



CANADA

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA

MINES BRANCH

SCIENTIFIC AND TECHNICAL PAPERS

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FOREWORD

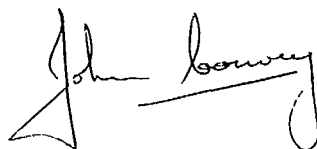
Information Circular IC 151 (June, 1963) was the first in a series of annual reviews of the scientific and technical papers published by the staff of the Mines Branch. This Information Circular IC 264 is the eighth supplement to IC 151 and is divided into three sections.

Section 1 consists of the titles of papers published during 1970 in the Mines Branch Series (Monographs, Research Reports, Technical Bulletins, Information Circulars and Reprint Series) together with an abstract or summary of each paper. These reports are available from Information Canada, Ottawa, at the prices indicated and may be ordered by the catalogue number given for each report. (Pre-1962 reports are listed in Canadian Government Sectional Catalogue No. 12, July 1962).

Section 2 lists the titles of all papers published in scientific and technical journals during 1970 by the Mines Branch staff. The periodicals containing these papers are available in many technical libraries.

Section 3 contains a list of the 1970 titles available in the Investigation Report Series and also of the titles from previous years that now have been released for general distribution. This series includes the results of investigations carried out by the Mines Branch at the request of industry and other government agencies and also of investigations initiated by the Mines Branch of specific materials and processes. Many Investigation Reports are not available because they are either confidential or of very limited interest. Those that are listed in the Information Circular are available for reference in the divisional files, but in most cases there are no additional copies for distribution. However, it is felt that even this limited availability will be of value to many individuals or companies with specific interests and will help prevent unnecessary duplication of investigations already made by the Branch.

I hope that this supplementary index will be as well-received as the first in this series and that it will provide the reader with a more complete view of the work of the Mines Branch in aiding Canada's mineral and metallurgical industries.

A handwritten signature in cursive script, appearing to read "John Convey". The signature is written in dark ink and is positioned above the printed name and title.

John Convey,
Director.

AVANT-PROPOS

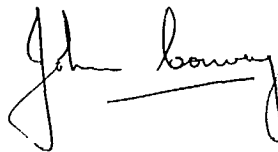
La Circulaire d'information IC 151 (juin 1963) était la première d'une série de revues annuelles des travaux scientifiques et techniques publiés par le personnel de la Direction des mines. La présente circulaire IC 264, qui comprend trois sections, est le huitième supplément à IC 151.

La première section comprend les titres des travaux publiés en 1970 dans les séries de la Direction des mines (monographies, rapports de recherches, bulletins techniques, et circulaires d'information), ainsi qu'un résumé ou un sommaire de chaque étude. On peut obtenir ces différents rapports chez Information Canada, à Ottawa, aux prix indiqués, en les commandant d'après leur numéro au catalogue. (La liste des rapports publiés avant 1962 figure dans le Catalogue partitif n° 12 du gouvernement canadien).

La section 2 comprend les titres de tous les travaux publiés par la Direction des mines en 1970 dans les revues scientifiques et techniques. Encore ici, un résumé de l'étude accompagne chaque titre, afin de donner au lecteur un aperçu de la teneur. Les périodiques où paraissent ces travaux sont à la disposition du public dans plusieurs bibliothèques techniques.

La section 3 énumère les titres des travaux qui ont paru dans la série des Rapports d'Investigations en 1970 et auparavant qui ont été rendus publics. Cette série comprend les résultats des recherches effectuées par la Direction des mines à la demande de l'industrie et d'autres services officiels, ainsi que les résultats des recherches entreprises par la Direction des mines sur des matériaux et procédés déterminés. Plusieurs de ces Rapports d'Investigation ne peuvent être consultés à cause de leur nature confidentielle ou du peu d'intérêt qu'ils présentent. Ceux qui sont énumérés dans la présente circulaire d'information peuvent être consultés dans les archives des diverses divisions, mais, dans la plupart des cas, il n'existe pas d'exemplaires pour la distribution au public. Cependant, on estime que même cette disponibilité limitée est de nature à favoriser de nombreux particuliers ou des sociétés qui s'intéressent à des domaines très précis et contribuera à éliminer le double emploi inutile en ce qui concerne les recherches déjà effectuées par la Direction.

