# The Mines Branch



DEPARTMENT OF MINES AND TECHNICAL SURVEYS

**MINES BRANCH**

●

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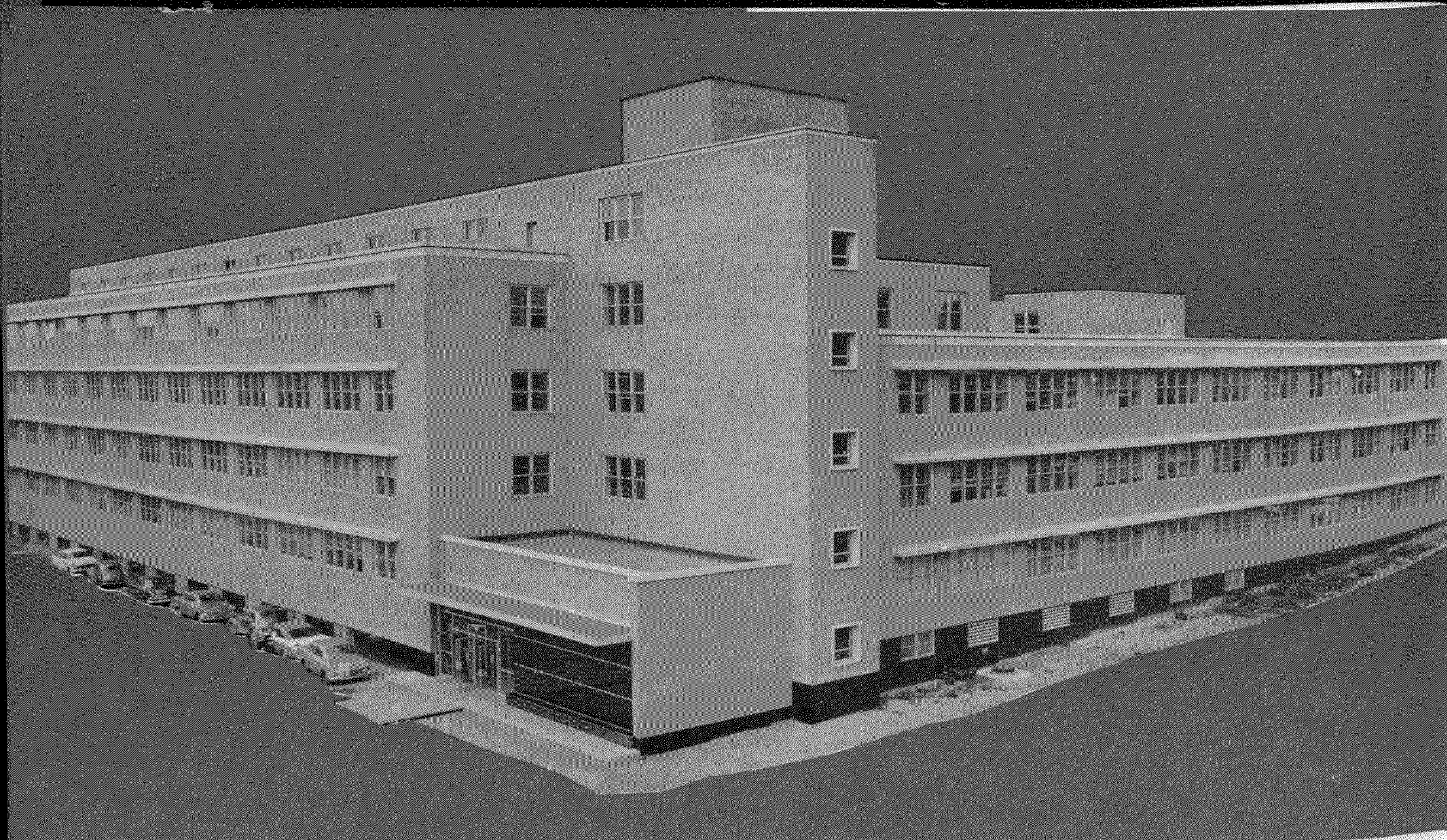
# Foreword

THIS account of the activities and facilities of the Mines Branch was prepared to enable a ready understanding of the role and capabilities of its laboratories in assisting in the development of Canada's wealth of metals, minerals and fuels.

The growth of the Branch in buildings, scientific staff and equipment has been an accomplishment of many years and has proceeded at a rate commensurate with the increase in importance of the mineral and associated industries in Canada. During 1959, concurrent with the occupancy of additional spacious laboratories in a large new building, there was a substantial reorganization which has regrouped a major part of the functions and services of the Branch in three new divisions now known as Mineral Processing Division, Extraction Metallurgy Division and Mineral Sciences Division. There are three other divisions: Physical Metallurgy Division which continues research and development in metals; Fuels and Mining Practice Division (formerly Fuels Division); and Technical Services Division (shops and mechanical services).

The Government of Canada, in providing these facilities and a growing staff of scientists, recognizes the importance of research in expanding the utilization of the country's minerals. Many further changes can be expected in the years ahead for a research institution cannot remain static and increasing emphasis will need to be given to fundamental research to deal with the complex ores and develop new products. The Mines Branch will continue in its historic role of developing new sciences and new technologies in order that Canada may do its part in meeting the rising tide of world needs for products of the mines.



# The Mines Branch

CANADA has a wealth and variety of mineral resources which can give the country increasing strength as an industrial nation but its progress is dependent upon the development efforts and research applied to the utilization of the specific minerals.

The research activities of the Mines Branch are geared to meet the challenge. They are concerned with the processing, production, utilization, and marketing of Canada's ores, minerals, fuels and their products.

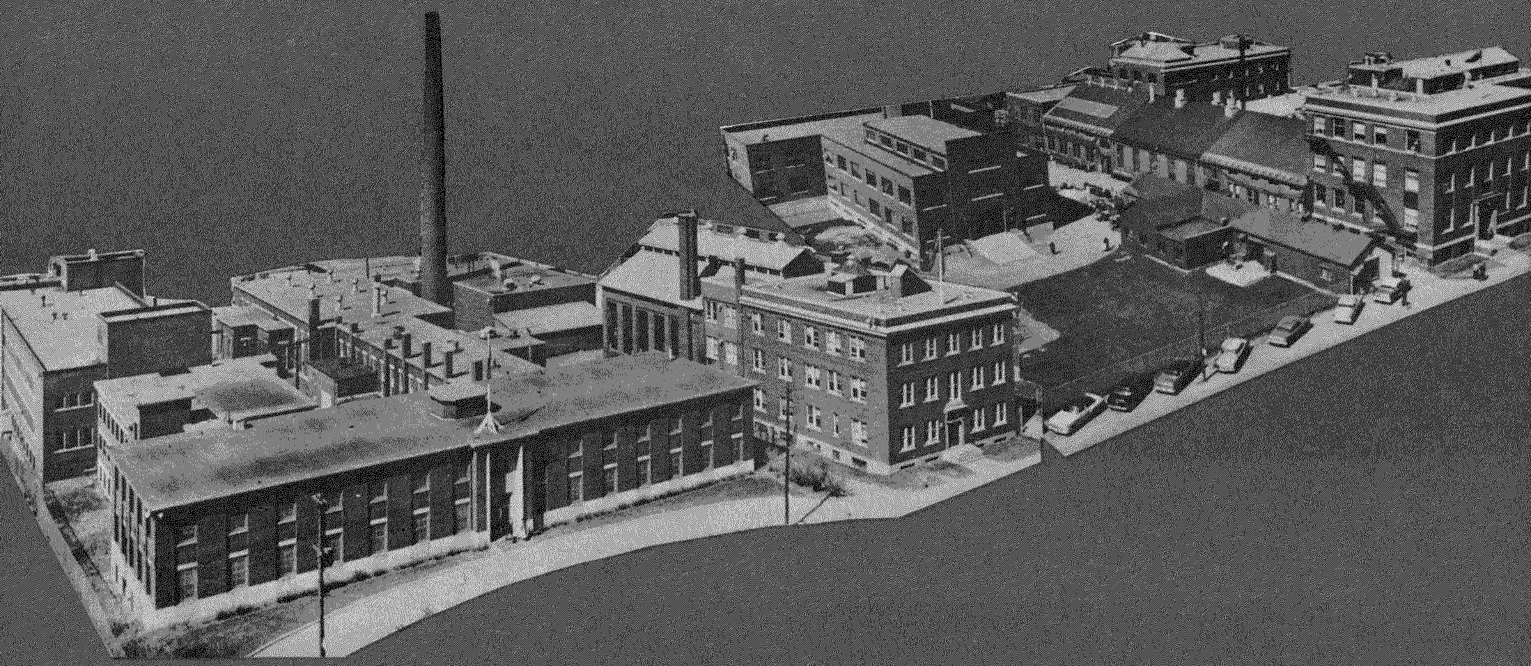
The Branch has its main laboratories in Ottawa and smaller units in Alberta and Nova Scotia.

Its assistance to industry takes in five fields of endeavour and is carried out in five divisions: **Mineral Processing,** the processing of metallic and non-metallic ores and the technology and utilization of industrial minerals; **Extraction Metallurgy,** with emphasis on research to develop cheaper methods of ore treatment; **Mineral Sciences,** covering the fields of analytical chemistry, mineralogy, physical chemistry, physics and radiotracer science; **Fuels and Mining Practice,** the economic development and utilization of Canada's fuel resources and investigations of mining problems, including underground stresses; and **Physical Metallurgy,** covering all phases of physical metallurgical science and engineering.

This research work is of a twofold nature: 1) applied research and technical services to assist industry, the Department of National Defence, and Atomic Energy of Canada Limited in solving immediate problems related to metals, minerals and fuels, and 2) fundamental or creative research which looks to the future needs of industry. In the light of the rapid pace of industrial development the Branch plans a much greater concentration of effort on long-term and basic investigations which will range over the fields of complex ores, potential new mineral products from Canadian sources, fuels technology, and metals for use in new alloys possessing strength at high temperatures.

In the national interest, the Branch undertakes necessary development work on ores, industrial minerals, and fuels, and on the technological problems of the metal-producing industries. It does much of its work at the specific request of industry. Also, if it is in the national interest, it permits a private company to conduct experimental work in its laboratories. It does, however, attempt to discourage requests for routine tests and assays by maintaining charges slightly above the scale of charges for these particular services by commercial laboratories.

The Canadian mineral industry is forging rapidly ahead. The extent to which Canada realizes the value of its great mineral potential depends largely upon the extent to which it makes use of the key to this wealth — research.



# HISTORY

BEFORE the dawn of history, man was engaged in mining and in crudely extracting metals in his struggle to improve his way of living. Through the centuries the development of science in very large part has related to the utilization of minerals.

In Canada, the need for developing methods of mining and of treatment of ores became increasingly apparent after 1850 as evidence of mineral wealth accumulated. In quick succession, gold, copper, lead, silver, and zinc ores were found in British Columbia, nickel-copper ores in the Sudbury area, silver at Cobalt and gold in the Porcupine, Kirkland Lake and Larder Lake areas of northern Ontario. Prospecting soon spread far and wide across the country and resulted in scores of discoveries of ores and minerals that required research and investigational work.

To assist the fledgling Canadian mineral industry in solving the problems involved in developing the country's wealth, the Mines Branch was established in 1907 under the Mines and Geology Act. Its first assignment was to investigate the coal deposits of Canada and its first unit was a fuel-testing station on Booth Street in Ottawa at the present site of the Mines Branch. This was followed in 1911 with the organization of a mineral-dressing group and the construction of a mineral-dressing laboratory.

As Canada expanded industrially, increasing applications for the products of the mines included the non-metallics. Demand for such minerals grew rapidly and to assist in developing this section of the industry the Branch in 1938 added industrial minerals laboratories to its Booth Street facilities to carry out the extensive research and investigational work required on their processing, use and marketing.

Under the impetus of a strong export market and a steadily growing domestic demand, the Canadian mineral industry expanded rapidly as did the demand for the services provided by the Branch. By 1939 its staff had multiplied to many times that of the first laboratory unit and had reached 147 persons.

Early in World War II, the importance of physical metallurgy to the war effort became apparent. The Branch work in this field, previously very limited, expanded rapidly to keep pace with Allied war needs. New physical metallurgy laboratories were erected on Booth Street and Branch activities on metals and alloys quickly became a recognized integral part of Canada's war work and later of its rapid industrial expansion.

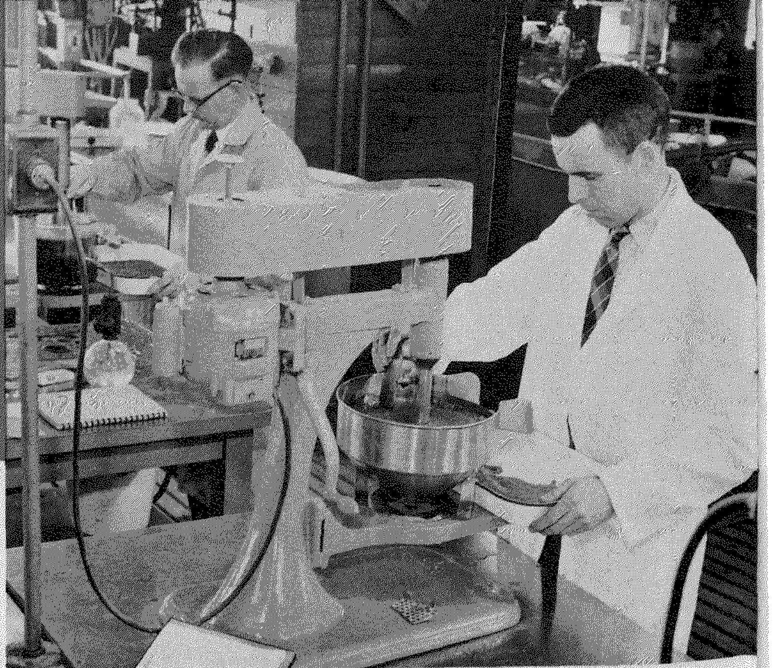
In the closing years of the war, uranium made a behind-the-scenes appearance in Canada's mineral industry. The urgent expansion of research in processing radioactive ores led to the establishment in 1948 of separate Branch radioactivity laboratories and these became an important factor in Canada's emergence as a leading world source of uranium.

During the next decade the almost phenomenal growth of Canada's mineral industry and the striking changes in the trends in metal and mineral requirements necessitated a marked broadening in the scope of Branch research. In 1959 the Branch reorganized its ore-processing and associated activities, regrouping the former Mineral Dressing and Process Metallurgy, Industrial Minerals and Radioactivity divisions into three new units: Mineral Processing Division, Extraction Metallurgy Division and Mineral Sciences Division.

Today, the highly organized research activities of Mines Branch engage a staff of 650 persons in a $15 million plant. The activities embrace all fields of mineral endeavour and are directed primarily to assisting industry to make marketable products from Canadian mineral deposits.

# MINERAL

# PROCESSING



**Engineers carry out flotation tests on copper-nickel ores.**

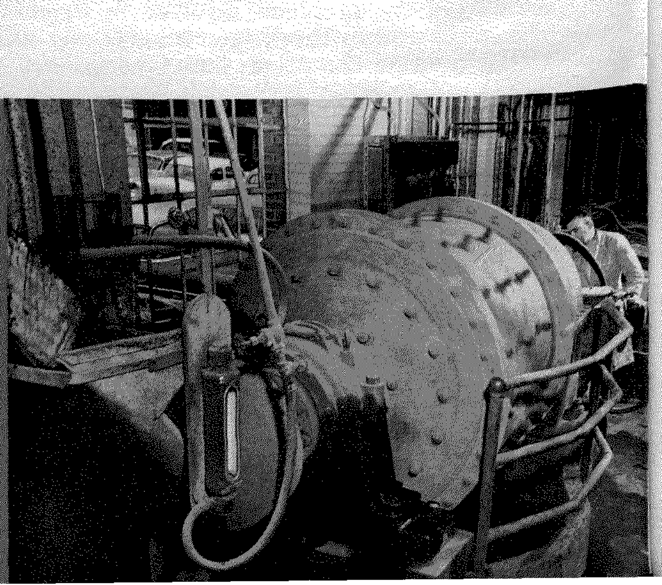
METALS and minerals must be won economically from ores in the best interests of industry and of mineral conservation.

The Mineral Processing Division is primarily concerned with the development of economical methods of processing Canadian ores and minerals and with carrying out research into ways and means of improving present processes to make operations more profitable. It works with all types of Canadian ores, metallic and non-metallic. In the latter field, it carries out tests, research and investigational work on industrial minerals, including water for industrial purposes.

The Division is completely equipped to carry out laboratory and pilot-plant investigations by crushing, grinding, gravity concentration, sink and float separation (heavy media), magnetic concentration, electrostatic concentration, amalgamation, cyanidation, flotation, and roasting.

