CANADA

THE RADIATION LABORATORY OF THE MINES BRANCH

1947-1959

by

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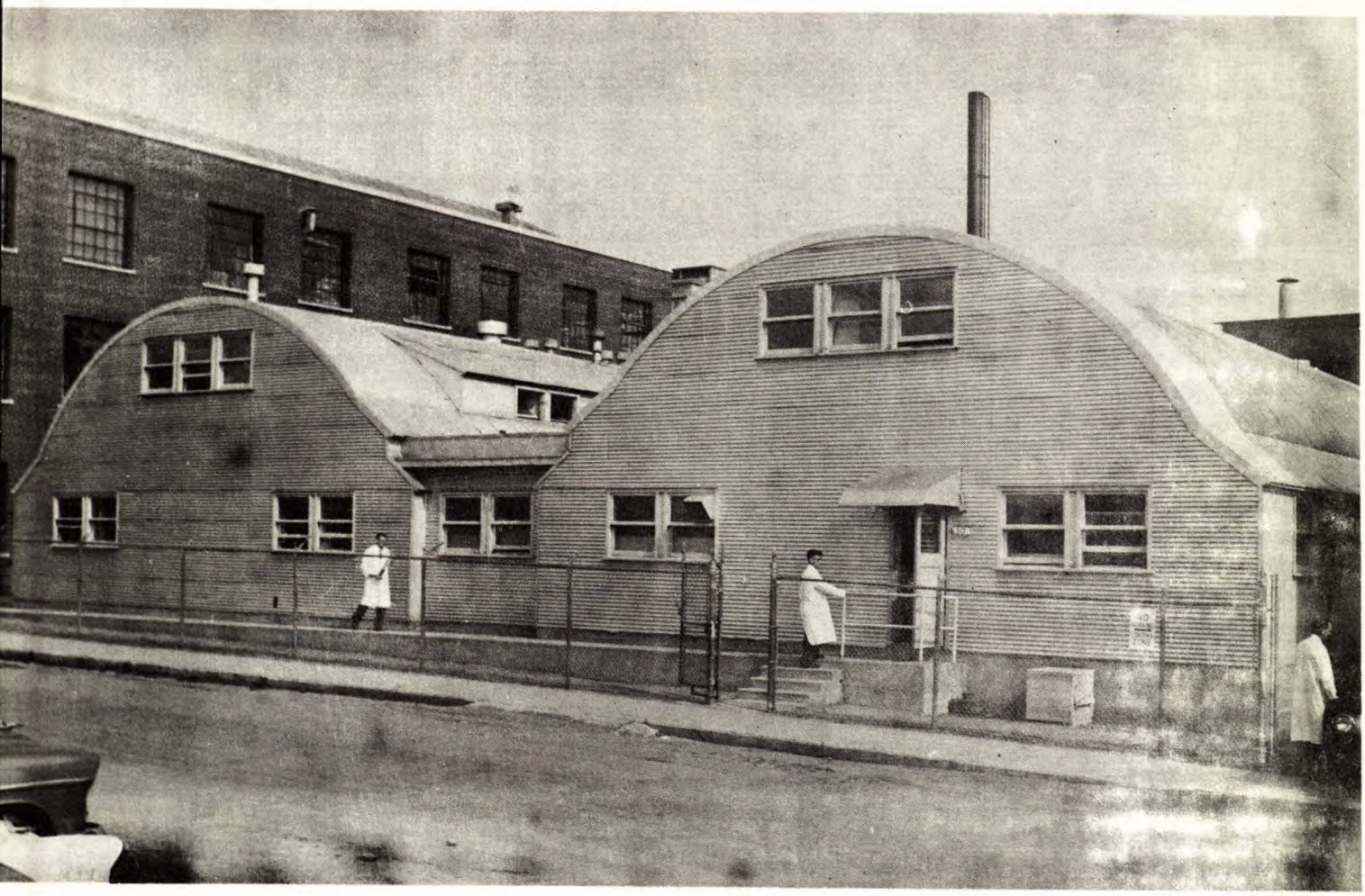
ABSTRACT

A general review of activities of the Radiation Laboratory Section of the Radioactivity Division during the years 1947-1959 is presented. This includes descriptions of major projects in uranium and thorium assaying, counter development, circuit design, as well as various applications of radioactive isotopes as tracers in extractive and physical metallurgy. A complete bibliography of papers and reports is appended.

RESUME

Voici une revue générale de l'activité de la Section du laboratoire des radiations, Division de la radioactivité, au cours des années 1947-1959. On y décrit les principales recherches sur la titration de l'uranium et du thorium, la mise au point de compteurs, l'élaboration de circuits, ainsi que diverses applications des radioisotopes employés comme traceurs en métallurgie extractive et physique. En annexe, une bibliographie complète des communications et des rapports.



The Quonset Huts, 30 Lydia Street, Ottawa.

FOREWORD

The removal of the Radioactivity Division of the Mines Branch, Department of Mines and Technical Surveys from its historic quarters in the Quonset Huts at 30 Lydia Street, Ottawa into new and more spacious quarters, and its re-integration into general Mines Branch activities marks a mile-stone in the history of the Mines Branch. It also provides an appropriate moment to look back over the years to review the activities of one of its components, the Radiation Laboratory, or, to give it its formal name the Physics and Electronics Section of the Radioactivity Division, of the Mines Branch of the Department of Mines and Technical Surveys.

In tracing the work and development of this small group from its beginnings one cannot fail to realize how much has been achieved in so short a time and how many worlds there are left to conquer, even in so restricted a field.

This review is intended as a record of the work done, as a bibliography for future reference, and as a tribute to all members, past and present, who through their loyalty and ever-willing enthusiasm each contributed their share to the achievements of the Section. To them all, therefore, the author gratefully dedicates this little booklet.