J'espère que cet index supplémentaire sera aussi bien accueilli que les précédents dans cette série et qu'il présentera au lecteur un inventaire plus complet des travaux effectués par la Direction des mines au service des industries minérales et métallurgiques canadiennes.



John Convey,
Directeur.

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Information Circular 151 (1962)

Information Circular 162 (1963)

Information Circular 171 (1964)

Information Circular 181 (1965)

Information Circular 195 (1966)

Information Circular 205 (1967)

Information Circular 217 (1968)

Information Circular 247 (1969)

SECTION 1 - MINES BRANCH SERIES

RESEARCH REPORTS

R 210 Tectonic Interpretation of Elastic Strain-Recovery Measurements at Elliot Lake, Ontario

H. U. Bielenstein* and G. H. Eisbacher**

Bedding-plane slip, contraction faults, slickensided fractures, matrix-clast displacements, quartz veins, joints, and regional folds and faults were analysed in detail near Elliot Lake, Ontario, to test the potential of this approach for predicting the orientation of in-situ stresses in rock masses.

The major principal compressive stresses during deformation of the region were oriented subhorizontally and south-southeasterly. Gradual stress release by slow regional arching during the last 1000 million years is expressed in post-tectonic quartz veins and joints which have predominantly easterly trends.

Measurements of in-situ state of stress by overcoring in vertical upholes indicate a boundary between stresses due to mining and field stresses unaffected by mining: about 3 to 6 metres above the mine roof, maximum elastic strain recovery changes from a north-south to an east-west direction.

In-situ elastic strain recovery within the field stress environment is greatest parallel to the trend of late quartz veins and joint sets. Field stresses, therefore, are interpreted as remnants of former regional tectonic stresses.

Le glissement dans le plan des couches, les failles de contraction, les fractures à miroirs de faille, les dislocations de la gangue et des sédiments, les filons de quartz, les diaclases et les plis et failles régionaux ont été analysés en détail aux environs d'Elliot Lake (Ontario) afin d'évaluer les possibilités d'une telle étude pour prévoir l'orientation des contraintes locales dans la masse rocheuse.

Les principales forces de compression qui se sont exercées lors de la déformation de la région étaient orientées en direction sud-sud-est suivant un léger pendage. La détente graduelle qui s'est traduite par un lent ploïement régional au cours du dernier milliard d'années est visible dans les filons de quartz et les diaclases post-tectoniques qui sont orientés principalement vers l'est.

Les mesures des contraintes locales effectuées par carottage vertical indiquent une ligne de démarcation entre les tensions dues à l'extraction minière et les tensions régionales qui n'ont pas été influencées par l'exploitation des mines: à environ 3 à mètres au-dessus du toit de la mine, la détente maximale des efforts élastiques passe de l'orientation nord-sud à l'orientation est-ouest.

La détente locale des efforts élastiques dans l'ensemble des efforts régionaux est la plus prononcée en direction des filons de quartz et des groupes de diaclases récents. Par conséquent, on considère les contraintes régionales comme des vestiges d'anciens efforts tectoniques régionaux.

*Geologist, Elliot Lake Laboratory, Mining Research Centre and **Geologist, Geological Survey of Canada, attached to Elliot Lake Laboratory, Mining Research Centre.

Price \$1.00

Cat. No. M38-1/210

R 211 The Determination of Mass Attenuation Coefficients for Titanium, Vanadium, Iron, Nickel, Copper, Praseodymium, Gadolinium, and Erbium

J. L. Dalton*

Mass attenuation coefficients have been determined for titanium, vanadium, iron, nickel, copper, praseodymium, gadolinium, and erbium. The coefficients for the transition elements were measured over the range 17 keV to 2 keV and the rare earth elements over the range 28 keV to 5 keV. The precision of the measurements --that is, the calculated relative sample standard deviation for all the replications for a single coefficient -- was less than one per cent in some cases. Agreement of the standard deviation predicted by the law of propagation of error with that obtained by measurement was achieved in favourable cases. Absorbing foils that were not ideally uniform accounted for discrepancies between the predicted and the actual standard deviations that occurred. The accuracy of the measurements is judged to be in the range two to four per cent of the mass attenuation coefficient reported. A statistical analysis of the data yielded constants and exponents making possible the calculation of mass attenuation coefficients in several atomic number-energy regions.