Because of the wide variety of ores received for testing and investigation, divisional mineral-dressing engineers must be adept at adapting mineral-dressing techniques to the beneficiation of ores in order to be able to devise the wide variety of treatment methods called for. From laboratory studies, they determine what problems are likely to arise during the processing of an ore, work these out, report fully on their tests, and suggest a flow sheet to the company con-


**Mill foreman adjusts the impact crusher before starting to crush an iron ore from northern Ontario.**



**Ball mills are used to grind practically all Canadian ores. They are also used for research to arrive at the most efficient grinding methods.**

cerned. The company is then in a position to determine the design of its new plant and the amount of capital outlay necessary to bring the property into production. Apart from ore examination and testing, the Division handles an average of 95 mineral-dressing investigations annually on both metallic and non-metallic ores.

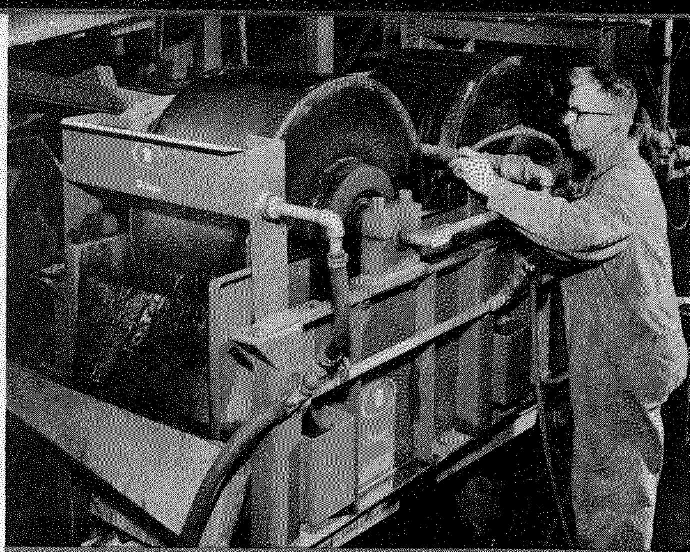
The bulk of the ores received for testing and investigational work in recent years have been non-ferrous base metal and iron ores. However, many of Canada's gold mines, which are sandwiched between rising costs and a fixed price for gold, have also sought technical assistance in an effort to reduce their costs and improve their metallurgy. In the period 1954-58 alone, the Division accepted and successfully completed over 40 requests for investigations on gold ores. In the 1930's, it was the Division's outstanding work on the development of processes for the treatment of many of the gold ores of the Kirkland Lake and other camps that helped to spell work and prosperity for gold-mining areas when the rest of the Canadian economy was battling the depression.

Today, perhaps the Division's most extensive work on metallic ores concerns the concentration of low-grade iron ores. Canada has great tonnages of low-grade concentrating iron ores. These have gained much popularity with the steel industry because the use of beneficiated ores has made possible an increase of as much as 20 per cent in blast furnace output.

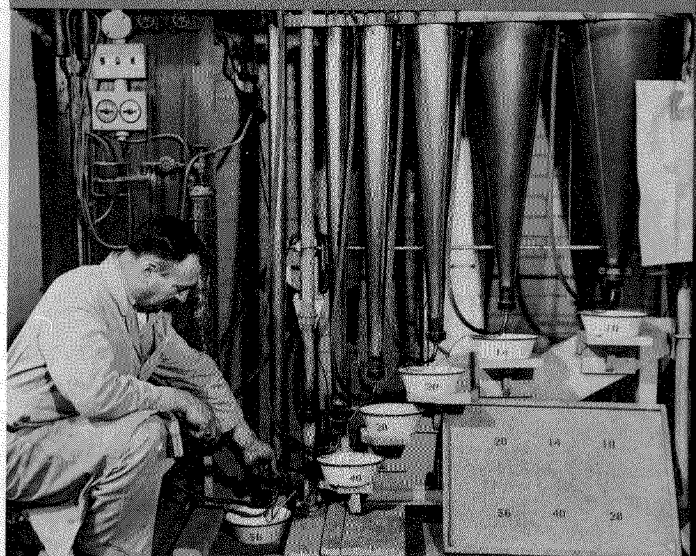
The Division, for instance, ran pilot-plant tests on material from iron ore deposits in the Ungava area of Quebec. These deposits are of interest because of the availability of markets in Europe through water transportation and of large markets in North America by means of the St. Lawrence Seaway. The tests showed that certain of these ores can be beneficiated magnetically to produce high-grade iron concentrates commercially acceptable to the iron and steel industry both in Europe and on this continent.

Many of the various ores coming to light are low-grade and complex, such as the niobium ores of Ontario and Quebec. Divisional engineers, working with metallurgists of several companies, have made substantial progress in the treatment of these ores. They have shown, in pilot-plant runs, that acceptable grades of concentrates can be produced by continuous flotation.

In other recent projects, they also carried out a pilot-plant investigation of a complex lead-zinc ore from the Bathurst area of New Brunswick, the results of which enabled the company to build a 150-ton pilot mill near Bathurst. They ran beneficiation tests on an

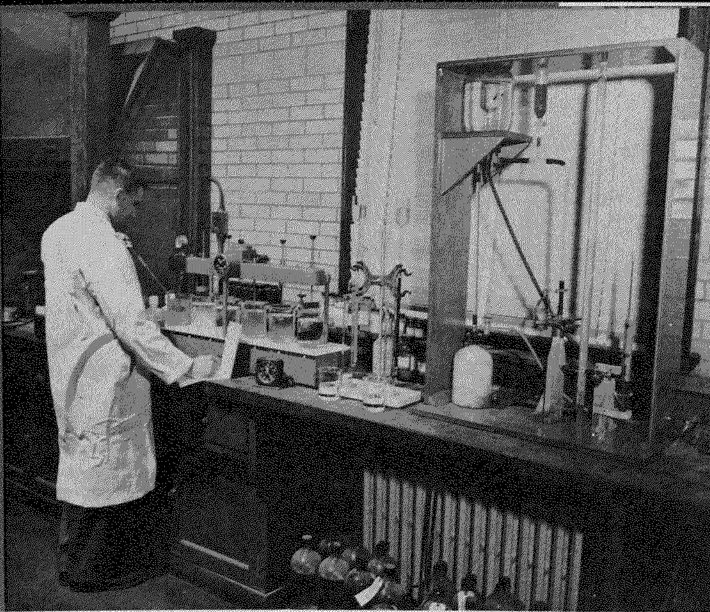


A large percentage of the wide variety of ores received for investigation are iron ores with a resultant high demand for magnetic concentration tests.



The infrasizer is an important aid in investigations on complex ores. It splits the minus 200-mesh fractions into seven parts, varying from minus 74 to minus 10 microns.

Froth flotation is by far the most widely used method of mineral beneficiation. An engineer tests a flotation procedure on an ore from a copper-zinc property in western Quebec.



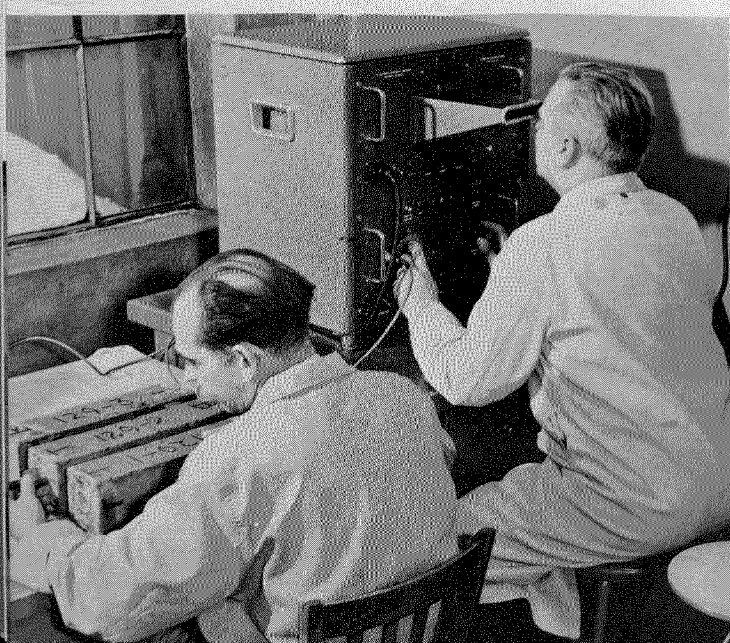
(Left)
The Branch is carrying out a comprehensive survey of Canada's industrial waters and it has published reports on water quality in most areas of the country. A chemist analyses water from Yukon.

(Right)
In the field of non-metallics, electrostatic methods hold much promise for the effective separation of minerals from unwanted material in ores. An engineer uses the method in the recovery of graphite.

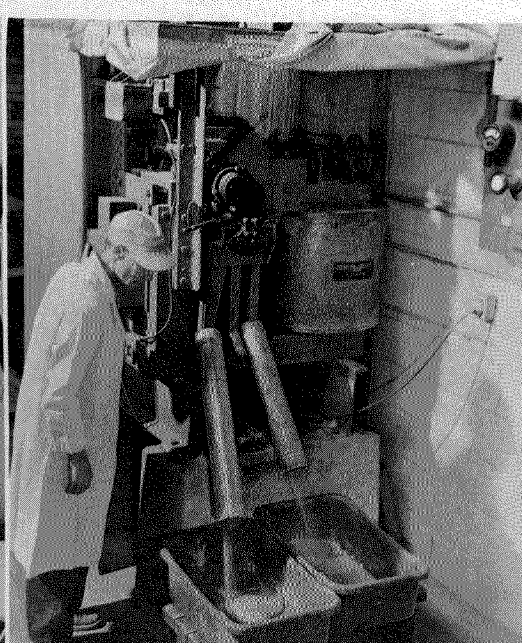
iron and titanium ore from Quebec, which led to the design of a new concentrator by the company. And they did extensive work, including gravity, magnetic roasting, and flotation tests on a low-grade manganese ore from Woodstock, New Brunswick, which resulted in sufficient beneficiation to permit the production of a commercially acceptable ferromanganese alloy by means of electric smelting.

In its study of Canada's non-metallic ores, the Division directs much of its effort to the development of methods of beneficiating products from low-grade deposits to assist industry to replace imported materials with Canadian products. It has, for example, indicated the possibility of a new Canadian industry by working out a method for concentrating the kyanite in northern Ontario deposits, which gives good recoveries. Moreover, it has developed a method for treating the concentrate so that it can be used in super-duty refractories in the metallurgical, glass and metal industries. At present, Canada imports its requirements of high-purity kyanite used in the manufacture of high-temperature mullite refractories. Testing has shown that the physical properties of mullite bricks made from the fortified mullite aggregate, which the Division obtained from its treatment process, compare very favourably with those of imported mullite refractories.

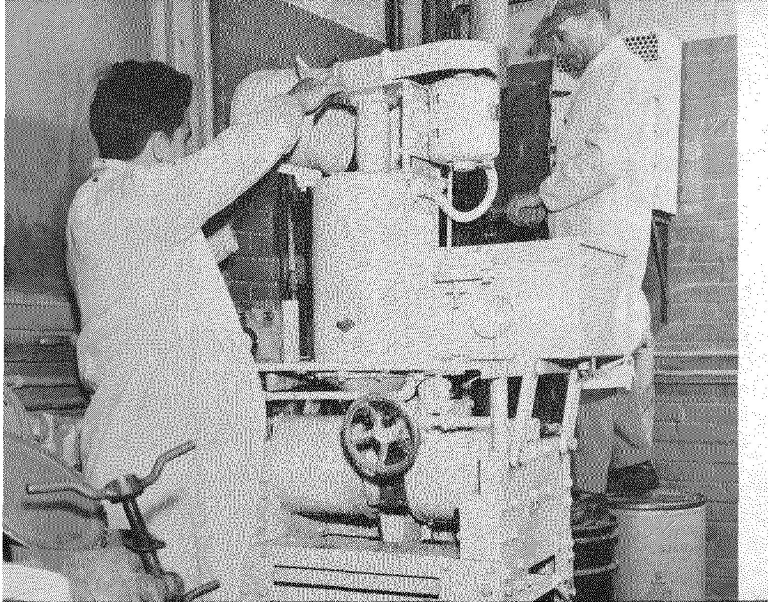
In a cross-section of projects, the Division is making a comprehensive study of the physical and chemical properties of asbestos—Canada's most important non-metallic commodity in annual dollar value—and the correlation of these properties with performance in industrial applications. It is investigating methods of recovery and the preparation of garnet from gneisses in the Sudbury area of northern Ontario for use in the abrasives industry, which imports its garnet re-



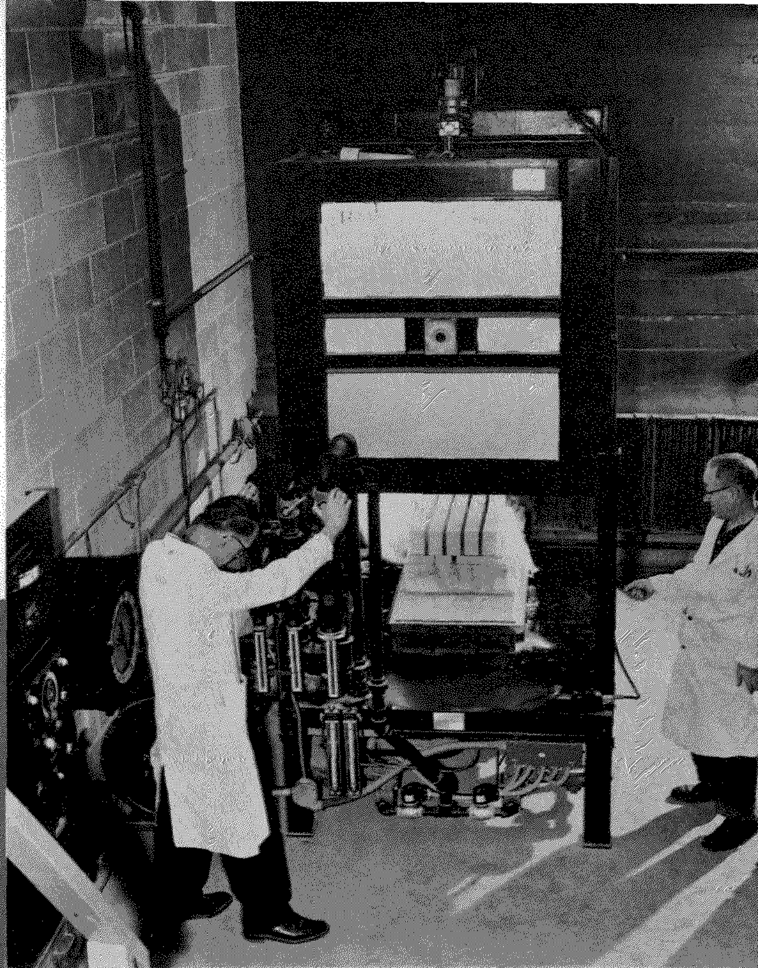
(Left)
Scientists determine the ultrasonic pulse velocity in concrete made from different types of stone aggregate, which has been exposed to accelerated freezing and thawing.



(Right)
Magnetic separation is being used in the concentration of kyanite.



The Jones high-intensity wet magnetic separator has introduced very promising possibilities in the concentration of weakly magnetic minerals. This is the only installation of its kind on this continent.



The Branch has developed methods of processing Canadian kyanite and alumina for use in refractory grogs working at temperatures of up to 3500°F.

quirements from United States. And it is running concentration and calcining tests on magnesite rock from British Columbia as potential refractory material. Preliminary tests have proved successful.

Another project involves a long-range study of all types of Canada clays and shales, including the determination of all physical and chemical properties and mineralogical analyses. This information will assist brick and tile manufacturers and other producers of ceramic products with processing problems and aid in the selection of suitable raw materials.

Industry is constantly seeking refractories for use at higher temperatures, under corrosive conditions, and for various special uses. The Division, which has complete facilities for refractories research and development, is working on the development of highly refractory mullite, high alumina super-duty refractories, castables, mortars and special refractories such as cermets.

Across Canada, the shortage of much-needed suitable construction materials to support the country's rapidly expanding industrial economy is a matter of much concern. Great difficulty was experienced, for instance, in locating sources of suitable aggregate for concrete for the construction of the St. Lawrence Seaway. The Division gave valuable assistance by locating and evaluating new sources of aggregate and by developing methods of upgrading the materials to permit them to meet required specifications for concrete aggregate. It is doing similar work in connection with hydro power developments and other projects.

Canada's rapid industrial growth has directed much attention to its industrial waters. The chemical quality of water is of vital importance both to established and to new industry seeking suitable locations in which to establish. Since 1948, the Division has been carrying out a comprehensive survey of waters in Canada and it has published reports on water quality in most areas of the country. Moreover, it is following up its broad surveys with special surveys to show such phenomena as seasonal variations, radioactivity and properties affecting irrigation.