G.G. Eichholz

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INTRODUCTION

The development of the atomic bomb during World War II suddenly thrust Gilbert Labine's Eldorado mine at Port Radium, on the shores of Great Bear Lake, into prominence as one of the two main sources of uranium in the free Western world. At the end of the war it was soon realized that considerable development work would be required to improve the efficiency of extraction of the uranium ore at the Port Radium mine. The original process for the recovery of radium from the Eldorado (Port Radium) ore had been worked out by Traill, Spence and McClelland [1] at the Mines Branch in 1932 and it was natural that the Government-owned Eldorado Mining and Refining (1944) Ltd. should turn to the Mines Branch for assistance. A group was set up to deal with this problem towards the end of the War. This "Eldorado Group" expanded rapidly and became successively the Radioactivity Section and then the Radioactivity Division under the able direction of Mr. Arvid Thunaes.

It soon became obvious that new quarters would be required quickly to house the growing Division. In 1948 it was decided, therefore, to erect a double Quonset Hut which was assumed to be cheaper and much faster to erect than a more permanent building. However, construction was slowed down by various accidents, two fires, and the death of the contractor, and it was not until late in 1950 that the building could actually be occupied. After that, it soon became clear that this building, too, would be inadequate, particularly when in 1952-54 the

sixty permanent members of the Division were joined at times by 30 to 40 persons on the payroll of various mining companies that shared in the operation of pilot plant tests[2]. A new building was planned again, and after many delays it will be ready for occupancy in April 1959.

Over the years the character of the work has changed, of course, keeping step with developments in what has surely been one of the fastest-growing industries in the world. In the beginning, almost all the work was done on behalf of Eldorado Mining and Refining Ltd., but as other companies entered the field, they, too, began to rely on the Radioactivity Division for most of their laboratory-scale and pilot plant test work. In 1953 Eldorado set up its own Research and Development Division and Mr. Thunaes left the Mines Branch to become manager of that new organization. He was succeeded as Chief of the Radioactivity Division by Dr. Ernest A. Brown who guided the destiny of the Division until his untimely death in May 1958. Mr. Harold W. Smith has been Acting Chief of the Division since then.

The Physics and Electronics Section, too, has seen considerable changes in its scope and activity since its inception in 1947. It began really in 1946, when Dr. Christian Lapointe, a former professor at Laval University, was hired to assist with the problems of determining the uranium content of ores by measuring their radioactivity. At that time he still had to build his own counters and his skill in blowing his own Geiger tubes has often proved useful. From 1947 to 1953 Dr. Lapointe was stationed at Port Radium as resident physicist to cope

with the immediate problems arising in the assaying and monitoring of radioactive ores.

At the same time it was realized that a broader attack on the practical aspects associated with the radioactivity of ores was required, and Dr. Frank E. Senftle was brought in, in 1947,to head a new section, the Physics and Electronics Section. Dr. Senftle brought to his job an infectious enthusiasm and soon managed to start several lines of research in the field of radioactive detection. When he left late in 1949 this work was carried on with Mr. Robert D. Wilmot as acting Section Head. At the beginning of 1951 Dr. Geoffrey Eichholz took over the direction of the Section and has remained in this position since then.

A difficult period occurred in the years 1952-54 when the effective scientific strength of the Section had been curtailed seriously by a loss of established positions. To meet this difficulty it was necessary to delegate to the senior technicians a great deal of responsibility for the conduct of various projects. Fortunately, most of them rose to this challenge successfully and the output of work was maintained at a sufficient level. As a result of this policy it will be seen in the Bibliography that the names of technicians appear as authors or co-authors of papers and reports to a much greater extent than is customary in other laboratories. Since that time it has been possible to build up a small, but highly qualified scientific group which is competent to tackle problems in the diverse spheres of interests in which the Section has been engaged in recent years.

In the following pages the various projects undertaken by the Section during the past years are reviewed and put into perspective to work in other places and to future applications. A fairly complete bibliography is appended for reference, and as a summary of completed work. Some indication will also be given in their context of projects that are in hand at present.

When the Section was first formed its main concern was the development and application of radiation detectors to the assaying of uranium ores and the design of electronic circuits for counting purposes. Since then the range of work has been extended to cover some of the borderline subjects between nuclear physics, solid state physics, metallurgy, mineral dressing, extractive and analytical chemistry, electronics and radiation safety. For several years this work has been divided in the quarterly reports into three main sections: Radiometric Laboratory, Electronics Laboratory and Tracer Laboratories. For the present purpose it will be necessary to adopt a more diversified scheme to relate the various activities of the Section.

RADIOMETRIC ASSAYING

It is proper to deal first with the subject of radiometric assaying for uranium and thorium in ores as this has been the bread-and-butter activity of the Section for many years and the one that mainly justified its existence till recently. The key man in this field has been Charles McMahon, the senior member of the Section both in age and years of service, whose careful and conscientious work has gained him an enviable reputation.

