carborization Research Association, Toronto, Ontario
Canadian Copper and Brass Development Association, Toronto, Ontario
Association canadienne de l'électricité, Montréal, Québec
Canadian Institute of Guided Ground Transport, Kingston, Ontario
Canadian Institute for Metalworking, Hamilton, Ontario
Canadian Standards Association, Toronto, Ontario
Canadian Petroleum Association, Calgary, Alberta
Canadian Welding Bureau, Toronto, Ontario
Cape Breton Development Corp., Cape Breton, Nova Scotia
Carleton University, Ottawa, Ontario
CEGEP de Trois-Rivières, Trois-Rivières, Québec
Central Coal Mining Research Institute, China
Centre de Recherches Industrielles de Québec (CRIQ), Sainte Foy, Québec
Centre de Recherches Minérales du Québec, Sainte Foy, Québec
Central Electricity Generating Board, Gravesend, U.K.
Centre for Frontier Engineering Research, Edmonton, Alberta
China Electric Power Research Institute, Xian, China
Clarkson College, Potsdam, N.Y.
Coal Association of Canada
Coalition of Northeast Governors, U.S.A.
Coal Mining Research Centre, Tokyo, Japan
Commissariat à l'Énergie Atomique, France
Committee on Coal Combustion Sciences, Washington
Commonwealth Scientific and Industrial Research Organization, Australia
Concordia University, Montréal, Québec
College of Cape Breton, Nova Scotia
Copper Development Assoc., New York, N.Y.

Dar es-Salaam, University of, Dar es-Salaam, Tanzania
David Taylor Naval R&D Centre, Annapolis, Maryland
Delft University of Technology, Delft, Netherlands

École polytechnique, Montréal, Québec
École nationale supérieure des Arts et Métiers, Paris, France
Electric Power Research Institute, Palo Alta, California
Energy, Mines and Resources Saskatchewan
Energy, Dept. of, London, U.K.
European Coal and Steel Community (EEC), Brussels, Belgium

Fanshaw College, London, Ontario
Federal Institute of Geosciences and Natural Resources, Hanover, West Germany

Gas Research Institute, Chicago, Illinois
Gansu Univ. of Tech., Lanzhon, P.R. of China
Grey Iron Research Unit, Columbus, Ohio
Government of India Reactor Research Centre, Tamil Nadu, India

Haileyburg School of Mines, Northern College
Hiroshima University, Hiroshima, Japan
Hirst Research Centre, London, England
Hydro Québec, Québec

Institut de Recherche de la Sidérurgie Française, Sainte-Germain-en-Laye, France
Institute for Atomic Energy, China
Institute for Chemical Science and Technology, Sarnia, Ontario
Institute for Research and Development, Haita, Israel
Institute of Mining Research, Zimbabwe
Institute of Technology, Nagpur, India
Instituto Superiore de Sanita, Rome, Italy
International Atomic Energy Agency (IAEA), Vienna, Austria
International Energy Agency, London, U.K.
International Copper Research Assoc., New York, N.Y.
International Lead-Zinc Research Organization, New York, N.Y.
Iron and Steel Institute of Japan, Japan

Japanese Government Industrial Research Institute
Japan Society for Tech. of Plasticity, Tokyo, Japan

Kawasaki Steel Corp., Chiba, Japan
Kentucky Center for Mining and Mineral Research Institute, Lexington, Kentucky
Korea Advanced Energy Research Institute
Korrosionscentralen ATV, Glostrup, Denmark

Lehigh University, Bethlehem, Pennsylvania
Laurentian University, Sudbury, Ontario
Lawrence Berkely Lab, Berkeley, California
London University – Imperial College, London, U.K.

Manchester University, Manchester, U.K.
Manitoba Research Council, Winnipeg, Manitoba

Manitoba Mines and Energy, Winnipeg, Manitoba
Manitoba Mining Association,
Massacussets Institute of Technology (MIT), Cambridge, Mass.
McGill University, Montréal, Québec
McMaster University, Hamilton, Ontario
Memorial University, St. John's, Nfld.
Michigan Technological University,
Mines Accident Prevention Association of Ontario
Mines Inspection Branch, British Columbia
Ministry of Mines, Energy & Petroleum Resources, British Columbia
Ministry of Coal, China
Ministry of International Trade and Industry, Japan
Mohawk College, Hamilton, Ontario

National Association of Corrosion Engineers, Houston, Texas
National Atomic Energy Commission, Argentina
National Coal Board – Coal Research Estab., U.K.
National Bureau of Standards Research Lab, Washington, D.C.
National Swedish Board for Technology Development, Sweden
National Swedish Laboratory, Sweden
New Energy Development Organization, Tokyo
New York State Energy R&D Authority, U.S.A.
Newfoundland Department of Mines and Energy, Newfoundland
New Brunswick, University of, Fredericton, New Brunswick
Northern College, Kirkland Lake, Alberta
Nova Scotia Power Corp., Halifax, Nova Scotia
Nova Scotia Department of Mines and Energy, Nova Scotia
Nova Scotia Research Foundation Corporation, Nova Scotia
Norsk Hydro, Oslo, Norway
Nuclear Research Centre, West Germany

Oakridge National Laboratory, Oakridge, California
Ontario Hydro, Toronto, Ontario
Ontario Ministry of Northern Development and Mining, Toronto, Ontario
Ontario Research Foundation, Mississauga, Ontario
Ottawa University, Ottawa, Ontario
Ontario Centre of Resource Machinery Technology,
Ontario Department of Labour
Ontario Ministry of the Environment
Ontario Ministry of Energy
Ontario Ministry of Labour
Ontario Ministry of Natural Resources
Oxygen Therapy Institute, Michigan, U.S.A.