Canada's abundant and varied mineral resources pose a constant challenge to the mineral-dressing engineer, a challenge which the Division's engineers are meeting by continually searching out, in their day-to-day research and investigational work, new concepts in winning mineral wealth from ores and new and improved techniques in mineral dressing.

# EXTRACTION METALLURGY

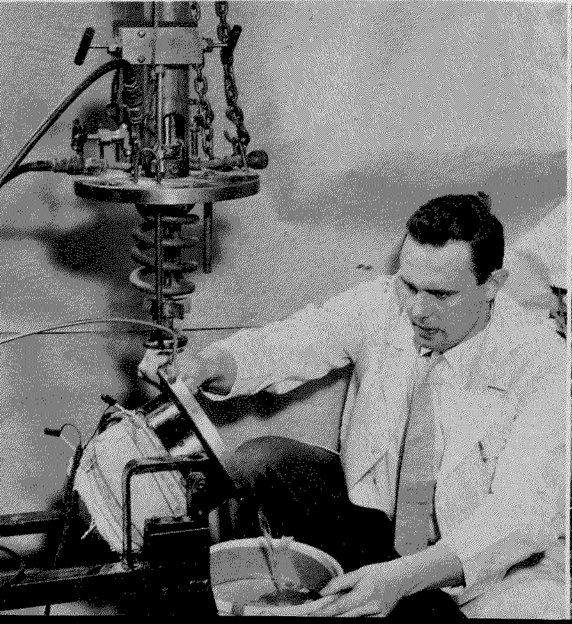
THE function of this Division is to encourage the efficient use of Canada's mineral resources. This it does through its studies and investigations in the field of extraction metallurgy. The Division accepts samples of ores or concentrates from holders of prospects or operators of new mining properties, and in cooperation with company engineers or consultants develops data that will assist in establishing efficient treatment processes adapted to Canadian conditions. Producing companies may also take advantage of the Division's facilities to improve their operations by arranging for investigations to be conducted in the Division under the joint guidance of their engineers and the Division's staff. In addition to these activities metallurgical problems that appear likely to be of general interest to Canadian industry are studied as opportunity affords.

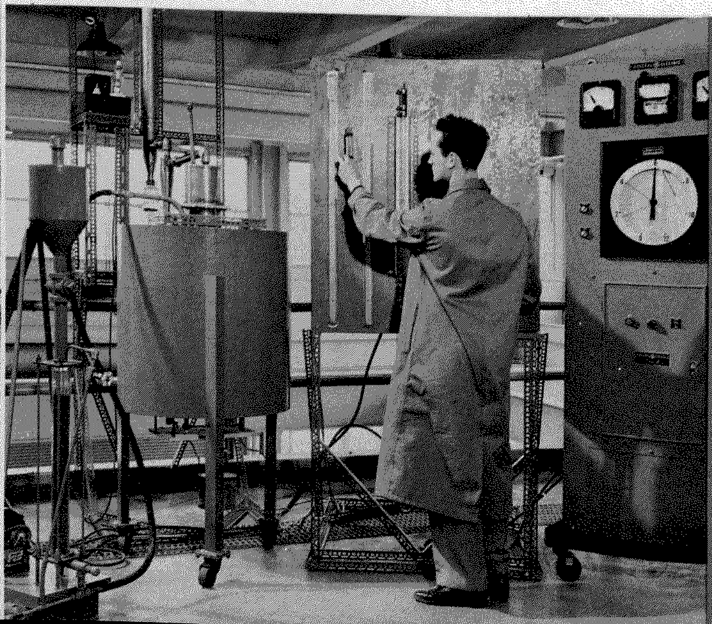
The Division is organized broadly into three sub-divisions. One is concerned with the development of hydrometallurgical procedures and has been interested in particular with the Canadian uranium industry. Another is concerned with ferrous and non-ferrous pyrometallurgical procedures and includes a section that deals with certain corrosion problems which are accepted by the Mines Branch. The third sub-division is a research group devoted to obtaining basic metallurgical data of special or general interest.

The Division has been closely connected with the Canadian uranium industry during its growth from a single mining operation in 1953 to a $320 million industry in 1959. When uranium appeared on the mineral horizon in the 1940's, the conventional uranium-ore-treatment methods were suitable only for treating high-grade ores. It was soon discovered that Canada's uranium ores are generally complex, low-grade and of varying nature. It was clear that a new approach was needed, including new methods of analysis and control, in devising treatment processes.

As the only organization in Canada equipped to do such work, the Mines Branch was required to undertake an extensive program of research in physical and chemical methods of extraction. Working closely with Eldorado Mining and Refining Limited, with consultants and with the engineers of uranium mining companies, the Division developed leaching processes, first for the ores of the Crown-owned properties and later for those of private companies. The diversity of Canada's uranium ores required the working out of new modifications of these processes to suit the ores of the various mining areas.

The milling operations at most of Canada's uranium properties are based on hydrometallurgical investigations, both laboratory and pilot plant, conducted in the Division. Moreover, many of the technical personnel at the plants and laboratories of these mines received their first introduction to uranium metallurgy in the Division's laboratories.





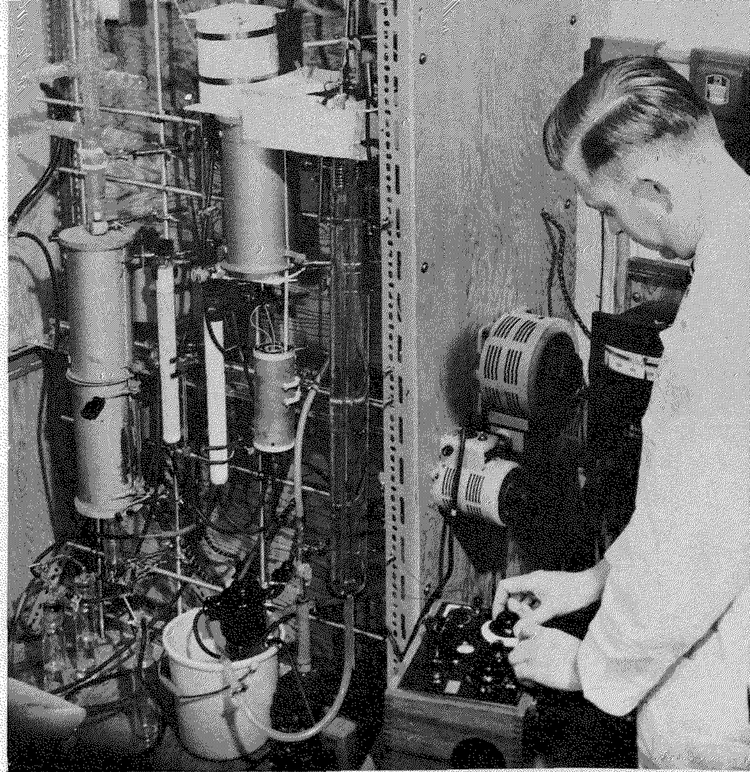
(Left)
Autoclaves, open vessels, and pachucas are used in studies to determine the optimum leaching conditions for ores, concentrates, and metallurgical products in acidic and basic solutions.

(Right)
Roasting in fluid beds is rapidly gaining acceptance in the metallurgical industry in operations where close control of temperature and gas composition are desirable.

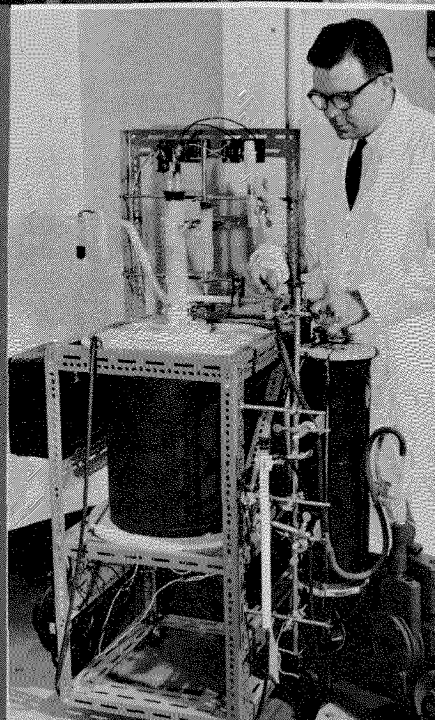
Continuing liaison with the uranium industry is provided through the Canadian Uranium Producers Metallurgical Committee which is composed of representatives of the mining industry, Eldorado Mining and Refining Limited, and the Division. This committee pools and correlates technical information dealing with the metallurgy of uranium and the related elements and helps to guide the research programs that are undertaken in the Division's laboratories.

The Division investigates and develops smelting techniques. This is done both on a small scale and in a continuous 250-KVA electric arc furnace installed in 1953 to explore applications of electric power in metallurgy. Furnace campaigns, using some 700 tons of ore, have shown that high-grade titanium slags can be made from Canadian ilmenites and that, by using a novel technique, commercial grade ferromanganese can be produced from the low-grade manganese ores that occur near Woodstock, New Brunswick. Manganese is essential in the manufacture of steel and owing to the lack of high-grade manganese deposits on this continent there is much interest in Canada's large low-grade deposits. In addition, it has been shown that marketable silicomanganese, spiegeleisen and ferronickel can be made from certain Canadian deposits.

Because of Canada's important position and potentialities as a producer of iron ores, extensive work on ore pretreatment is undertaken, such as calcining, pelletizing, sintering, and magnetizing roasting. Studies of various direct reduction methods have been made to assess their application in Canada, particularly with regard to the needs of the specialty steel industry and of the steel plants in western Canada. Studies of this type may lead to the marketing of ferrous products in more valuable form and the build-

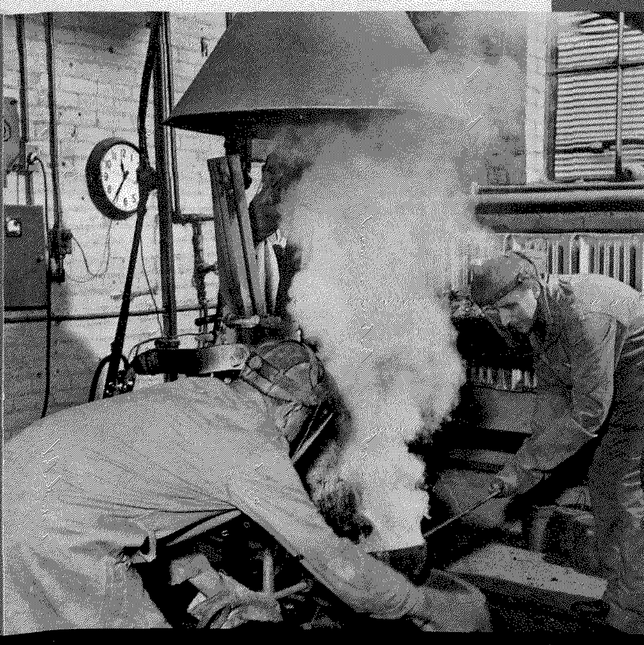


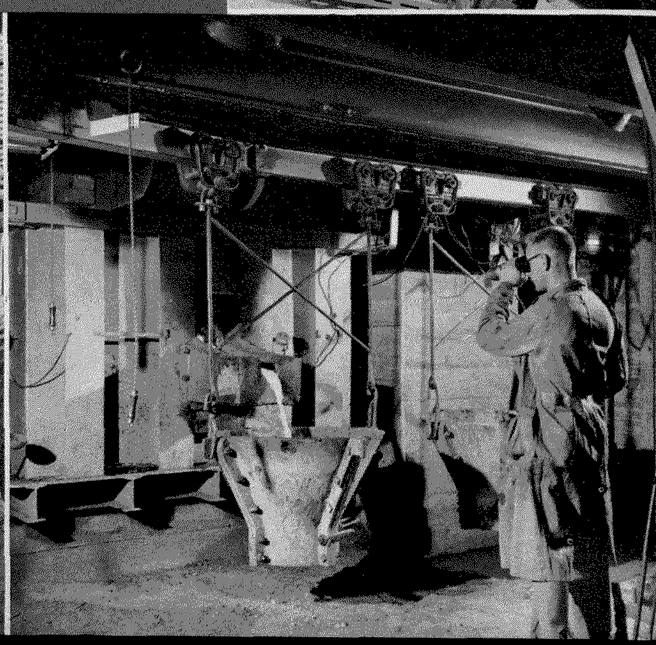
(Above)
A postdoctorate research fellow studies the conditions for the decomposition of iron and aluminum sulphates with the object of bringing about their separation from mixtures of the two.



(Right)
A scientist studies the electrochemical and thermodynamic properties of titanium chlorides in molten sodium and potassium chlorides.

(Left)
ngineers carry out a aboratory-scale invesigation of a lead-silver re in the 60 KVA elecric arc furnace. When varranted, follow-up ilot-plant investigaions are made on the 50 KVA electric arc urnace.





(Right)
lag is tapped from the 50 KVA electric arc urnace during a pilotlant investigation of n iron ore from northvestern Ontario.

(Photo by George Hunter).

ing of plants using indigenous non-coking coal as the principal reductant.

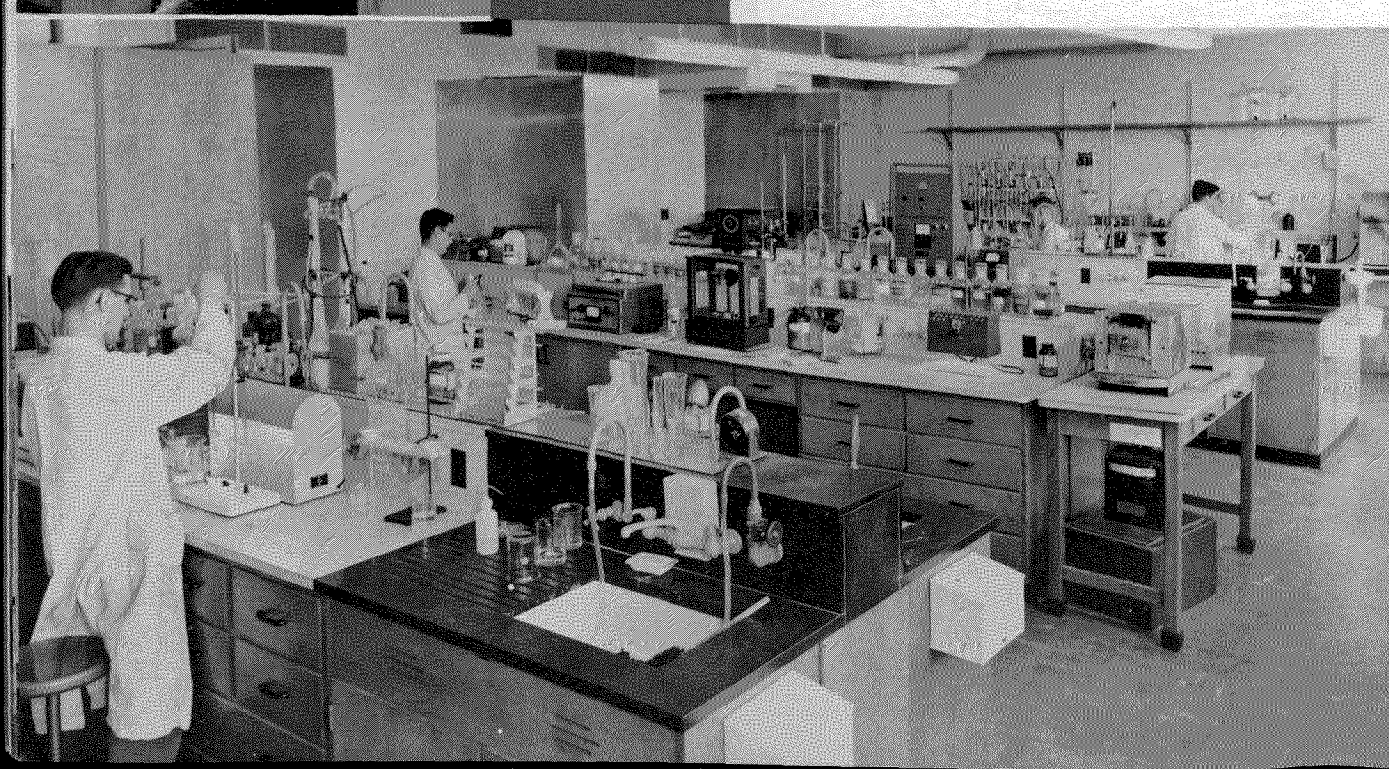
The Division investigates the corrosion and protection of the various metals and works with industry and other government departments toward reducing the annual waste of metal that takes place owing to this type of deterioration. During the five-year period 1953-58 it made about 130 investigations dealing with corrosion and its prevention on chemical and metallurgical process equipment, steel pilings, steam turbines, airframes and aero-engines, motor vehicles, army tanks and many other items.