As is well-known, the spontaneous emission of radiation, alpha, beta and gamma rays, from natural uranium and thorium ores is their peculiar property which distinguishes them from all other ores. This property makes it possible to determine the uranium and thorium content in ores by a unique approach called radiometric assaying. The details of this method may vary considerably, depending on which of the radiations is utilized for the purpose. The need to discriminate between uranium and thorium causes further complications which are reviewed in Reference (A14)*. In the early days, when only Geiger counters and simple ionization counters were available, assaying by beta detection using annular and end-window Geiger counters was preferred (G6, A5). It soon became evident, however, that this led to misleading results if the ore was "out of equilibrium" through the loss of radon by natural emanation or grinding, through natural leaching, or in those cases where both uranium and thorium were present in the ore. To overcome this difficulty Lapointe and Williamson in 1948 proposed a beta-gamma

*numbers in brackets refer to the Bibliography at the end of this Review

In the Radiometric Assay Laboratory
(At left the original equilibrium counter)

method (E2), usually called the Equilibrium Method, which was developed over the years (A6, D3) into a powerful tool. Its sensitivity limitations were overcome when a scintillation detector was used as the gamma detector (E24) so that low grade ores could now be assayed accurately (E28, A14). This development coincided with the discovery of new uranium mines in the Beaverlodge and Blind River areas which sparked a strong interest in commercial development of this method. Most of those mines adopted the Mines Branch system (E32, H4, H9) almost unchanged, and it was not until 1955 that an alternative commerical unit was designed in Canada. By then the method had been adopted by all Canadian uranium mines, as well as by the mines in Australia and South Africa where local commercial units appeared on the market.

The Section became the centre of an extensive training program, as many mines sent their assayers to Ottawa to be introduced to the equilibrium method and equipment, before taking over their new assay laboratories at the Mines. Their stay varied from a week to several months and many of them called on the Section for advice and assistance in later times whenever difficulties arose (H16, H25, H31, H33, H36, H44 and others). This led to a particularly close relation with industry in this field which was of mutual benefit.

Work on the equilibrium method has continued, particularly as the problem of precise thorium determinations became more serious. By correspondence with workers in this field in many other countries experiences were exchanged and it was found that Canadian ores

appeared to be easier to assay than others. For comparison Australian, South African and American samples were assayed (e.g. G14) and corrections were determined for self-absorption and emanation effects. Much of this work is being summarized for a report at the present time.

Many other approaches to this assay problem were also tried, among them a simple energy discrimination method and a more complete gamma-ray energy selection method by means of a pulse-height analyser ("kicksorter") which lends itself to a graphical solution of the assay values (F3). Another method utilized the fissionable property of uranium itself under neutron irradiation (E20, A10).

While this development work went on, provision had to be made for precise routine analysis of all samples coming in. These samples all originated from test work being done in other sections of the Division and by Eldorado. No prospectors' samples were handled as a rule, as the Geological Survey of Canada had provided facilities to assay those. These routine assays reached a peak in 1954-1955 when two assayers were occupied full-time in obtaining assay values by the equilibrium method.

At the same time other methods of determining uranium and thorium in ores radiometrically had not been neglected. For coarse ore samples a gamma-ray method was judged to be sufficiently accurate. A pressure ionization chamber was set up with a vibrating-reed electrometer for this purpose (E13, D2, A4) and has been in constant use for the last nine years without any trouble whatever, an excellent record.

Another approach was by fission-product analysis of uranium in ores (E20, A10), but this method has obvious limitations in the field. For the specific determination of thorium in ores a flow counter was set up which counted the alpha particles from thoron gas which was driven off from the thorium after it had been dissolved in a suitable container. The first version of this method (E9) employed an ionization chamber as the detector; however, this was too microphonic to be useful. A later version used a scintillation detector (3) and this method then proved fully as reliable, and faster, than conventional chemical methods.

Naturally, over the years the Section was frequently approached to advise on prospecting equipment and to advise on methods of field assaying. While it was felt that a sufficient range of commercial prospecting units was available, it proved helpful to cumulate information on available counters and to issue lists of such commercial units during the peak years of prospecting activity (E38, E46). These lists met with a favorable response and large numbers were sent out. On occasions new units were evaluated for the manufacturers (e.g.G13) and several firms sought advice on practical design considerations for field work. To assist the inexperienced prospector in making field assays a brief guide was prepared (D1, D1a) which supplemented the excellent booklet on Prospecting for Uranium in Canada (4).

In this connection sets of boxed standard samples were prepared for distribution to prospectors (E11). A more important service has

been the provision of standard uranium and thorium ore samples for the calibration of assay equipment. These samples have been in steady demand for many years, both by Canadian mines and assay laboratories, and by many foreign laboratories, as far away as Australia, South Africa, Finland and Italy. A nominal fee has been charged for this service which has helped to maintain accurate assay values in the uranium industry.

A more specific approach to the determination of uranium itself is by alpha-radiation detection which is more direct than gamma-ray detection, but suffers from a number of serious practical draw-backs (A14). However, particularly for many mineralogical problems alpha detection is invaluable and equipment has been set up over the years for this purpose (E18, H17). This equipment was used by Dr. Murthy of the Geological Survey in zircon age determinations and more recently in the Radioactivity Division by Mr. Ingles and his staff for the determination of radium in waters. At the present time an alpha-ray spectrometer, based on a large gridded ionization chamber, is being set up to help with the identification of individual elements in the uranium and thorium decay series.

Another element that is naturally radioactive, though only weakly, is potassium. This activity becomes important in certain ores and minerals and has been studied from time to time (A1, A14, F3) to determine the effect of its radiation on uranium prospecting, assaying and aerial surveys.

Radium, of course, occurs in trace quantities in all uranium ores. Its content in ores can be calculated from equilibrium counter results. More directly it can be determined by a chemical concentration procedure followed by counting with an alpha detector. This is the course usually followed, particularly for water samples, a large number of which were assayed during 1958 (e.g. H43, G15). In the case of underground waters such determinations supplement measurements of radon concentrations in mines which are of considerable interest as the potential hazards of excessive radon concentrations have been recognized (5, 6, H28). This problem has been closely watched and the Section has assisted in the establishment of agreed monitoring procedures.