Le coefficient d'atténuation de la masse du titane, du vanadium, du fer, du nickel, du cuivre, du praséodyme, du gadolinium et de l'erbium a été déterminé. Le coefficient des éléments de transition a été mesuré sous une tension de 17 keV à 2 keV et celui des terres rares sous une tension de 28 keV à 5 keV. Le degré de précision des mesures, c'est à dire l'écart-type relatif de l'échantillon pour toutes les répétitions relativement à un seul coefficient, était de moins d'un p. 100 dans certains cas. La concordance de l'écart-type établie par la loi de la propagation de l'erreur avec l'écart mesuré a été réussie dans certains cas idéals. Les divergences qui se sont révélées entre les écarts-types prévus et ceux qui se sont produits étaient dues au manque d'uniformité de la feuille d'absorption. Les mesures ont été jugées exactes jusqu'à deux à quatre p. 100 du coefficient d'atténuation de la masse rapporté. L'analyse statistique des données obtenues a livré des exposants et des constantes qui ont permis de calculer le coefficient d'atténuation de la masse dans plusieurs zones de la corrélation nombre atomique-énergie.

*Scientific Officer, Spectrochemistry Section, Mineral Sciences Division.

Price 75 cents

Cat. No. M38-1/211

R 212 Continuous Automatic Cyanide Titration in Copper-Bearing Gold Mill Leach Liquors

J. C. Ingles*

This report describes the preparation and evaluation of a new silver-complex reagent formulation for the continuous titration of cyanide in cupriferous gold-leaching solutions. Some improvements in the design of the continuous automatic titrating apparatus are also described, and the significance of the "free" cyanide value in the control of the cyanide gold-leaching process is discussed.

Ce rapport décrit la préparation et l'évaluation d'une nouvelle formule de réactifs à argent, pour le titrage continu du cyanure dans les solutions cuprifères provenant du lessivage de certains minerais d'or. On y décrit aussi quelques améliorations dans le modèle de l'appareil pour le titrage automatique continu, et on y discute la signification du terme "cyanure libre" en rapport avec le contrôle du procédé de lessivage de l'or au cyanure.

*Head, Chemical Analysis Section, Extraction Metallurgy Division.

Price 75 cents

Cat. No. M38-1/212

R 216. The Growth of Arsenopyrite Single Crystals by the Closed-Tube Iodine Vapour Transport Technique

S. Fushimi* and A. H. Webster**

Growth of arsenopyrite crystals was attempted by the closed-tube iodine vapour transport technique. It was necessary to choose the conditions of synthesis properly or else loellingite and pyrrhotite would form in association with arsenopyrite. Indeed, the transported products always contained at least a trace of loellingite or pyrrhotite. Small but fairly well-shaped arsenopyrite crystals with dimensions up to 0.3 x 0.1 x 0.1 mm were obtained. It has not been possible, up to the present time, to obtain large single crystals: the product has generally consisted of agglomerated, dendritic crystals with dimensions of up to 2 mm.

La croissance des cristaux d'arsénopyrite a été tentée par la méthode de transport chimique en présence d'iode dans des ampoules scellées. Les conditions de croissance devaient être choisies avec soin, autrement du löllingite ou du pyrrhotine se formera. En effet, les produits transportés contiennent toujours au moins une trace de löllingite ou de pyrrhotine. Des petits cristaux bien formés d'arsénopyrite jusqu'à 0.3 sur 0.1 sur 0.1 mm de grandeur s'obtiennent. Il n'a pas été possible, jusqu'au présent, d'obtenir des monocristaux grands: le produit consiste d'ordinaire des cristaux agglomérés et dendritiques, jusqu'à 2 mm de grandeur.