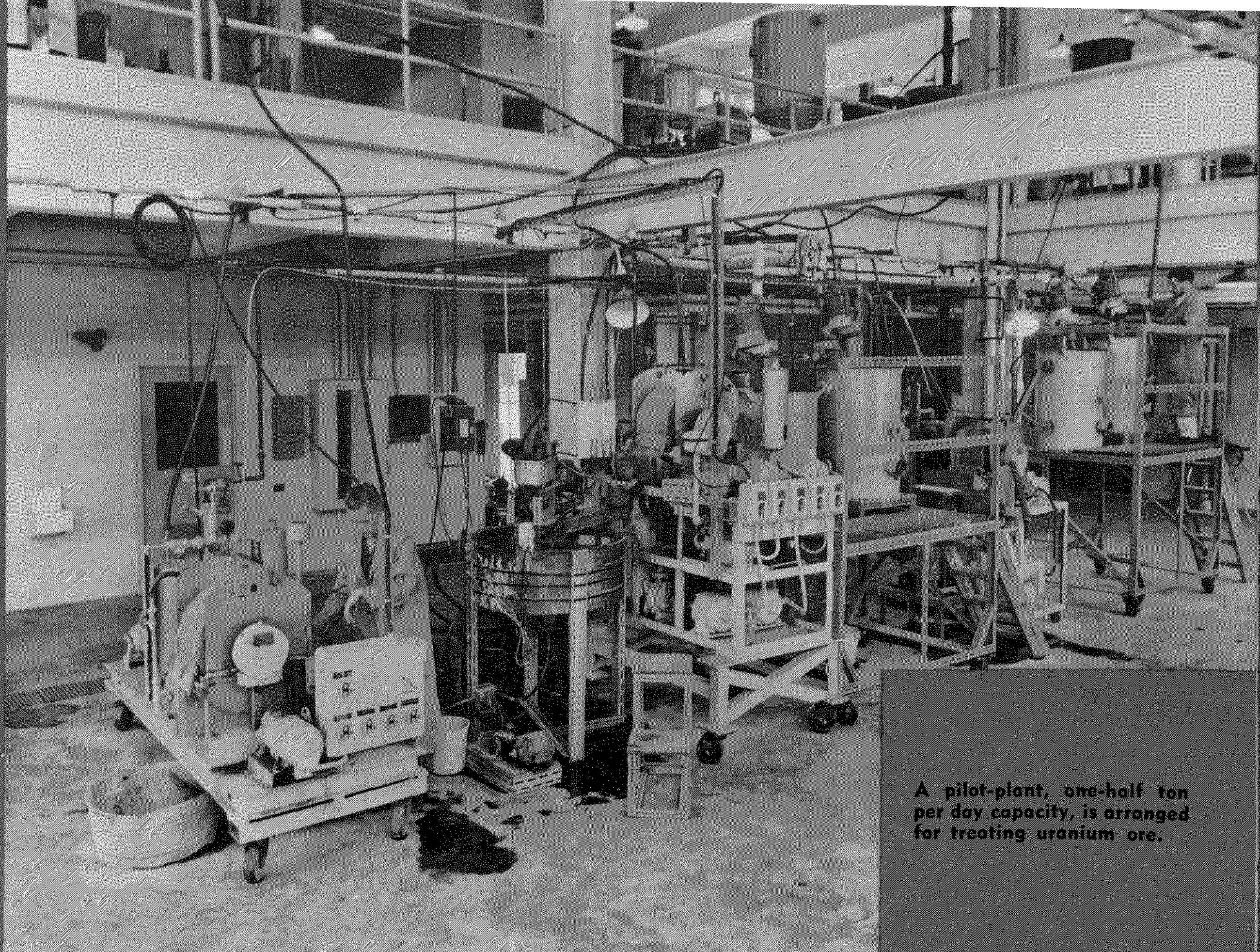
(Left)
**The Frantz isodynamic magnetic separator is a powerful and sensitive laboratory unit which makes delicate separations of many minerals not usually thought of as magnetic.**

(Below)
**The Branch carries out process development research for the recovery of metal values from ores and solutions by chemical methods on both laboratory and pilot-plant scales.**

The research activities of the Division may be broadly divided into short-term and long-term projects. Among the former is a study of the operating characteristics of hydrocyclones which are increasing in popularity for classification and dewatering operations in the processing of ores and minerals. In this study the influence of such variables as pressure, pulp density and the characteristics of the pulp are being examined. Another project is the study of the recovery of niobium from Canadian niobium concentrates. Niobium metal has properties of interest both in metallurgy and in nuclear reactor technology, but it appears that any major expansion in its use on this continent will have to be based on the utilization of Canadian niobium deposits. Since these are low-grade and yield comparatively low-grade concentrates, it is essential that efficient recovery processes be worked out if niobium is to be made available at a reasonable price. The chemistry of uranium leaching by sulphuric acid solutions is also under study, with particular reference to the role played by oxidizing agents in the dissolution of tetravalent uranium minerals.

Two short-term projects in reference to ferrous metallurgy are under way. One is an attempt to elucidate the mechanism by which lime reduces the transfer of sulphur from sulphur-bearing coals to iron in direct iron processes conducted in kilns. This is of importance if Canadian high-sulphur coals are to be used in direct reduction processes. A second project is a study of dephosphorization of iron in the oxygen converter process. This gives trouble at times in steel plants and an attempt is being made to reproduce in the laboratory the conditions existing in a top-blown converter. Radioactive phosphorous is being used in



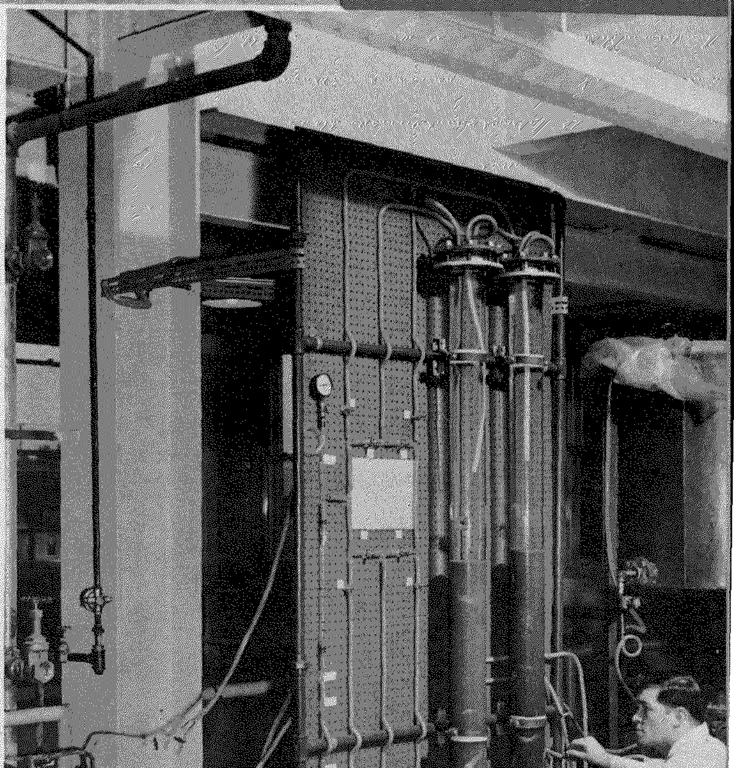


A pilot-plant, one-half ton per day capacity, is arranged for treating uranium ore.

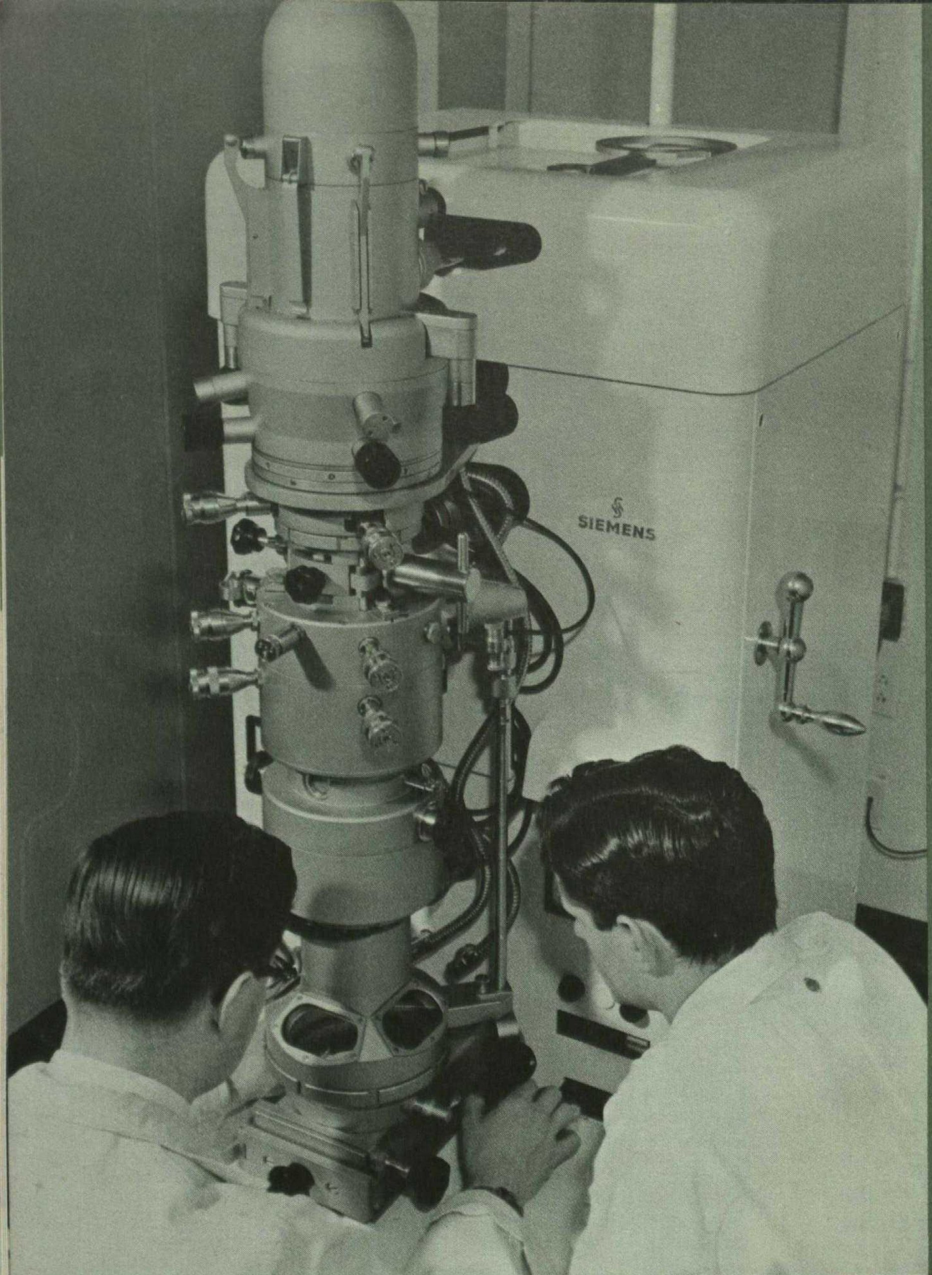
the work. A basic study of the kinetics of the reduction of iron oxide at high temperatures is also under way.

Among the long-term investigations is a project dealing with fused salt systems. This has become a very active field, as the possibility of recovering such refractory metals as titanium, zirconium and niobium by fused salt electrolysis is being realized. There are also possibilities in the nuclear reactor field where the technique might be used to separate uranium from its fission products. The program is designed to elucidate the basic chemistry of fused salt electrolysis so that its possibilities might be to some extent predictable and its potentialities thoroughly developed.

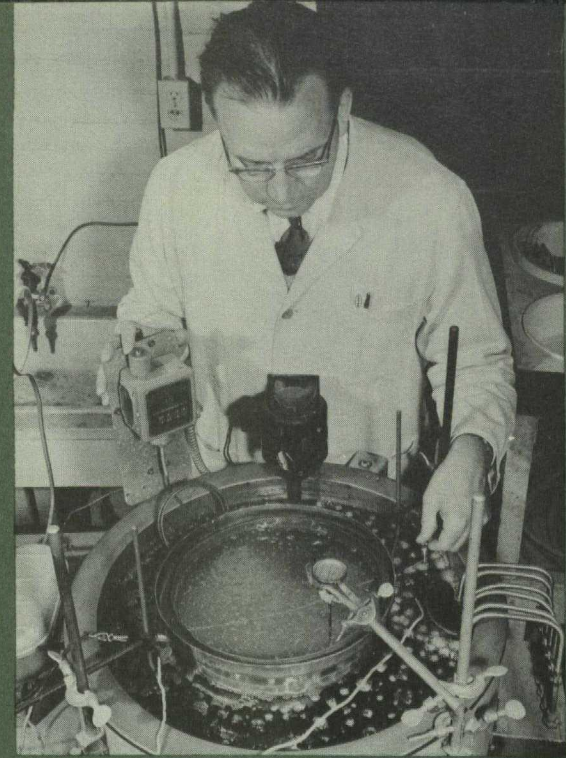
The task of the metallurgical industry is to utilize the mineral resources of the country to satisfy the needs of modern technology. Technology is evolving today at a pace never before equalled and only by using all the resources of science can metallurgy hope to meet the demands made on it.



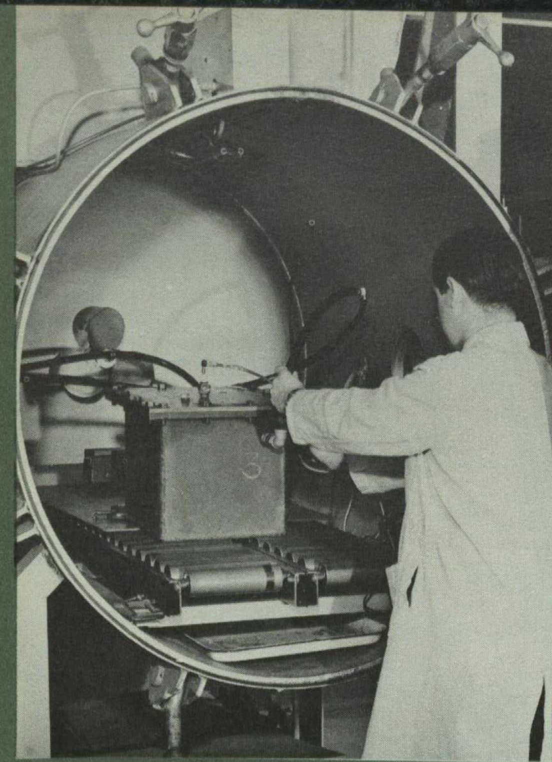
A two-column ion exchange unit is used in conjunction with the recovery of uranium from solutions produced in a leach pilot plant. Ion exchange has proved a valuable process in the treatment of uranium ores.




Fine-scale imperfections in metals exert marked influences on their mechanical behaviour. The electron microscope permits the study of metals at magnifications of up to one million times. It thus enables the correlation of the imperfections with the previous history of the metal and with its mechanical properties.