DEVELOPMENT OF RADIATION DETECTORS

When the need for large-scale assaying and prospecting for uranium ores first arose after the War the equipment available was pitifully limited and ill-adapted to industrial use. Geiger-Mueller counters were still largely a laboratory tool, fragile and limited in their applications, and their manufacture was an art rather than a science. Most laboratories found it best to make their own and our Dr. Lapointe became an expert in this art which stood him in good stead during his five years at Port Radium, N.W.T. Other detectors include electrometers of the gold-leaf and Lindemann types, both of which were suited only to the most careful laboratory conditions. As a result much work was done all over the world which resulted soon in the commercial availability of Geiger tubes, first alcohol-filled tubes, then after 1950 the halogen-quenched type, which is greatly superior in stability and useful life. Nevertheless, many of these types were not well suited to the special conditions encountered in prospecting and mining requirements, and work in the Radioactivity Division was devoted to the development of specialized types for special operating conditions (A3, E16, E18, E41). Other work was done on annular counters and other arrangements designed for sensitive assaying methods.

In 1947 the scintillation counter was discovered and again work went on in many laboratories to advance this technique. This method depends on a fluorescent substance, called a phosphor or scintillator,

which emits light when irradiated by rays from radioactive sources. The feeble light emitted must then be detected and amplified in photo-multiplier tubes before the resultant electrical pulses can be counted. Every stage in this process was investigated and the Section made some contributions to knowledge in this field, and to the utilization of these detectors. The choice of scintillator depends on the radiation to be detected. For alpha-particles a thin layer of activated zinc sulphide powder is the most efficient detector and various configurations have been tested for assay purposes and contamination detection (E6, E8, G1). For gamma-radiation a heavy-element containing fluorescent crystal is used, initially substances like calcium and cadmium sulphide (E17, E18), and later sodium iodide activated by thallium. Facilities have been set up for the mounting and sealing of sodium iodide crystals, which are highly hygroscopic, and most scintillation detectors in the laboratory contain home-mounted crystals, resulting in a considerable saving over the cost of crystals when purchased already mounted.

Beta-rays are best detected by organic scintillators, and anthracene crystals have been in common use for this purpose (G9). When it was found that certain organic liquids could be used as large-volume detectors of gamma radiation a comprehensive programme was started to develop large-volume organic scintillators. This resulted in a detailed investigation in 1951-53 of the properties of mixed organic liquids, particularly the effects of composition and self-absorption on the efficiency as bulk detectors; unfortunately most of the results of

this work have not been published so far. This work was really a companion investigation to another one on the development of plastic scintillators, containing mixed organic scintillating compounds in a polystyrene matrix. A procedure for pressure-moulding such scintillators was developed (A8) and patented (C2) and their properties were studied in detail. Only some aspects have been described so far (B2, B3) but such scintillators have been used in several pieces of equipment. Thin-film plastic scintillators have been made and some, with a weak radiation source moulded in, have been supplied as feeble standard light sources to other laboratories. Liquid scintillators were used as detectors in the bag-assay unit (E34) and the bulk-assay unit (E31) and are still in current use for the detection of carbon-14 in tracer investigations (F5). Their main use elsewhere is now for cosmic-ray studies, whole-body counting and Cherenkov detectors.

An entirely different type of detector which has been studied is the spark counter which will detect heavy ionizing particles, like protons or alpha particles, by the localized breakdown into sparks of a corona discharge whenever such a particle passes. The simplicity of this process made it attractive for alpha detection and several types were developed (E27, A11), but their wider use was abandoned because of the temperamental nature of these devices and their limited sensitivity. Another type of detector which was studied briefly was the diamond conductivity counter. This line was not pursued because of the limited counter geometry enforced by the small size of available

diamond crystals. The general field of solid-state detectors has lately bounced back into favour, and semiconductor crystals are being re-introduced as detectors at present. Similarly photosensitive devices, such as solar cells, are being studied at present as simple radiation detectors, either directly or with scintillating intensifiers.

SPECIALIZED DETECTORS FOR MINES, MILLS AND LABORATORIES

One of the main functions of the Section has been the development of special equipment for use in uranium mines and mills, arising from the radiation-emitting property of uranium ores, and to render advice to the industry on all aspects of radiation detection, monitoring and assaying(2, A24). The development of the equilibrium method of assaying has already been mentioned. Another notable development was the introduction and gradual improvement of the electronic picker belt, or "Lapointe picker". This method utilizes the radiation emitted by coarse pieces of uranium ore to sort them according to grade, so that a high-grade preconcentrate is produced and a large proportion of the waste rock can be thrown away. In its original form, which was patented (C1), the picker consisted of several Geiger tubes mounted over a conveyor belt which actuated a pneumatic ram to push high-grade ore off the belt, leaving the waste ore (E26, D4, 7). This type of picker was installed in the old gravity mill at Port Radium and was destroyed in the fire there in 1952 and never replaced. The low sensitivity of the Geiger tubes limited the use of that picker to high-grade ores; to extend it to other uranium fields a new system was devised with a sensitive scintillation detector under the belt, and a swinging gate instead of the ram (E42, E48). This type of detector was applied to ores from the Beaverlodge and Blind River areas (G12, D5, H15) with satisfactory results. The main reason delaying the installation of pickers in mills has been their low tonnage capacity and their limitation to coarse sizes, 1 1/2 inches andup.

However, the changing economic picture is likely to revise that position soon. The Section advised Atomic Energy of Canada Ltd. in its construction of units for export and has kept in close touch with commercial developments in this field (H49). Test work with the Mines Branch picker unit goes on from time to time.