Peking Institute of Metallurgy, Peking, China
Penn State University, State College, Pennsylvania
Portland Cement Association
Portugese National Uranium Company

Pulp and Paper Research Institute of Canada, Montréal, Québec

Queen's University, Kingston, Ontario
Queensland Water Commission, Australia

Research & Productivity Council of New Brunswick, Fredericton, New Brunswick
Royal Institute of Technology, Stockholm, Sweden
Royal Military College, Kingston, Ontario

Sandia National Laboratories, Albuquerque, New Mexico
Sandia National Laboratories, Livermore, California
Saskatchewan Research Council, Saskatoon, Saskatchewan
Saskatchewan Power Corporation
Saskatchewan Department of Mineral Resources
Shanghai Research Institute of Building Science
Simon Fraser University, British Columbia
Singapore Institute of Standards and Industrial Research, Singapore
Southern Research Institute, Mobile, Alabama
Stuttgart, University of, Stuttgart, West Germany
Swedish Institute for Metals Research, Stockholm, Sweden
Swedish State Power Board, Stockholm, Sweden

Technical Research Centre, Finland
Technical University of Nova Scotia, Halifax, Nova Scotia
Toronto, University of, Toronto, Ontario
Trinity College, Dublin, Ireland
Turkish Atomic Energy Centre Laboratory
Turkish Mineral Technology Institute

United Kingdom Technical Cooperation Program
United Nations (UNIDO), Latin America
Univeridad Michoacama de San Nicolas de Hidalgo, Morelia, Mexico
University of Calgary, Calgary, Alberta
University of British Columbia, Vancouver, British Columbia
Université Laval, Laval, Québec
Université de Montréal, Montréal, Québec
Université de Sherbrooke, Sherbrooke, Québec
Université de Paris, Paris, France
Université du Québec
University of New Brunswick, Fredericton, New Brunswick
University of Saskatchewan, Regina, Saskatchewan
University of Bristol, Bristol, England
University of Zambia, Lusaka, Zambia
University of Zhejiang, Hangzhou, China
U.K. Atomic Energy Authority, London, U.K.
U.S. Department of State
U.S. Environmental Protection Agency
U.S. Bureau of Mines,

U.S. Department of Energy,
U.S. Naval Research Lab., Washington, D.C.
U.S. Steel Research Lab., Munroeville, Pennsylvania

Virginia State University, Virginia, U.S.A.

Waterloo, University of, Waterloo, Ontario
Western Ontario, University of, London, Ontario

Windsor, University of, Windsor, Ontario
Winnipeg City Waterworks, Winnipeg, Manitoba
Welding Institute (The), Abington, U.K.
Welding Institute of Canada, Oakville, Ontario
Wollongong, University of, Wollongong, Australia

Yale University, U.S.A.
Yukon Department of Energy

DISTRIBUTION OF RESOURCES

1986-1987

	CAPITAL FUNDS $ 000	OPERATING FUNDS $ 000	PERSON YEARS
MINERAL AND ENERGY TECHNOLOGY			
Mining	688.9	6 066.0	71
Coal Mining and Preparation	837.7	5 945.2	67
Mineral Processing	753.0	14 469.9	181
Fuels Technology	2 855.5	16 868.0	187
Metals and Materials	1 084.1	9 031.3	137
Technology Information	38.4	2 570.3	33
Technical Services	118.4	2 421.8	47
Management and Support (Branch HQ Only)	155.6	4 365.1	50
Contributions and Grants		377.0	
ADMINISTRATION OF THE CANADA EXPLOSIVES ACT			
Explosives Testing and Research	45.5	63.8	12
TOTAL	6 577.1	62 752.3	785

DISTRIBUTION DES RESSOURCES

1986-1987

	FONDS D'IMMOBILISATION 000 $	FONDS D'EXPLOITATION 000 $	ANNÉES-PERSONNES
TECHNOLOGIE DES MINÉRAUX ET DE L'ÉNERGIE			
Exploitation minière	688,9	6 066,0	71
Exploitation et préparation du charbon	837,7	5 945,2	67
Traitement des minéraux	753,0	14 469,9	181
Technologie des combustibles	2 855,5	16 868,0	187
Métaux et matériaux	1 084,1	9 031,3	137
Information technologique	38,4	2 570,3	33
Services techniques	118,4	2 421,8	47
Gestion et soutien (Administration centrale de la Direction seulement)	155,6	4 365,1	50
Subventions et Contributions		377,0	
APPLICATION DE LA LOI CANADIENNE SUR LES EXPLOSIFS			
Mise à l'essai et recherche en matière d'explosifs	45,5	63,8	12
TOTAL	6 577,1	62 752,3	785