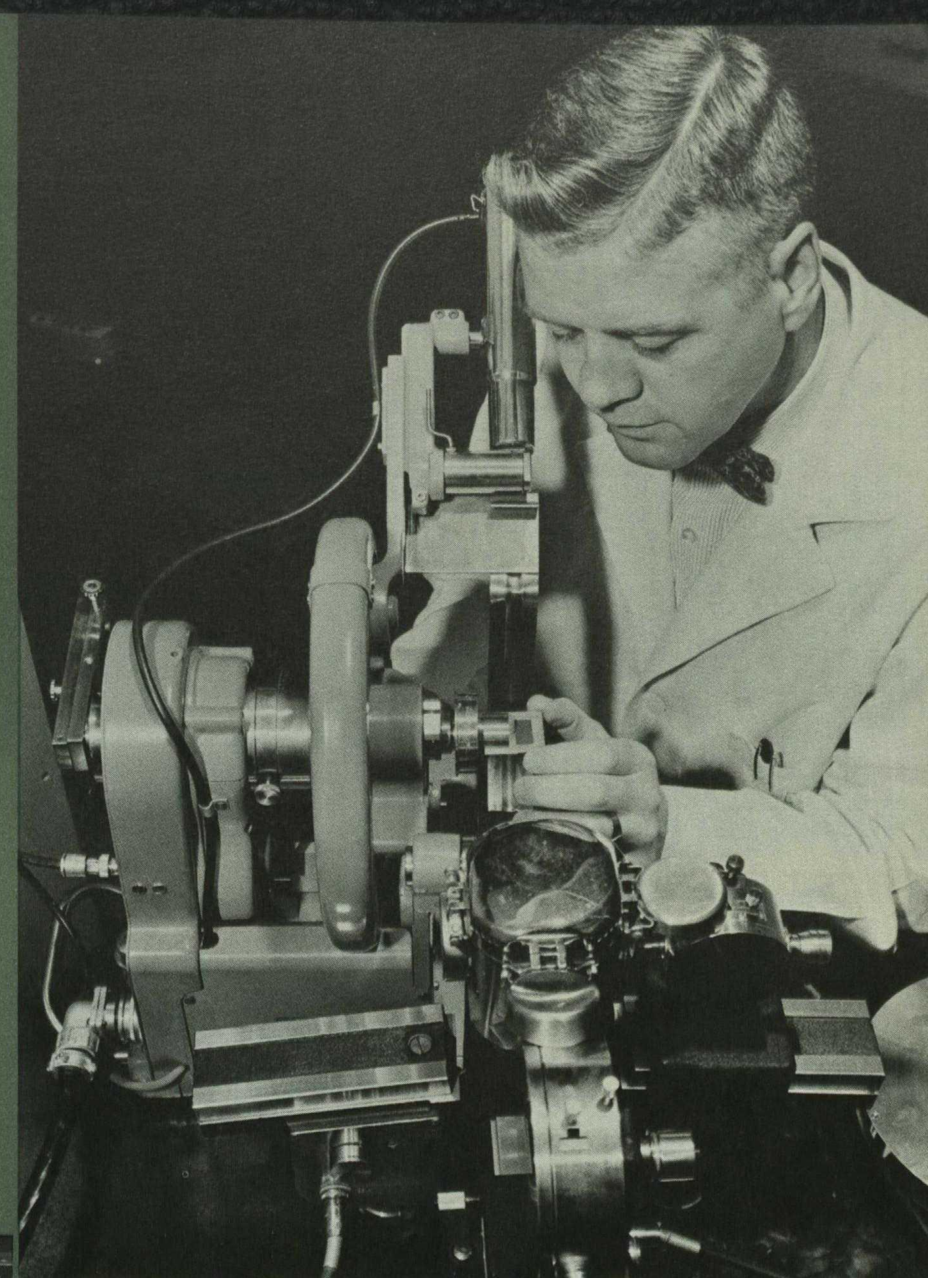


A scientist studies the corrosion resistance of niobium in an alkaline solution. Its corrosion resistance to acids is fairly well known.



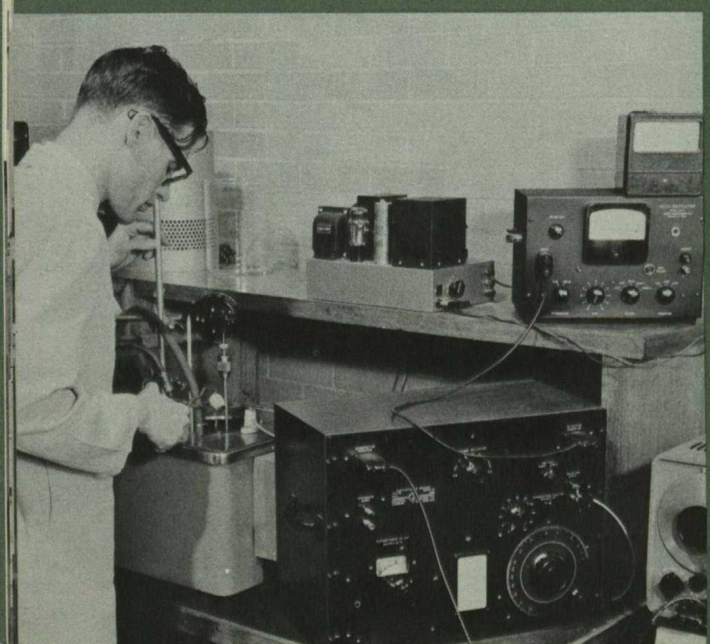
Electrical equipment operated in hazardous (explosive gas) locations in mines is tested in the Branch's electrical certification laboratory.

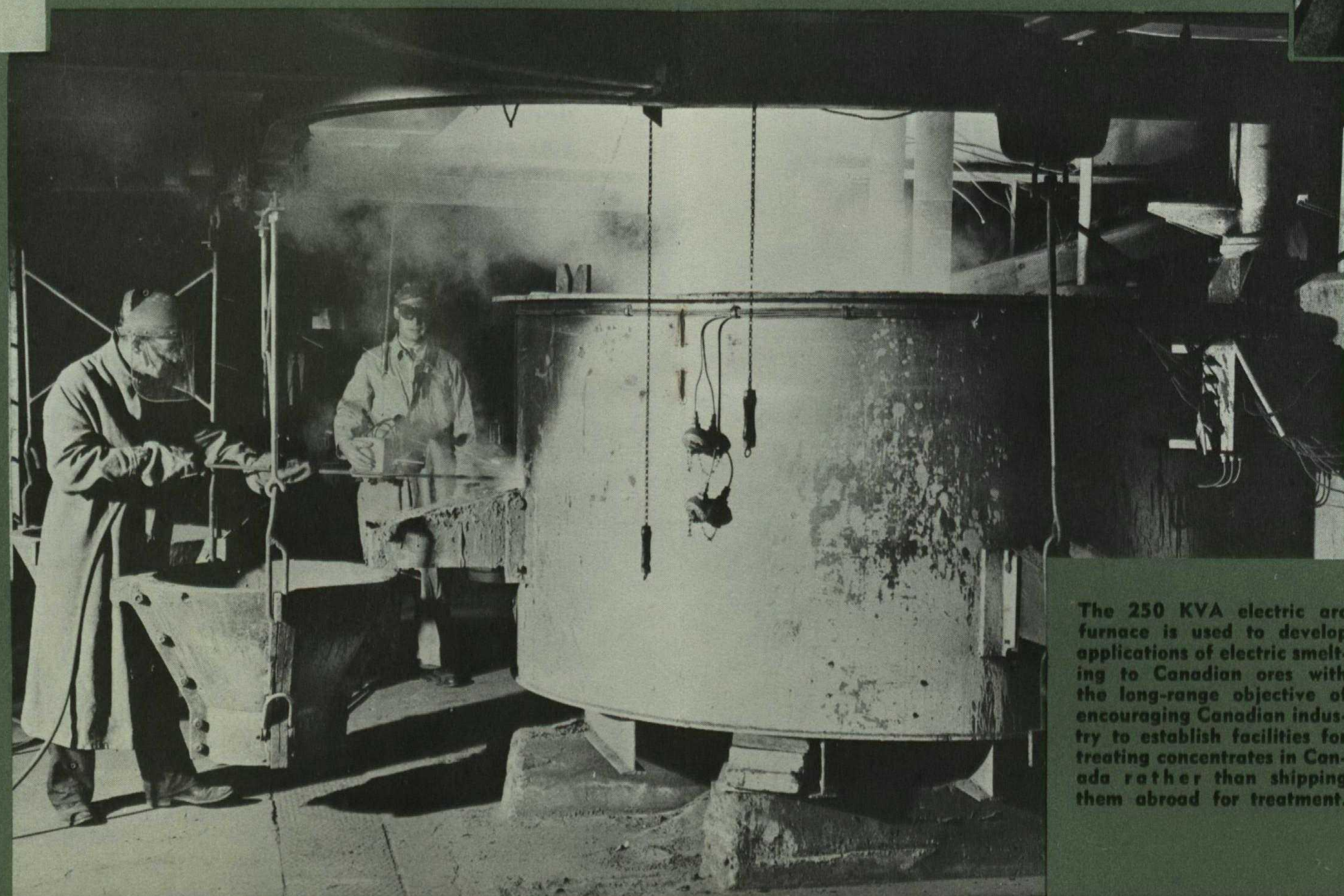
# Mines Branch research looks to Canada's needs of tomorrow...



X-ray diffraction equipment, showing powder cameras and operator mounting sample on diffractometer, is used for measuring quantities of minerals present in mixtures.

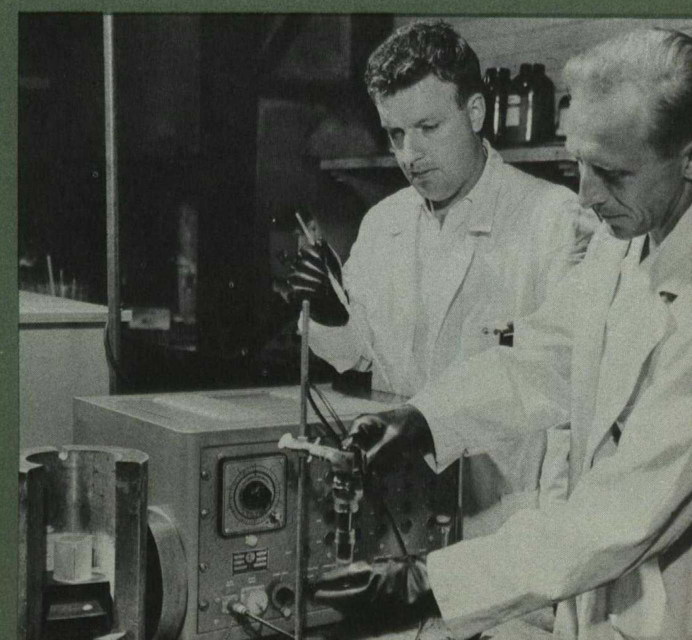
In its work on the development of piezo-electric ceramics, the Branch developed a superior composition which was found to be especially useful in high-power applications and which is now in commercial production.



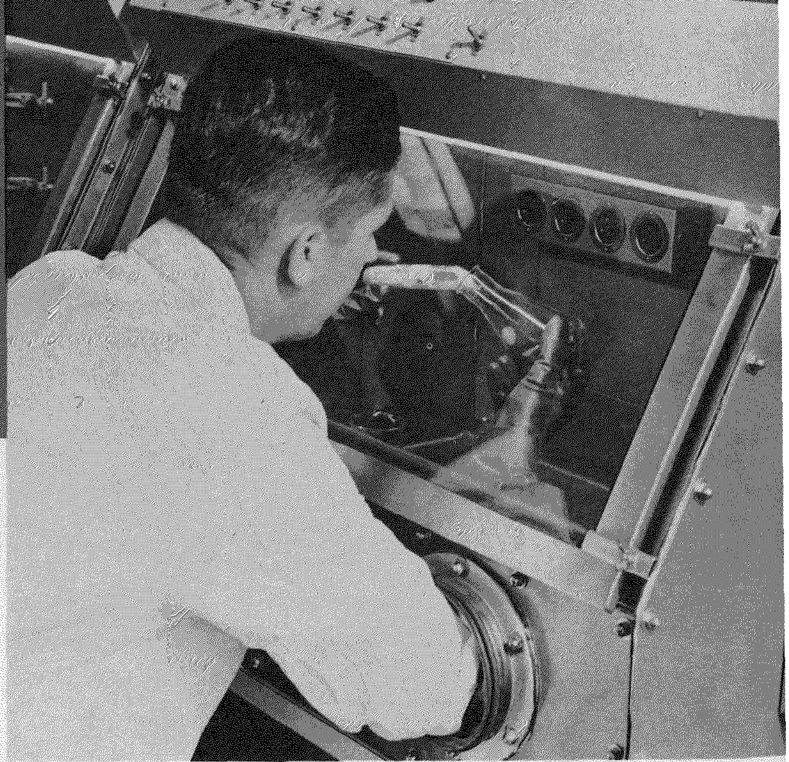


The 250 KVA electric arc furnace is used to develop applications of electric smelting to Canadian ores with the long-range objective of encouraging Canadian industry to establish facilities for treating concentrates in Canada rather than shipping them abroad for treatment.

Scientists make use of radioactive isotopes in their work in analytical chemistry.



# MINERAL SCIENCES



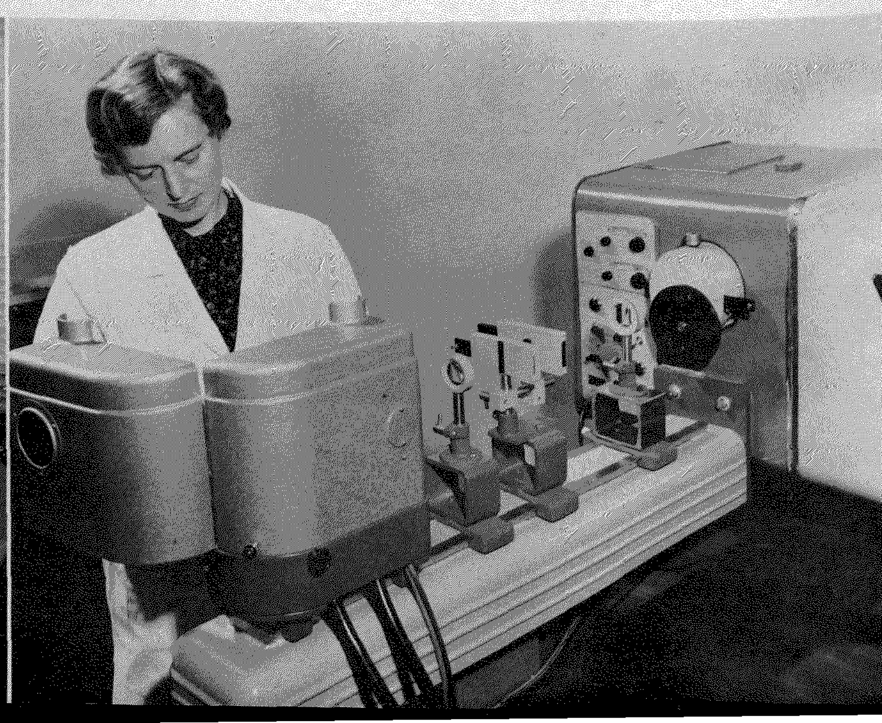
The 'dry box' permits work on highly reactive materials in controlled atmospheres, such as nitrogen, argon or completely dry air.

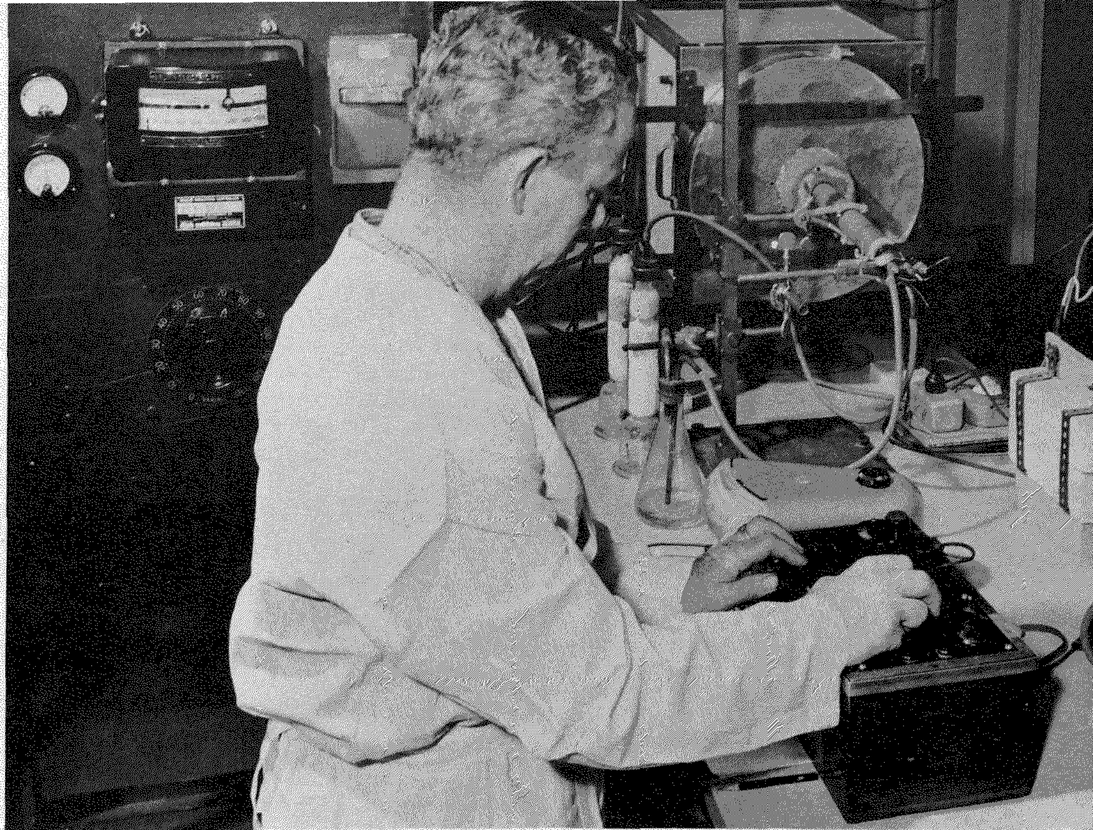
THE Mineral Sciences Division applies the sciences of chemistry and physics to fundamental and long-term problems arising in the field of mineral technology and related aspects of metallurgy. It deals with ores, mineral and metal products, inorganic crystalline materials and radioactive substances in modernly eqipped laboratories. Its work ranges from simple routine determinations to difficult research problems requiring the most modern scientific methods and equipment.