Another field in which the Laboratory has been busy has been the provision and development of special ore monitors, particularly for Eldorado Mining and Refining Ltd. The simplest was a Geiger detector suspended over the hand-cobbing belt at Port Radium to help check the activity of doubtful pieces, selected by hand. Other monitors were installed to record the grade of the feed to the mill (E36, H48) and the grade of mill waste (E37). A picker monitor, to assist manual picking of ore, was developed for use in South Africa (E49). A special unit for locating ore at the bottom of Great Bear Lake was also developed and tested (E50, H28). Other monitors for loaded cars and other underground uses were developed or discussed.

This brings us to another field in which a considerable amount of work was done: portable counters for detecting and assaying ore in location underground. This is a recurring problem and one for which there is no really good solution that is satisfactory to all concerned. However, a number of portable, transistorized detectors were designed and built which did meet the requirements of portability and directionality (E41, E52, A26) without sacrificing too much sensitivity. This work led to a number of related problems in the selection of

suitable circuits (E45), the choice of suitable batteries, and the development of other, less directional detectors (A22).

Other units which have been developed for mill use include an assay unit for bagged ore (E34, E47), which has become an indispensable accessory to all picker test work, and a smaller assay unit for the quick assaying of coarse ore samples (E31). Considerable work has been done over the years to develop a continuous solution monitor to detect the break-through of uranium in ion-exchange lines. This system, which uses thin plastic scintillators as alpha detectors, has encountered many practical difficulties and has been the cause for the setting up of an alpha-ray spectrometer.

ACTIVATION ASSAYING AND RELATED WORK

Many elements, when exposed to a stream of neutrons, are transmuted into radioactive nuclides which decay with a characteristic half-life* and emit beta or gamma rays of characteristic energies. This fact has been used in many laboratories, where nuclear reactors are available, to determine the content of trace impurities in a variety of supposedly pure substances (e.g. 8, 9). On the other hand it was felt that some of those elements which are particularly susceptible to such neutron activation could possibly be detected when exposed to a weaker, portable neutron source, thus making it possible to determine the content in ores of certain elements which are difficult or time-consuming to assay by conventional chemical means. Such portable neutron sources, usually consisting of mixtures of radium and beryllium, or polonium and beryllium, have been available on loan or purchase for many years. Thanks to an extended loan of a portable Ra-Be neutron source, which was kindly provided by the National Research Council, it has been possible to study a number of such assay problems. The first one studied in detail was the assay of tantalum (E25, A12), where it was shown that tantalum in ores could be assayed accurately by this method in the presence of niobium without the usual laborious chemical separation. Other activation assays studied were for calcium, copper and indium (H3). Considerable work has been done on the activation

* the time required for the activity to decay to half its initial intensity

analysis of tungsten in ores. Although very consistent results have been obtained some unexplained interfering activities have made it necessary to study the radiation in more detail. Similarly, some work has been started on the activation analysis for rare earths in thorium ores, but the solution of this problem has been complicated by varying amounts of gamma radiation from the thorium decay products.

A by-product of the research in this field has been the accurate determination of the half-lives for certain isotopes for which there were conflicting data in the literature. This work was done by means of the high-pressure ionization chamber. The isotopes studied were Tantalum-182(A9), Tungsten -187(A13), and Mercury -203 (A22).

Other applications of induced activation have been the proposed mine analysis of copper ore, using a local nuclear reactor, and the belt assay of beryllium in ores, first proposed by Senftle and Gaudin (10) and recently developed by Brownell (11).

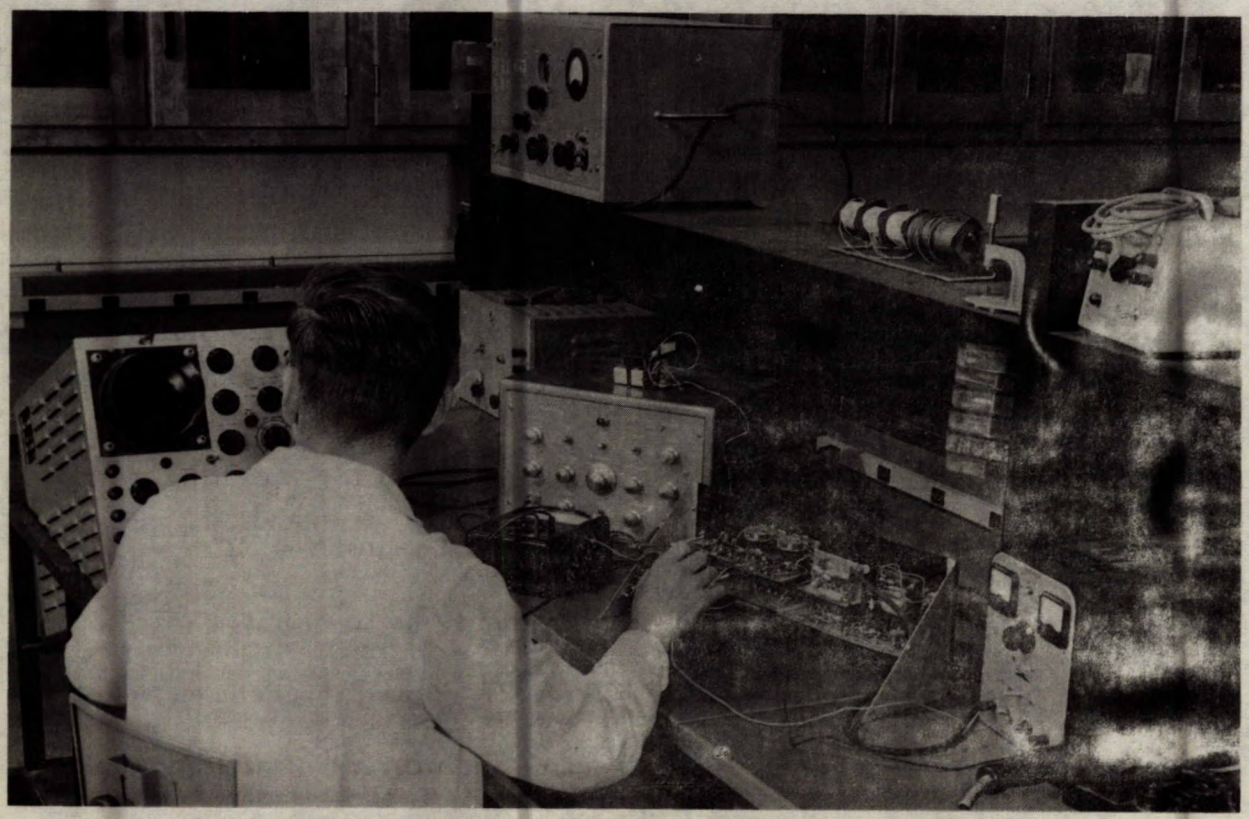
Since setting up the gamma-ray spectrometer some identification of trace impurities in activated metal samples has also been done.