*National Research Council of Canada Postdoctorate Fellow (Present address: Electrical Communication Laboratory, Nippon Telegraph and Telephone Public Corporation, Musashino, Tokyo, Japan) and

**Research Scientist, Physical Chemistry Section, Mineral Sciences Division.

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Cat. No. M38-1/216

R 217 A Comparison of Thermal and Catalytic Hydrogenation as a Preliminary Step in the Refining of Athabasca Bitumen

J. J. Cameron*, M. A. O'Grady* and B. I. Parsons**

The report describes a laboratory-scale investigation of thermal (non-catalytic) and catalytic hydrogen treatment processes for converting the residuum material (+990°F) in Athabasca bitumen to distillable hydrocarbon fractions. The experiments were made in the liquid phase, using a conventional flow apparatus with a bottom-feed pipe reactor at pressures from 500 to 3500 psi. The rate of accumulation of sludge (combined tar, coke, and mineral matter) in the reaction vessel was greatest at high conversion levels and low pressures. Continuous operation was not possible at 500 psi, but at 1000 psi the concentration of residuum (including clay) could be reduced to 18-20% without serious difficulty. Considerable gas formation occurred at all pressures in the thermal experiments and at low pressures in the catalytic system. It was only at high pressures that the catalyst suppressed gasification relative to the conversion of the residuum, resulting in a marked increase in the yield of liquid product. The maximum permissible extra cost for catalytic processing, compared to thermal hydrocracking (capital cost plus catalyst), is estimated at 25-30¢/bbl.

Le présent rapport décrit l'essai à l'échelle expérimentale des procédés d'hydrogénation thermique (non-catalytique) et catalytique servant à convertir des résidues (+990°F) de bitume de l'Athabasca en fractions d'hydrocarbures distillables. Les essais ont été effectués à l'état liquide, au moyen d'un appareil d'écoulement classique comportant un réacteur tubulaire alimenté par le fond sous des pressions de 500 à 3500 livres au pouce carré. Le taux d'accumulation des déchets de raffinage (combinaison de goudron, de coke et de matière minérale) le plus élevé a été enregistré lorsque la pression était au minimum et le niveau de conversion au maximum. Le fonctionnement continu était impossible à une pression de 500 livres au pouce carré, mais à 1000 livres il était possible de réduire la concentration de résidus (y compris l'argile) de 18 à 20 p. 100 sans difficulté. Une quantité considérable de gaz était produite à toutes les pressions lors des essais thermiques et à basse pression lors des essais catalytiques. Ce n'est qu'à hautes pressions que le catalyseur supprimait la gazéification relative à la conversion des résidus, ce qui avait pour effet d'augmenter sensiblement la production de liquide. Le coût estimatif supplémentaire admissible du traitement par catalyseur comparativement au coût de l'hydrocraquage (installation plus le coût du catalyseur) est de 25 à 30 cents le baril.

*Technicians and **Research Scientist, Fuels Research Centre.

Price 50 cents

Cat. No. M38-1/217

R 218 The Bromination of Titanium, Thorium, and Titanium-Thorium and Titanium-Thoria Alloys

L. G. Ripley*

The development and appraisal of a method of bromination of titanium, thorium, and titanium-thorium and titanium-thoria alloys at temperatures of 200 to 500°C are described.

The results obtained give a clearer understanding of the reactions occurring in these types of material when they are prepared from the melt. It is concluded that titanium does not reduce thoria during the melting of a titanium-thoria alloy.

Le présent rapport décrit la mise au point et l'évaluation d'une méthode de bromuration du titane et du thorium ainsi que des alliages titane-thorium et titane-thorine à des températures de 200°C à 500°C.

Les résultats obtenus font mieux comprendre les réactions que subissent ces matériaux lorsqu'ils sont préparés à partir de la fonte. On peut conclure que le titane ne réduit pas la thorine durant la fusion d'un alliage titane-thorine.

*Research Scientist, Physical Chemistry Section, Mineral Sciences Division.