It channels its effort in four directions: analytical chemistry, mineralogy, physics and radiotracer work and physical chemistry. Its main function is to assist Mines Branch research and investigational work on base-metal ores, industrial minerals, ceramic products and all types of metals and alloys. It also assists industry and other government agencies in specialized investigations of the kind not usually performed by professional consulting laboratories.

Its scientists have under way, for instance, an ever-widening program of research in applied analytical chemistry to find new and improved methods of analysis to meet the more exacting demands of research and industry, mineralogical studies of ores in which the emphasis is on the more complex and low-grade ores; and research on the use of radioactive isotopes for the solution of industrial and research problems in close cooperation with plant operators and with research workers.

The analytical laboratories have modern instruments for spectrography, X-ray spectrometry, spectrophotometry, electrochemistry and radiochemistry. The emission and X-ray spectrographic laboratories work in conjunction with the chemical laboratory and, in many cases, afford the only satisfactory means of determining some elements, especially when present in extremely small quantities. The spectrograph is a very useful instrument when dealing with samples





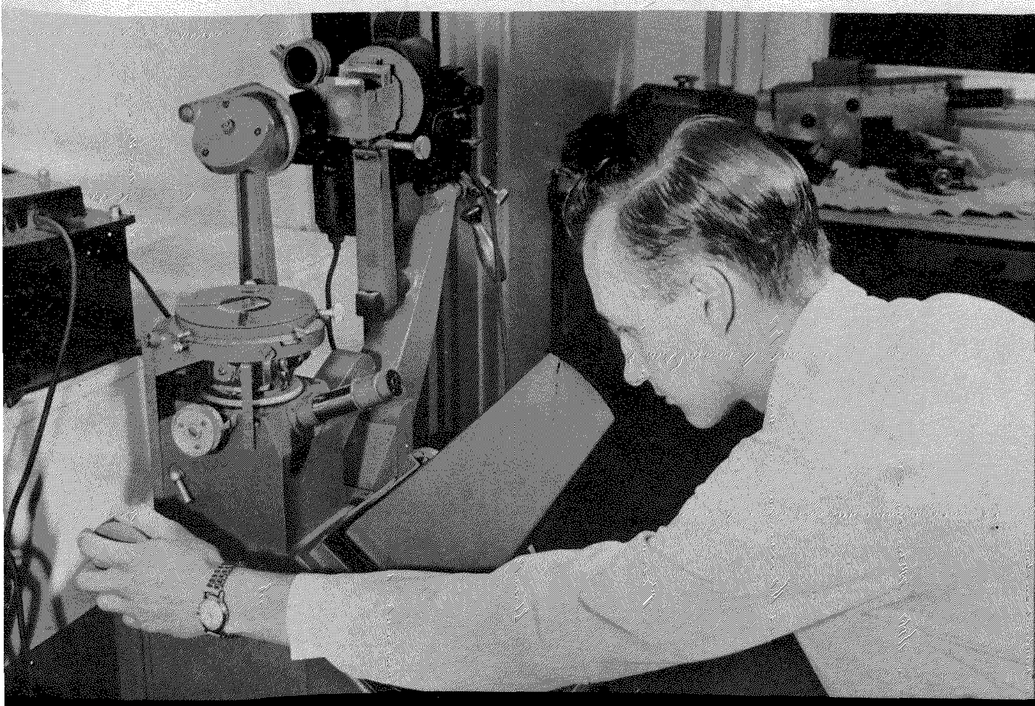
A high-temperature tube furnace is employed in the controlled atmosphere sintering of refractory materials. Temperature measuring and control equipment are also shown.

of unknown composition, since a quickly made spectrographic analysis will reveal the approximate composition of the sample and thus save the chemist much preliminary work, which otherwise would be necessary before he could proceed with the chemical analysis.

Because of the importance of rapid and accurate analysis to metallurgical investigations, the Division gives high priority to the development of new and improved methods of analysis. In this field, it is constantly bringing instrumental methods into use to replace older and slower techniques. It has, for instance, found that a combination of polarographic methods with controlled electrodeposition greatly simplifies the determination of impurities in certain alloys. Such determinations were formerly time-consuming and frequently inaccurate.

Divisional scientists are also making increasing use of radioactive tracer techniques, when applicable, in the search for new analytical techniques. Recently, for example, they applied radioactive isotopes to the problem of analyzing platinum metals in the face of industry's dissatisfaction with existing methods of analysis. The investigation is still under way but the use of this technique has already thrown light on some of the difficulties.

Mineralogy is of twofold assistance in dealing with mineral-dressing problems. The initial mineralogical study involves the identification of the minerals present, the determination of their composition, a study of their textures and intergrowths, and possibly a mineralogical analysis, that is, the determination of the percentage of each mineral present. The second



(Left)
A Leco furnace is used for the rapid determination of sulphur and carbon in metals and alloys.

(Centre)
Many elements in ores, minerals, alloys and mineral products may be determined in trace quantities by means of the emission spectrograph.

(Right)
Photomicrographs of mineral sections are taken with the Vickers microscope at magnifications up to 1000 times.

**Quantitative X-ray diffraction studies are done on a high-angle goniometer and recording equipment.**

phase is concerned with the study of beneficiation products to solve problems that arise during the course of the work, and to serve as a continuing guide as beneficiation progresses. The initial study is of considerable importance as it may well determine the general beneficiation program. Another important reason for a mineralogical examination is that unsuspected valuable constituents may come to light for which an analysis has not been made or requested. Mineralogical studies of this kind within the Division are directed toward the more unusual problems rather than to those of a routine nature.

One of the Division's recent studies of material from Canadian deposits involved a titanium ore which Branch engineers found difficult to concentrate. Mineralogical tests traced the trouble to a particular type of titanium-iron spinel. The composition of the spinel makes mechanical beneficiation impossible so other means of recovery now have to be found.

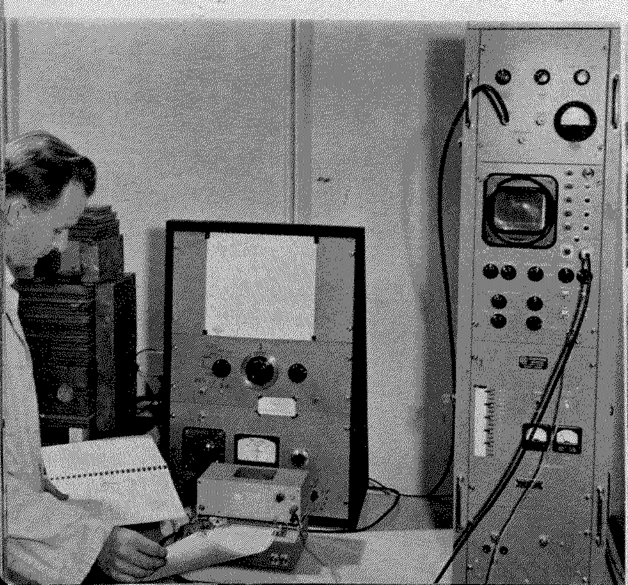
Another study revealed a niobium mineral, not hitherto described, in a Quebec ore deposit. The mineral was given the name 'niocalite'. Its discovery explains some of the problems which have been encountered in concentrating this ore. These studies also revealed that the ores of niobium are exceedingly complex.

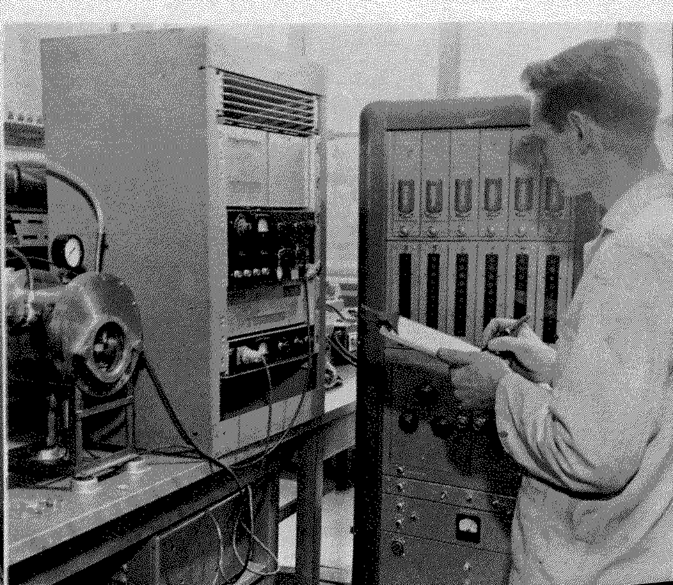
The Division's Physics and Radiotracer Section has three major functions. It makes determinations and assays of natural or artificial radioactive elements in ores and other substances. It works on the development of new methods and equipment for this purpose, and the design of electronic units and circuits for this and other research applications. It also does research on the application and development of methods for the use of radioactive tracers in industrial and laboratory problems, principally in the field of extractive and physical metallurgy.

Divisional scientists, for instance, are using tracers to study the movement of metal and slag in electric furnace operations and the adsorption of various elements on mineral particles to explore possible methods of large-scale tracing of mineral particles in ore-concentration processes. One of their recent developments is a viscometer with a radioactive timing device for measuring the viscosity of mineral slurries and molten metals.

Fundamental physical chemistry studies are proving increasingly valuable to industry in the solution of long-term process problems. The Division is stressing the phase equilibrium and constitutional approach and the sintering of refractory oxides. Its studies range from investigations of metallurgical slags to the elucidation of the important iron-titanium-oxygen system. Much of the basic work on the chemistry and sintering of uranium dioxide for use as a fuel element in atomic power reactors was done by this group. A recent project concerned quality control in the manufacture of refractory brick. The Division's studies of reactions occurring during the manufacture of the brick showed that such phenomena as slumping, marking, and sticking were due to a type of spinel compound, formed under certain conditions, which adversely affected the properties of the product.

From simple analysis to the complex investigation of constitution, such studies of ores, minerals, and their products pave the way to ensuring the economic utilization and sound conservation of Canada's wealth of mineral resources.



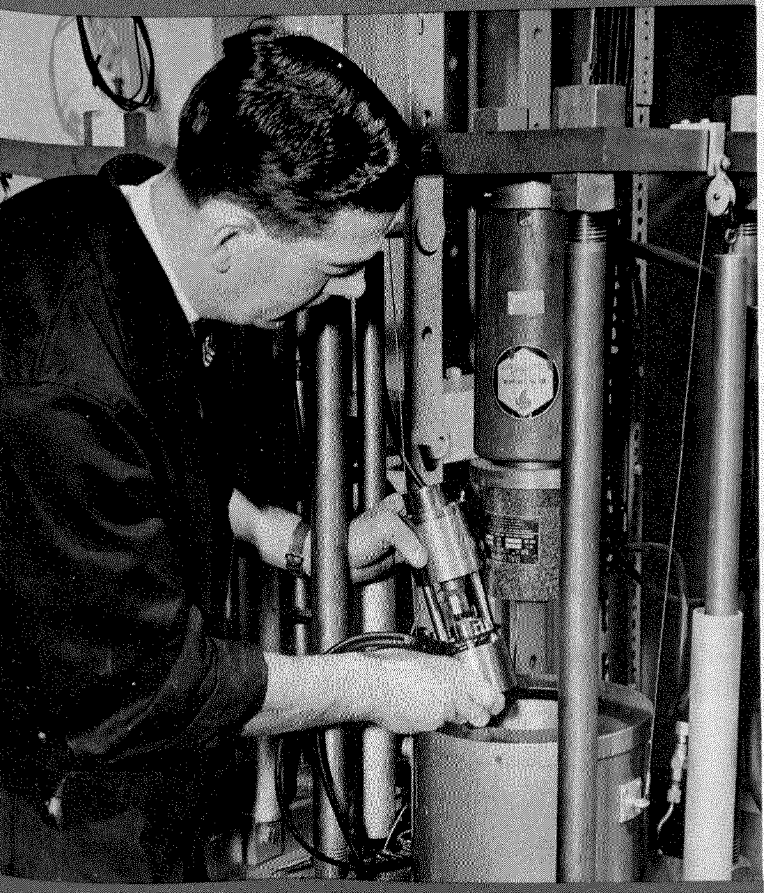


**(Left)**
**A gamma ray spectrometer is used to identify radioactive isotopes in ores and also in 'fall-out' products such as airborne dusts and vegetation.**

**(Right)**
**An alpha ray spectrometer provides a means of identifying radioactive elements in a uranium leaching system.**

# FUELS AND MINING PRACTICE

The Branch is carrying out an hydrogenation program on its high-pressure pilot plant, which operates at pressures up to 20,000 psi, to develop techniques for the economic refining of the low-grade oils and bitumen of western Canada.



The Mines Branch is studying the ground and rock mechanics problems of mining at depth in Canada. An engineer tests rock from a coal mine in Nova Scotia for creep.

CANADA is rich in mineral fuel resources, but their geographic location with respect to markets, their quality, or the difficulties involved in their extraction complicate the problems of their exploitation. The important role which these resources play as a source of power on which the intricate fabric of modern civilization depends demands that they be studied in considerable detail from the point of view of their utilization and conservation.

Within the framework of these broad objectives the Fuels and Mining Practice Division studies the properties of Canadian fossil fuels, and the production, beneficiation, and utilization of these fuels and their derivatives. The Division also carries out research and investigations into mining problems, including underground stresses.

Its work on fuels is threefold.

It takes inventory of Canada's reserves of these fuels and catalogues them according to their quality and suitability for conventional use.

It seeks, by engineering and scientific means, to promote the more efficient and economic production and utilization of mineral fuel products. These comprise coal, peat, oil shale, natural gas, oil and bituminous substances including oil sands, and derivatives of these minerals.

It carries out long-term research on lower grade or less accessible fuel resources to arrive at more advanced technological methods of exploitation, beneficiation, or refining. Its research in this field is designed to promote the economic and orderly development of these low-grade fuel resources in times of peace and to provide a sound technical basis for rapid expansion with a minimum of waste in times of emergency.

A scientist uses a laboratory oven for evaluating coking coal from the Crowsnest area of western Canada.

Extensive research on combustion and carefully executed experiments in industrial steam plants enable Branch engineers to make design modifications to stokers burning coal from the Maritimes.

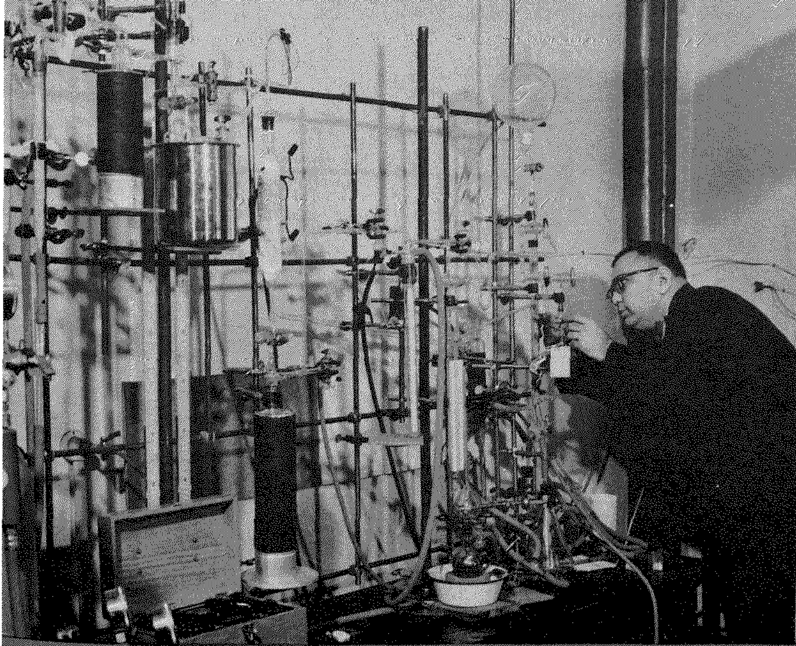
The Division's major effort has been directed to research and investigational work on the problems of the coal-mining industry, arising from the loss of a substantial portion of the industry's market to other fuels. This assistance largely comprises investigation of the technical and economic aspects of coal-mining operations in Canada, and an evaluation of the possibilities whereby technology might contribute to new uses of Canadian coal. Divisional engineers are working, for instance, on devising cleaning and beneficiation methods to improve products and to reduce wastage, and on research on a) coal products, particularly of coal tar pitches, and b) the blending of coals to provide high-quality cokes for foundry and blast-furnace use. Two divisional scientists received the Bituminous Coal Association award for 1957 for their work on the chemical structure of pitches.