RADIATION AND PLANT SAFETY

The handling of large amounts of concentrated radioactive ores both at the Mines Branch and at the various mines naturally caused concern and a demand for safety inspection or advice on suitable instrumentation. From the early days the staff of the Radiation Laboratory has, therefore, been engaged in the monitoring of radiation levels, the design of detectors,and in consultations on the reduction of potential hazards. Such occasions have involved the measurement of radiation levels near ore concentrates, discussions on radon levels underground and in mills, onmeasurement of radon activities (H28) and on safe disposal of waste tailings and liquors. Radioactivity in dust samples has been measured and mine waters were assayed (e.g. G15).

Similarly,the radiation levels in all laboratories, where radioactive tracers were used, have been monitored regularly. In 1957 Mr.J.B. Zimmerman of the Analytical Chemistry Section was appointed Radiation Safety Officer with special responsibility for watching over housekeeping practices in the Mines Branch laboratories. Care has been taken in tracer activities at outside locations to monitor the radiation levels at all points (e.g. H27, H37). Some interesting results have recently been obtained during routine monitoring of airborne dust in Ottawa plant areas. Other dust analyses have yielded some interesting information on the gamma-ray spectra of airborne fall-out products (F4, A32).

Another project was undertaken to try to avoid the hazard arising in mining operations when a drill bit accidentally hits a piece of unexploded dynamite. In a series of tests (H23, H27, H29) it was shown that it was feasible to introduce a radioactive marker into the dynamite and to detect such unexploded pieces behind several inches of rock (A22). General adoption of this method has been held up, because of the added cost, small though it is.



Part of the Electronic Shop

DEVELOPMENT OF ELECTRONIC CIRCUITS

The use of radiation detectors, often in dirty or humid plant locations, requires some knowledge of the design and construction of these counters to facilitate their operation and maintenance. As more and more specialized applications of radiation detectors were required new types of units had to be designed of a kind usually not available commercially and often only needed in small numbers. In all those cases the Physics and Electronics Section had to supply the electronic know-how and usually provided some equipment to do the job. The design of pickers, monitors and portable counters has already been mentioned; however, it must now be pointed out that in most cases novel circuits had to be designed, and frequently these systems went through several stages over the years as the electronic circuits were improved steadily (e.g. E29, E43, E48). Power supplies and coincidence circuits were developed (E22, E21, H35) and many improvements to existing pulse and scaling circuits were made (e.g. E33, A18, E39). Two fields have been of particular interest, the use of scaling tubes for compact scaling circuits and the development of transistor circuits for use in compact portable counters.

In 1952 several firms brought out compact tubes which permitted scaling to ten within a single tube envelope (12). However, little information was available on practical circuits and several units were, therefore, designed using the different types of scaling tubes available (E35, E37, A17). These circuits were distinguished by their

simplicity and several of the units designed then are still in use now. Another transistorized scaler of that type is under construction at present.

The development of the transistor has revolutionized electronic circuits all over the world. The small size and low power consumption of transistors made their use logical for all types of portable equipment. The Section entered this field fairly early and has remained in touch with developments, thanks in part through the author's membership of the "Transistor Panel" of the Defence Research Board from its inception. The first major step was taken when a transistor oscillator and voltage multiplier was developed for portable detectors in replacement of previous vibrator units (E45, A19). This circuit has been used and modified for many applications, and at one stage a detailed series of tests was carried out to determine suitable transistor types and transformer designs.

Many transistor pulse circuits, trigger units and timing circuits have been developed (E48, E49, E50, E52, E54, F1) and several new systems are under construction at present. One complication of work in this field is the rapid obsolescence of transistor types due to the immense industrial progress made with these devices.

Among recent applications of transistor amplifiers or scalers are a pre-amplifier for a "Soniscope" crack detector (H51), a timing system for a fast flowmeter for jet engine fuels and another timing device to measure the swings of a sensitive galvanometer used for basic