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Cat. No. M38-1/218

R 220 Interrelationship of Deformation and Fracture Contours

L. P. Trudeau*

Analytical work on the aspects of the stress field that cause a slant fracture to start forming is described. The "build-up" distance for transverse stress and the orientation of the stress field both point to the importance of the quantity $(\sqrt{2} - 1)R$ for a circular contour. It is shown, further, that a unit zero isoclinic beginning from the location defined by this quantity is practically an osculating curve of the unit circle. Using this interrelationship, it is demonstrated that fractures, in a number of sections from crack-notch toughness specimens, follow the elastic zero isoclinic precisely even though considerable plastic flow preceded the fracture. For cup-cone fractures in round tensile-test specimens, this same quantity appears to define the interrelationship between surface contour and the width of the cone.

L'auteur décrit les travaux analytiques effectués sur les aspects du champ de contrainte qui provoquent l'amorce d'une fracture inclinée. La distance de développement de la contrainte transversale et l'orientation du champ de contrainte mettent toutes deux en relief l'importance de la valeur $(\sqrt{2} - 1)R$ pour un profil circulaire. L'auteur montre ultérieurement qu'un isocline zéro unitaire partant de l'endroit déterminé par cette valeur est pratiquement une courbe osculatrice du cercle unitaire. A l'aide de cette relation, il montre que dans un certain nombre de coupes provenant d'éprouvettes servant aux essais de résistance à l'effet d'entaille, les fractures suivent très exactement l'isocline zéro élastique, même lorsqu'une déformation plastique considérable a précédé la fracture. Dans le cas des fractures en forme de cônes dans les éprouvettes cylindriques soumises à des essais de traction, il semble que cette même valeur détermine la relation entre le profil de surface et la largeur du cône.

*Research Scientist, Engineering Physics Section, Physical Metallurgy Division.

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Cat. No. M38-1/220

R 221 A Rapid Colorimetric Solvent-Extraction Procedure for the Determination of Cyanide in Gold-Mill Effluents and Receiving Waters

D. J. Barkley* and J. C. Ingles**

A colorimetric procedure is described for the determination of the total cyanide content of effluents from gold cyanidation plants and of water from basins into which they discharge.

The method has several advantages over the official American Water Works Association Methods for routine mill use. First, the colour reagent is stable and easily prepared. Second, the initial colour development, which takes only 25 minutes, provides a visual indication as to whether the cyanide content exceeds 0.5 ppm and hence permits a quick screening-out of high-level samples. Determinations on samples with lower cyanide content can then be completed within an additional 45 minutes by a simple solvent extraction-spectrophotometric step. Actual working time is of the order of 20 minutes per sample and, since equipment requirements are minimal, a high throughput is possible.

The method determines cyanide present as hydrocyanic acid, cyanide ion, zincocyanide, cuprocyanide and nickelocyanide, but not cyanide present in the form of ferrocyanide or cobaltocyanide. It is free from interference by thiocyanate or cyanate and other common constituents of gold-mill effluents. It is also unaffected by the products resulting from the decomposition of cyanide by hypochlorite; and, by means of an addition of sodium arsenite to the sample, the interfering effect of hypochlorite itself can be eliminated. It can therefore be used as a means of following the progress of the hypochlorite process for the destruction of cyanide.

On décrit un procédé colorimétrique pour le dosage du cyanure total dans des effluents provenant des usines pour le traitement des minerais d'or, et des eaux provenant des bassins dans lesquels ces effluents se déversent.

Cette méthode possède plusieurs avantages sur les méthodes officielles de l'American Waterworks Association pour l'usage routinier à l'usine. Premièrement le réactif colorimétrique est stable et se prépare facilement. Deuxièmement, la formation au préalable du colorant ne prend que 25 minutes et forme un moyen d'estimer visuellement si le contenu en cyanure excède 0.5 ppm. Ainsi un triage rapide des échantillons d'une plus forte teneur peut se faire.