In western Canada, the bituminous coal industry with its high proportion of friable coals has a major problem in the cleaning and marketing of fines. The Division has done much work on the briquetting of these fines to make briquettes that will meet the specifications of industrial and domestic markets. One of its engineers has designed and completed an atomizing nozzle which greatly improves the dispersal of liquid binder in briquetting.

The Division has undertaken, with the Research Council of Alberta, a number of cooperative projects on the cleaning of coal fines. In one such project, it is experimenting with a water-cyclone fine-coal cleaning plant that has been installed in the Research Council's laboratories in Edmonton, Alberta.

In its investigations of possible new uses for coal, it is directing its efforts particularly to the two promising fields of bulk use, the thermo-electric and metallurgical industries. It is studying, for instance, flash smelting with the objective of producing pig iron by the direct use of coal fines in equipment of relatively low capital cost. In another project, it is investigating the possibilities of using the coking coals of the Crowsnest area of British Columbia and Alberta as cokes for various uses in metallurgical industries both in Canada and abroad.

The Division also provides extensive consulting services to government and industrial agencies on the



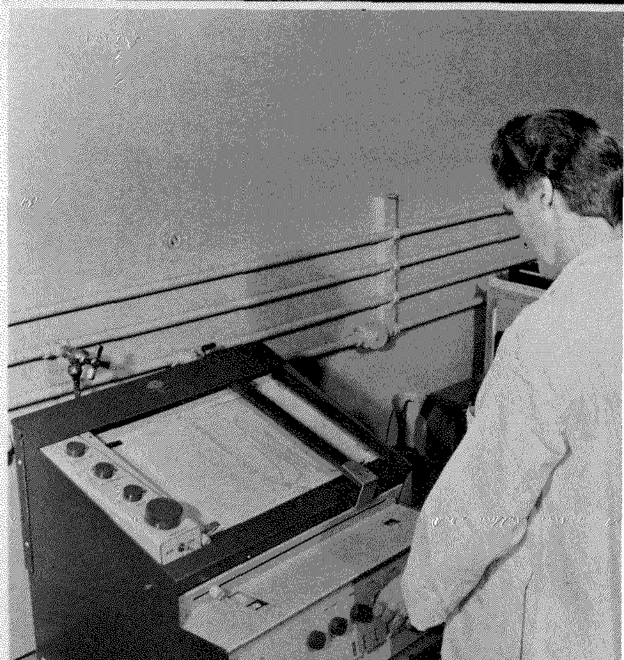
**The Branch is making a careful study of the fundamental chemistry of the desulphurization of petroleum. A scientist studies the kinetics of the desulphurization of thiophene.**

**A scientist investigates the *thermal decomposition of paraffins in the presence of gamma radiation.***

evaluation and efficient use of Canadian coals in heating and thermal-power installations.

Research on fuels inevitably leads to investigation of the combustion phenomena in their various forms. In relation to mechanical engineering, particular emphasis is placed on the development, by laboratory and full-scale tests, of techniques and apparatus for the more efficient combustion of Canadian fuels. One major project, conducted cooperatively with industry, is concerned with improving the combustion of stoker-fired furnaces of low ash fusion coals mined in Nova Scotia. In the Explosives Section, the laboratory, formerly a unit of the Department's Explosives Division, is now under the direction of the Fuels and Mining Practice Division.

Research on petroleum forms an important part of the Division's effort. It is especially interested in improving the quality and in making marketable products of the low-grade oils and bitumen of high-sulphur content, which occur in such large quantities in western Canada. The upgrading of these immense reserves of oil would be a major contribution to the conservation of Canada's oil supplies, and of great strategic value in the event of any interruption in the flow of oil from the Middle East which possesses



**The recording spectrometer is used for studying the chemical structures of coals, tars, and oils.**

almost three-quarters of the world's known oil reserves.

The Division worked out a cold water process for the economic recovery of bitumen from the bituminous sands of Alberta. The separated bitumen is not, however, a marketable product, and the Division is carrying out a long-term hydrogenation program on the desulphurization of the bitumen and of high sulphur crude oils and the production of marketable products.

In this connection, its engineers in 1955 completed the construction of a high-pressure pilot plant which will operate at pressures up to 20,000 pounds per square inch. They have shown that high-quality diesel oil can be produced at 10,000 pounds per square inch. Part of the program is directed to the development of suitable catalysts.

In the field of catalytic chemistry, the Division is taking a new avenue of approach in devising means of improving refining procedures which, in turn, hinge upon improving the catalysis of the various chemical processes involved. Using a cobalt bomb, it is studying the effect of intense gamma radiation upon solid catalysts and upon the decomposition of hydrocarbons.

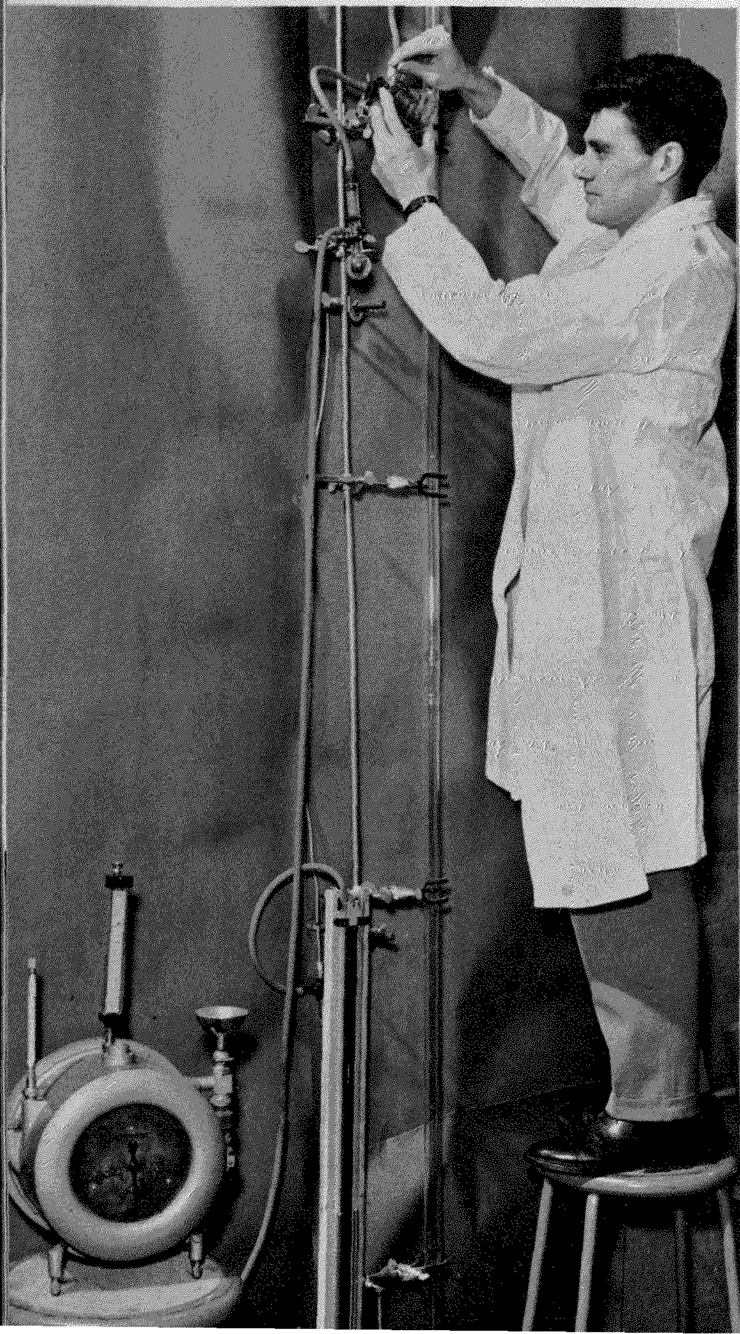
Another project concerns the distillation of western Canada's heavy-low-grade oils from the viewpoint both of the importance of this operation in the refining of these oils and of its immediate importance to the asphalt industry.

The Division took a real step forward in its petroleum research with its recent development of a technique whereby it can speedily and systematically characterize and classify oils and bituminous substances. This will effect a great saving of time and effort in the study of naturally occurring hydrocarbons and in the characterization of hydrocarbon fuels.

In the field of mining practice, divisional engineers and physicists are carrying out a long-range integrated program of study of the various problems of ground stress in underground workings to arrive at a better understanding of ground stress relief and thus contribute toward the optimum recovery of Canadian mineral resources. Much of the country's mineral output comes from the older well established mines which have already reached considerable depths. This together with the trend towards the mining of lower grade, large-tonnage orebodies makes the solving of ground-control problems a present day necessity, especially as the complex nature of these problems and the difficulty of making full-scale observations make such investigations essentially long term. In this work divisional engineers are cooperating with geologists from the Geological Survey of Canada.

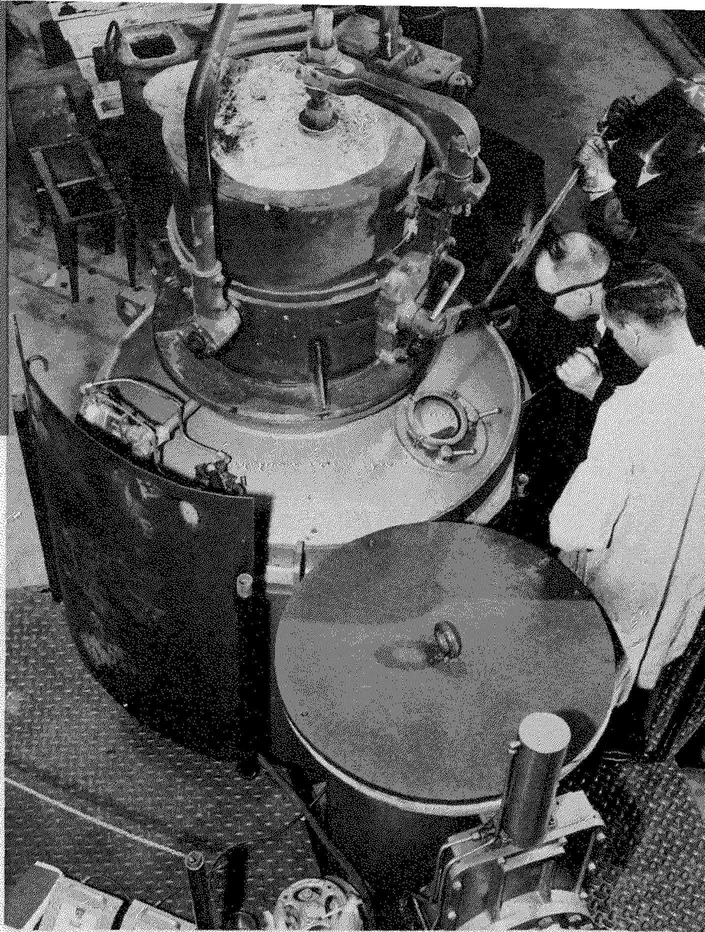
Through its electrical certification laboratory, the Division provides Canadian electrical manufacturers with facilities for the testing and/or certification of electrical equipment for use in mines, particularly coal mines, and in hazardous locations.

The importance of the efficient utilization of Canada's mineral resources, particularly those of low-grade origin cannot be over-emphasized. Through its research on fossil fuels and its work on mining practice, the Division is looking to the prosperity of future generations of Canadians.



**A chemical engineer studies some of the dynamic properties of fluidized beds of catalysts to predict the behaviour of these beds under high pressure.**

# PHYSICAL METALLURGY



In the vacuum degassing of steel, much work has to be done to determine the effects of vacuum casting on the properties of forged and cast steels. Branch engineers have carried out experimental work on vacuum degassed 250-pound steel castings and on 500-pound carbon alloy steel ingots in the Branch's 500-pound vacuum steel degassing unit.

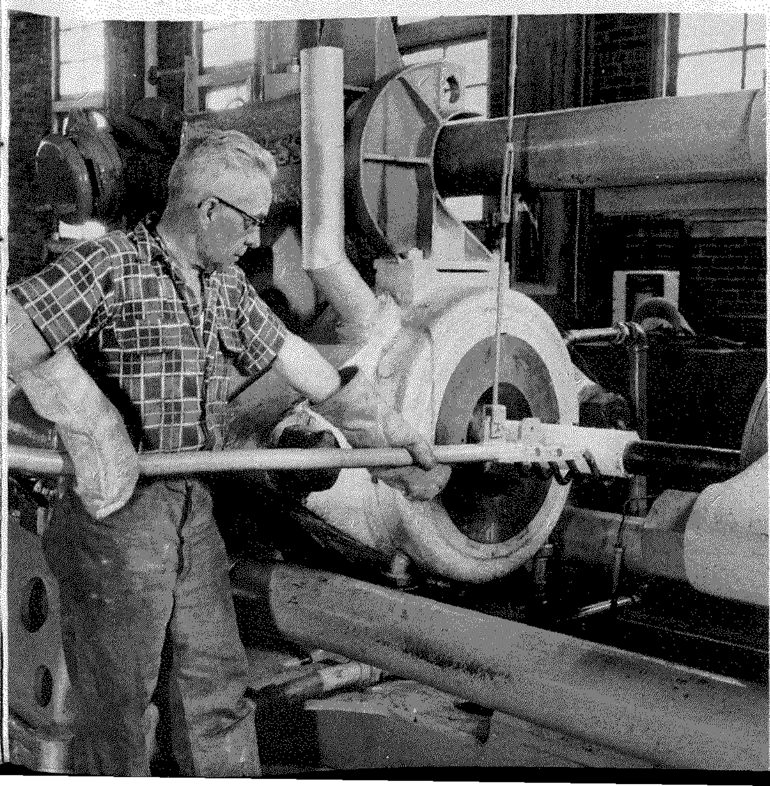
MODERN progress is continually opening up new spheres to development and, in so doing, broadening the scope of possible applications to which metals and their alloys can be put.

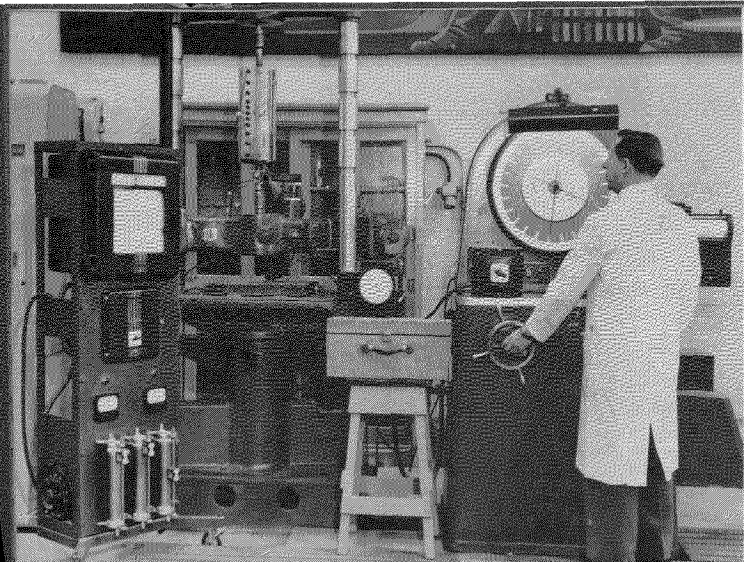
Canada has large quantities of metals such as cobalt, copper, lithium, iron, magnesium, niobium, nickel, lead, titanium, uranium, and zinc, which are essential for defence equipment, atomic energy purposes, and for special alloys for high temperature service in jet engines, in missiles and in materials for use in space and in Arctic regions. However, research, applied and fundamental, is needed to fashion them and their alloys to meet the advances of modern progress and the needs of modern defence.

The work of the Division covers practically all phases of physical metallurgy. Its laboratories are equipped for operations ranging all the way from casting and metal forming to the precise determination of atomic positions in alloys, and it has excellent facilities for applied research on an industrial or semi-industrial scale, including complete foundry, heat treatment, metal working and welding equipment.

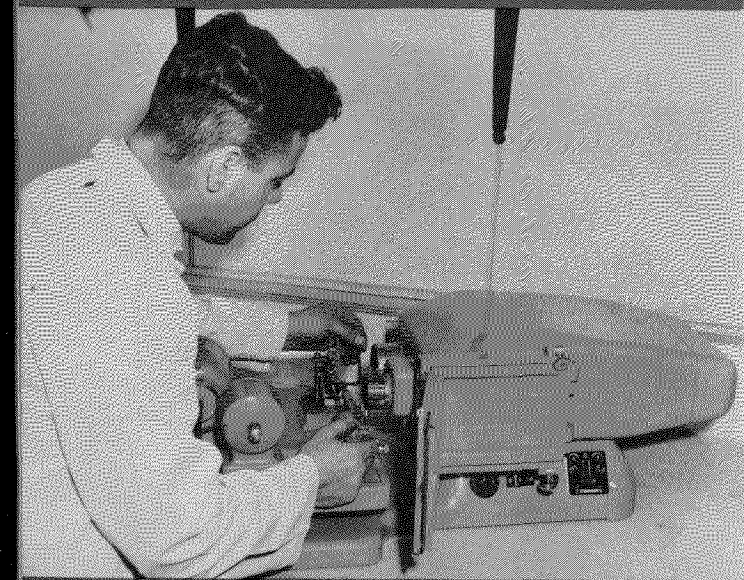
It directs its research, applied and fundamental, to the fields of metal fabrication, alloying, refining and testing and, through technical investigation, it assists the Canadian mining and metals industry, the Defence services and other government departments in the solution of problems pertaining to the fabrication and uses of metals and their products.