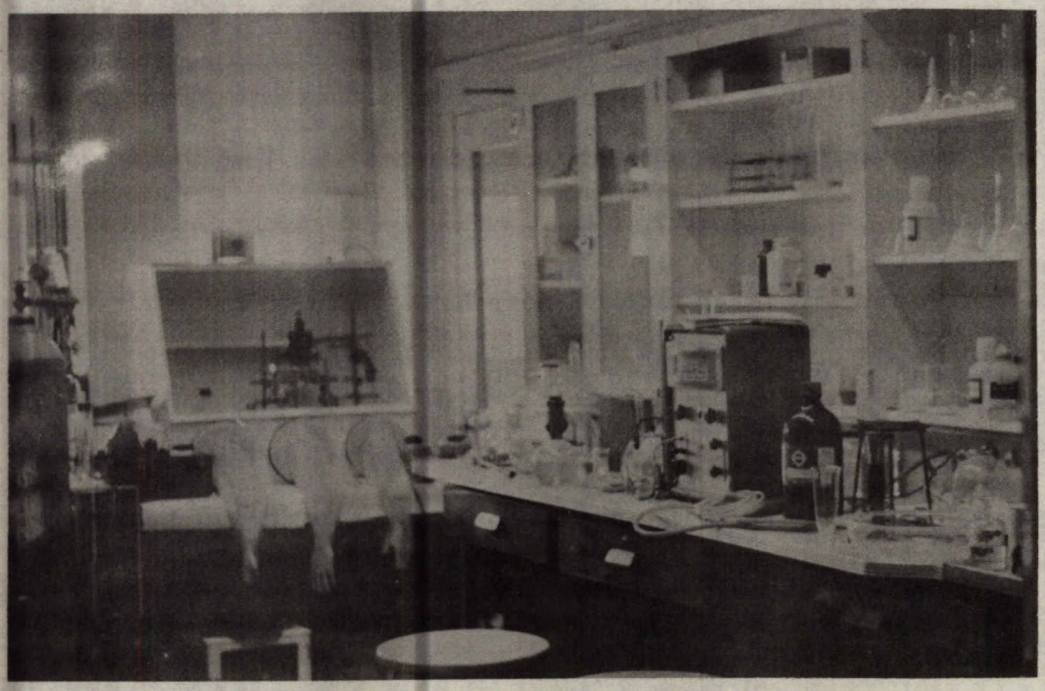
elasticity measurements on fine alloy wires. This last system employs photoconductive cells, one of many types of photovoltaic and photoconductive units which have been used in experiments over the years as solar batteries, radiation detectors and trip devices.

MAINTENANCE AND CONSTRUCTION OF ELECTRONIC UNITS

Although the development work on novel electronic circuits and gadgets tends to overshadow the less glamorous aspects of the Electronics Laboratory, namely maintenance and construction of electronic units, these have nevertheless always been an important function of the Section over the years. Intended initially to deal only with the servicing problems of the Section's own equipment, like scalers, amplifiers and power supplies, the availability of a group of experienced electronics men soon led to considerable demands for their services; both within the Mines Branch and from the uranium industry. All kinds of equipment such as recorders, pH meters, spectrophotometers, X-ray units and others had to be repaired and serviced. Many scalers, ratemeters, power supplies and other units had to be constructed, and advice was freely given to other Divisions, Government Departments and private firms on suggested procedures, suitable equipment for specific purposes and possible methods of lay-out and design. For many years the experience of the Section with different types of scalers and detectors was accepted by the growing uranium industry as a guide in purchasing its own equipment, and care was taken to keep in touch and test, whenever possible, any new electronic equipment which was offered to the industry. In this the Section enjoyed the confidence of the electronic manufacturers as well as the uranium mines and in this capacity probably fulfilled a unique, but useful function. One result of this was that members of the staff were asked frequently to visit mines

to check equipment or locate troubles in electronic equipment (see e.g. H11, H16, H25, H31, H33, H36, H44). In other cases equipment was shipped to Ottawa for repairs (H18, H46) and on many occasions equipment was lent to mines to tide them over some maintenance difficulties.

As far as the construction of "gadgetry" goes, these projects are difficult to record, as they usually only involve an improvement in some existing system or the construction of units following published circuits. Examples of this type are the installation of an inter-communication system, the setting-up of a radiation alarm system for the Fuels Division, a flow integrating device (A15) or the construction of an improved automatic titrimeter (H42). Many electronic circuits, that their commercial manufacturers have claimed to be almost trouble-free or fault-proof, have absorbed an astonishing number of man-hours on service and maintenance, often because insufficient allowance was made for industrial conditions, acid-laden air, or just for the simple needs of adequate heat dissipation.



View of a Tracer Laboratory at 568 Booth Street.

RADIOACTIVE TRACERS IN EXTRACTIVE METALLURGY

With the facilities that were at hand for the detection and measurement of radioactivity it was natural that the possibilities of applying radioactive isotopes in industry, especially in mining and metallurgy should be explored thoroughly. In spite of all the publicity this new scientific tool has received in the popular press, the actual applications in industry anywhere have been surprisingly few. This has partly been due to the small number of scientists interested in such work who had working contact with the industries concerned, and partly to the inherently cautious attitude of many of those responsible for plants and mills when confronted with methods and procedures which were untried and usually unfamiliar. This situation has made work in this field an unusual challenge and most projects that were undertaken by the Section broke new ground and opened up new possibilities. A Government laboratory is probably in a particularly favorable position to undertake pilot work of this type, as its impartiality in promoting a project is understood, and it can engage in consulting work and experimental activities at a minimal cost to the industry, an important factor when new methods are tried and the outcome is not firmly predictable. In 1954 a group of rooms was made available in the new wing of the Physical Metallurgy Division laboratories at 568 Booth Street, which were set up for work with radioactive tracers, mainly in the field of metallurgy. Progress was handicapped somewhat by overcrowded

conditions, but new quarters are expected for this work shortly in the new Mines Branch Building at 555 Booth Street.

In metallurgy most previous investigations had been confined to small-scale laboratory investigations. Our efforts have been consciously directed towards demonstrations of the usefulness and practicability of certain types of test work with radioactive isotopes which can be done in the field and on a full plant scale. Such tests were carried out to measure the contact times in leach agitators (E43, A20) and leach tanks (H12, H31). A fairly detailed series of tests was done to investigate various aspects of the flow of mineral particles and reagents in flotation systems (H22, H26, H34, E53, A23, F2). Various methods of labeling different mineral species with radioactive isotopes have been studied (E56, A28). Experiments are in progress to measure the adsorption of oleic acid on mineral particles. Similarly, the loss of the organic solvent in solvent extraction systems has been measured using a radioactive tracer (F5). Other experiments are under way to measure the surface area of coarse metal powders by means of a suitable tracer to obtain a measure of their relative chemical activity in precipitating uranium salts.

Another field where radioactive isotopes have been tried to investigate plant processes is in furnaces and smelters. This work has ranged from gold precipitation and purification (H13) to copper smelting (H45) and iron smelting (G16, G19), and several other applications have been discussed.

RADIOACTIVE TRACERS IN PHYSICAL METALLURGY

Radioactive tracer tests in this field have usually been carried out in close cooperation with the Physical Metallurgy Division of the Mines Branch. They started with some experiments on segregation in zirconium alloy billets in 1954 (unpublished) and cooperation in calibration tests carried out to compare the relative sensitivities of photographic emulsions used for autoradiography (13). Since then many fundamental problems in physical metallurgy have been studied that seemed amenable to the use of radioactive isotopes as markers or tracers. Such problems have included the oxidation of titanium metal (G18) and current studies on surface exchange kinetics between cobalt, zirconium, zinc and silver metals and their salts in solution (H50). Grain boundary effects have been investigated (H48) and some diffusion measurements have been started. A project to check the purification rate in zone melting is being started.

Another more unusual effect studied has been the Haeffner Effect, where some isotopic segregation has been observed in pure liquid metals when a current passes through them (B4, H19). A falling-cylinder method with a radioactive marker has been developed to measure the viscosity of liquid metals over a range of temperatures (E55); however, full utilization of this method has been delayed by recurring material failures, unconnected with the radiation aspect of this work. An adaptation of this method has also been developed to determine the viscosity of mineral slurries (G17, A30). Much of this work will be greatly facilitated by the impending move of the Tracer Laboratory into new and less crowded quarters.

OTHER USES OF RADIOACTIVE ISOTOPES

Owing to a lack of readily available advice on the use of radioactive isotopes in industry by commercial consultants outside the field of radiography and gauges, the staff of the Section has been engaged in a variety of interesting engineering applications. These have involved the marking of radioactive dynamite (A22), the design of a system to provide automatic inspection of ammunition primers (E54, A29), and the marking of the dials of an aircraft navigation unit to make possible automatic aerial photography at pre-determined locations (F1). A system is under development to measure the flow rates of jet engine fuel and the Section assisted in the setting up of a kilocurie cobalt-60 irradiation unit used by the Fuels Division for study of irradiation-induced catalysis of petroleum products.

While deliberate attempts have been made to avoid fields that were already covered adequately by existing commercial suppliers, various types of liquid and solid level detectors for mills and smelters have been tested and discussed (e.g.H8). Similarly, commercial density gauges have been inspected and serviced.

Lastly, another important field of application is in analytical chemistry. This work has been done by staff of the chemistry sections of the Mines Branch with active assistance from the Radiation Laboratory. This work has already yielded some useful results, particularly as applied to rare earth elements (14) and the noble metals (15), and many further important applications can be envisaged.

CONCLUSION

This has necessarily been a rather cursory review of the many and varied activities of the Physics and Electronics Section over the past twelve years. A glance over the bibliography on the following pages will give a further picture of the range of activities covered. The Section has been fortunate in being able to pursue its work in so many different directions without any attempts on the part of the Department to confine it to a narrow line of investigations. This generous support and the loyal efforts of a conscientious and hard-working staff have made it possible for the Radiation Laboratory to remain in the forefront of the active isotope laboratories, despite the small number of its personnel and its limited space and facilities. In doing this it has, I believe, vindicated that sometimes rather ambiguous position of a Government laboratory in a field that is bound to be developed by private, commercial interests once the ground has been broken. By opening up this field the Mines Branch laboratories are contributing to the industrial progress of Canada in a vital area and to an extent which is quite out of proportion to the cost and effort required. It is hoped that it will be possible to maintain the present rate of progress and to help keep and improve Canada's position in the field of uranium and radioactive isotope technology in the years to come.

GGE/dm

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C. Summer Students

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Marvin I. Bernstein	1947-1948
Yves Dube	1948
John Greenberg	1948
Ronald F. Harris	1949
Pierre Normand	1950
Conrad Maheux	1950
William W. Happ, B.Sc (McGill), M.Sc(MIT) Ph.D (Boston)	1950
John W. Hilborn, B.Sc (McGill)	1951
H. Reginald Hardy	1952
Jean-Guy Tessier	1953
Robin P. Mallory	1954, 1955
Kenneth A. Laurie, B.A. (U.B.C.)	1955
Hyman H. Schwartz	1955, 1956
Jean P. Cartier	1956
Maxwell A. Pollard	1957
J. Robert Barkley	1957, 1958
Gary R. Purdy B.A.Sc (Alberta)	1958

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G14	SR-479/57	C. McMahon, A.F. Seeley and G.G. Eichholz, Radiometric Assay Tests on U.S. AEC Ore Samples, August 1957.
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G17	IR 58-211	G.R. Purdy, A Viscometer for Mineral Suspensions, August 1958.
G18	IR 59-10	J.C. Turgeon, The Mechanism of Oxidation in Titanium, Oct. 1956 (revised Sept. 1957).
G19	IR 59-25	G.G. Eichholz, Measurement of Kiln Residence Times by means of Radioactive Tracers, March 1959.

H. Internal Reports

The "H" references in the text pertain to Internal Reports which were not prepared for public distribution. A list of these reports is, therefore, omitted from this Information Circular.