An aluminum billet is charged into the extrusion press where it will be subjected to 900 tons pressure to form a sheath tube for a prototype uranium fuel element.

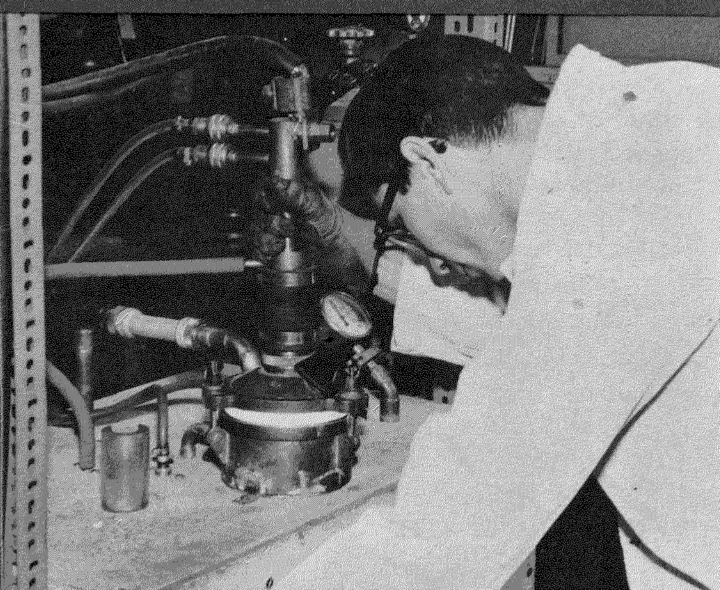




A refractory alloy is subjected to tensile testing at an elevated temperature.



The Branch is making an intensive study of the mechanism of the fatigue failure of metals. A test piece is mounted in a micro-torsion fatigue machine to determine the relation between internal micro-stresses and the progress of plastic deformation.



Branch research on the melting, alloying, and fabrication of refractory metals, such as titanium, includes the study of the consumable-electrode vacuum arc-melting process as applied to high- temperature alloys and special purpose steels.

The Division makes full use of modern instrumentation and techniques, including such scientific tools as the electron microscope and such modern techniques as the floating zone method of refining metals.

Much of the Division's investigative work stems from service failures. These are mainly caused by fatigue and are a constant source of concern to industry. In one of its many projects directed to combating fatigue, the Division is using X-ray diffraction, ultrasonic, magnetic and microscopic methods to study the changes that take place in metals and alloys under cyclic loading to learn more about their nature and causes. A better understanding of these changes would pave the way for the design of materials more resistant to fatigue.

Such investigative work recently led to the Division's development of a new process, spiral rolling, for manufacturing mining drill rods, which has resulted in greatly increasing the strength and extending the service life of these rods. In another recent project, the Division designed and constructed a crack depth indicator to detect and measure cracks. It is now working to perfect the indicator for field applications and to provide adequate calibration charts for the various types of cracks encountered in service.

The study of steels, their development, and various applications form a major field of endeavour. This work ranges from the development of promising ferritic alloy steels from Canadian materials for rotor forgings in future commercial thermal and nuclear power plant installations to the development of economically priced steels suitable for construction purposes in Canada's far northern regions. One such project concerns the development of steel of good notch ductility at low temperatures.

A study which has been completed on the rate of wear of snow plow shoe materials has received wide acceptance and work is now being carried out on grader blade materials for the Ontario Department of Highways and ploughshare points for the Canadian Federation of Agriculture. Laboratory tests are carried out as a preliminary to extensive field testing.

The increasing use of vacuum processing to enhance the quality of steels at higher temperatures by enabling them to withstand high stress has led the Division to study the effect of the vacuum degassing of steel prior to forging and prior to pouring into heavy section castings. The solution of gases during the steel melting process and its subsequent evolution during solidification have long been major problems in large forgings and large section castings. Vacuum degassing removes the hydrogen which not only makes steel brittle but is particularly harmful to steels which have to withstand high stress. The Division is also studying slag-metal reaction in a ladle of steel in the vacuum chamber. From these studies it hopes to provide Canadian industry with information on 1) some of the effects of vacuum casting, and 2) the properties of low gas content steels and slag-metal reactions.

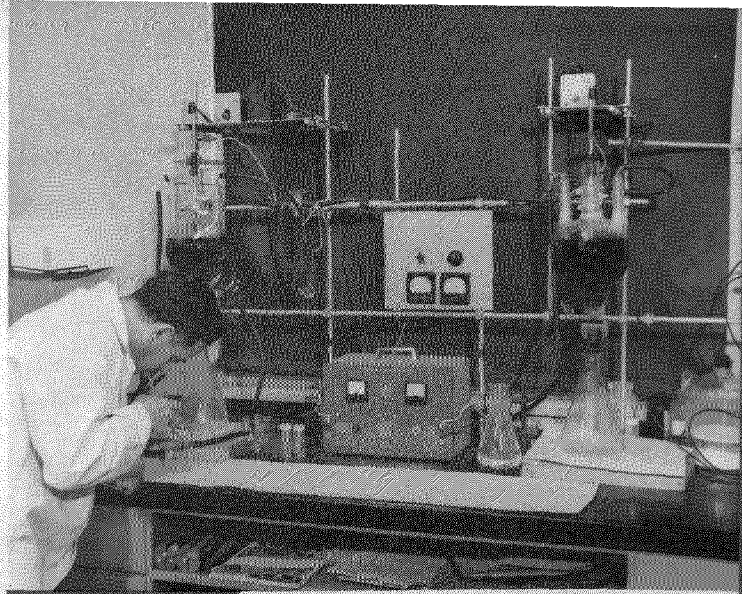
It has developed a practical method of reducing the sulphur content of acid electric steel by adding an aluminum-magnesium alloy. The high sulphur content of these steels made it difficult to produce crack-free castings and had a harmful effect on the properties of these castings in sub-zero weather.

The Division's research in the field of non-ferrous metals and alloys includes studies of liquid properties of various alloy systems and various solidification phenomena as well as the use of different physico-chemical treatments, such as degassing and grain refining, to improve the melt quality.

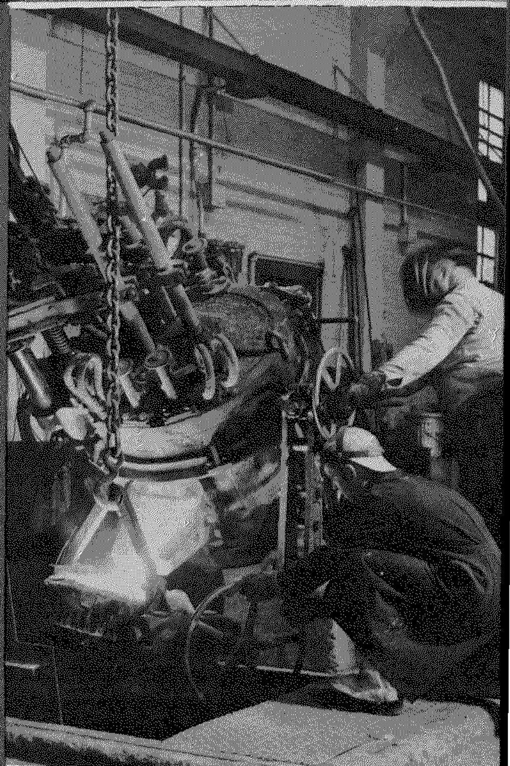
It has under way two research projects designed to enhance, through technological advances, the sales of Canadian zinc in world markets. Working in close cooperation with the Canadian Zinc Research and Development Committee, a body composed of the main primary and secondary zinc producers and users in Canada, it is investigating zinc alloy systems in an attempt to produce stronger alloys with improved corrosion resistance, low temperature properties and creep behaviour. It is also studying the use of various grades and alloys of zinc in galvanizing baths to learn more about the fundamentals of the galvanizing process, and to increase the uniformity, thickness and adherence of galvanized coatings.

In its research on new alloys, aimed primarily at the attainment of the highest possible strength-to-weight ratio, it is working extensively with aluminum and magnesium, and supplementing its investigations of foundry characteristics and mechanical properties of the alloys with thermal analysis, hot stage microscopy, and age-hardening studies.

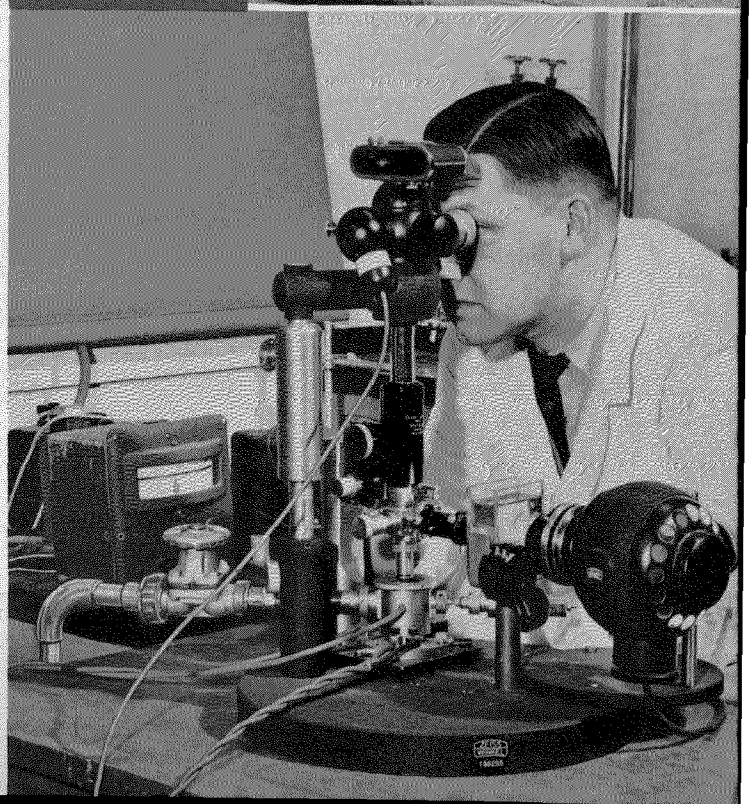
Current developments in missiles, ultra high speed air vehicles, and atomic energy power plants emphasize the need for highly specialized alloys, possessing premium properties of high strength-to-weight ratio, high strength at elevated temperatures, and corrosion resistance. All of which makes it necessary to be able to design alloys with predetermined properties. To



(Above)
A scientist isolates carbide particles in a chromium - molybdenum - vanadium steel.



(Centre)
A melt of high-strength steel is poured from the 500-pound direct-arc electric melting furnace.



(Below)
Microscopic examination of metals is made at elevated temperatures to determine the onset of a phase change.

do this an accurate knowledge of the role of structure, micro-constituents, variation in chemical composition and heat treatment in determining the mechanical properties of alloys is necessary. To this end, the Division is studying the titanium-base, nickel-base, and iron-base ternary systems. The knowledge gained from such studies should facilitate the design of high-temperature and refractory-metal alloys to meet the highly specialized demands created by today's rapidly expanding technology.

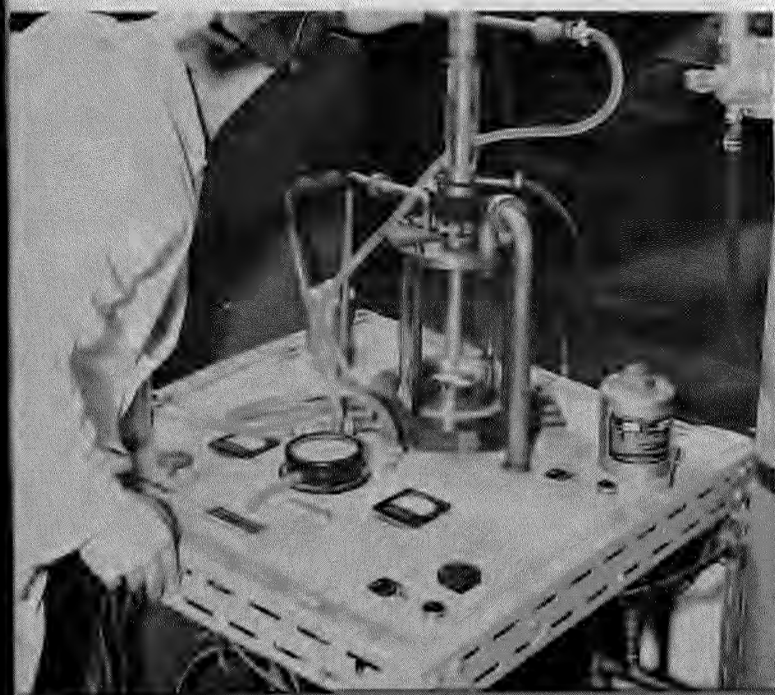
In nuclear metallurgy, the Division is primarily concerned with the development and assessment of metallic materials for nuclear reactor application, including uranium metal and alloys for fuel elements, and aluminum and zirconium alloys for fuel sheathing and pressure tubes. This work is important in the development of economical power reactors of Canadian design.

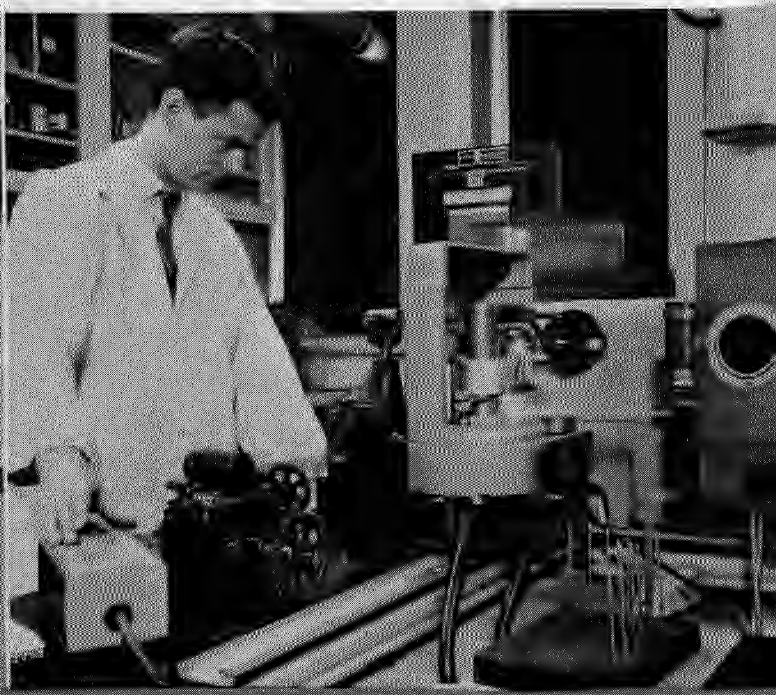
Industry is today seeking the answers to many questions on the structure and physical properties of metals and alloys. In this field, the Division is studying, for instance, the atomic structure of the boundaries between the very small grains that make up metals, and the manner in which these boundaries influence mechanical properties. To do this, it is using metals which it has produced in the laboratory by means of recently developed crystal growing techniques.

It is studying the effect of small amounts of impurities on the physical and chemical properties of metals. It is producing, in its laboratories, ultra high purity metals by means of the latest development in refining methods, the floating zone melting technique, so that it may compare the properties of these super purity materials with those of commercial-grade metals.

It is making wide use of the electron microscope to study imperfections in metal lattices and the role these play in controlling the mechanical properties of solids. Likewise, it is using the latest techniques in X-ray diffraction to study the forces holding together the atoms of metals and alloys to arrive at a better understanding of their ultimate strength.

Much remains to be learned about the intrinsic properties of metals. A fundamental understanding of these subjects is essential to permit the design of materials with optimum properties to meet the stringent demands of modern applications, such as the need for lightweight metal coatings that will remain tough and flexible in frigid outer space, semi-conductors that will regulate the flow of electricity in the high-temperature and high-frequency ranges, and alloys that will reflect neutrons in nuclear engines. Such understanding can be won only from fundamental research.





Left: An inert arc vacuum melting unit is used to produce new alloys for nuclear energy applications. Right: The spectrographic microvolume analysis apparatus is used for the analysis of segregations or inclusions. The changes in concentration of the elements in the segregate can be found from the changes in intensity of the spectral lines.

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