Cette méthode détermine le cyanure qui se trouve sous forme d'acide cyanhydrique, d'ion cyanure, de zincocyanure, de cuprocyanure et de nickelocyanure, mais ne détermine pas celui qui se trouve sous forme de ferrocyanure et de cobaltocyanure. Ni le thiocyanate, ni le cyanate, ni les autres composés constitutifs habituels des effluents des usines pour le traitement des minerais d'or ne gênent. Les produits qui résultent de la décomposition du cyanure par le hypochlorite sont également sans effet, pendant que, par moyen de l'addition de l'arsenite du soude à l'échantillon, on peut éliminer l'effet gênant de l'hypochlorite lui-même. Alors cette méthode peut servir comme moyen de suivre le progrès du procédé au hypochlorite pour la décomposition du cyanure.

*Scientific Officer and **Head, Chemical Analysis Section, Extraction Metallurgy Division.

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Cat. No. M38-1/221

R 222 The Role of Calcium Sulphite in Desulphurizing Gases Containing Sulphur Dioxide

P. Marier* and T. R. Ingraham**

CaSO₃ is formed as an intermediate in the sulphation of CaO with gases containing SO₂. CaSO₃ is a reactive material; it may be oxidized readily by O₂, SO₂, or SO₃. In SO₂ atmospheres it reduces SO₂ to elemental sulphur. Calcium sulphite cannot be thermally decomposed to produce CaO and detectable pressures of SO₂. It undergoes a peritectoid reaction preferentially, to a mixture of CaS and CaSO₄. When the reaction temperature is above 800°C, CaSO₄ is the only oxidation product of CaSO₃. CaSO₄ forms a protective coating on CaSO₃. The coating retards the oxidation reaction.

Le CaSO₃ est un composé intermédiaire de la transformation en sulfate de CaO en présence de gaz contenant de l'anhydride sulfureux. Le CaSO₃ est une substance réactive; il peut être oxydé facilement par O₂, SO₂ ou SO₃. Dans les atmosphères qui contiennent du SO₂, il réduit cet anhydride en soufre élémentaire. Le sulfite de calcium ne peut être décomposé sous l'action de la chaleur pour produire du CaO et des pressions discernables de SO₂. Il subit une réaction péritectoidé préférentielle et on obtient un mélange de CaS et de CaSO₄. Lorsque la température de réaction est supérieure à 800°C, le CaSO₄ est le seul produit d'oxydation du CaSO₃. Le CaSO₄ forme une couche protectrice sur le CaSO₃. Cette couche retarde la réaction d'oxydation.

*Research Scientist and **Head, Research Section, Extraction Metallurgy Division.

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Cat. No. M38-1/222

R 223 The Extraction of Strontium from the Mineral Celestite

Sutarno*, R. H. Lake** and W. S. Bowman**

Two potential industrial methods of extracting strontium from the mineral celestite were investigated. These are (i) the direct carbonation method and (ii) the solid-state reduction method. Comparison between the two methods from the technical point of view is discussed. Reduction of synthetic strontium sulphate with various reducing agents was also studied in order to reach an understanding of the mechanism of the above processes.

Les auteurs ont examiné deux méthodes d'extraction du strontium de la célestine qui offrent des possibilités du point de vue industriel. Ce sont: (i) la carbonatation directe, et (ii) la réduction à l'état solide. Le rapport établit une comparaison technique entre les deux méthodes. Les auteurs ont également étudié la réduction du sulfate de strontium synthétique à l'aide de divers agents réducteurs, afin de mieux saisir le mécanisme des deux procédés cités.

*Research Scientist and **Technical Officers, Physical Chemistry Section, Mineral Sciences Division.

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Cat. No. M38-1/223

R 224 Development of Design Specifications for Rock Bolting from Research in Canadian Mines

D. F. Coates* and T. S. Cochrane**

Over the years a considerable amount of work has been done by the Mines Branch of the Government of Canada on the subject of rock bolting. Most of the work has been done in the mines; some studies have been conducted in the laboratory. A selection of some of the significant findings has been made for this report.

From the experience obtained in testing the anchorage capacity of different types of hardware in formations varying from strong sandstone to soft shales and also salt, it has been found that different anchorage shells with similar mechanical designs can have quite different anchorage capacities. It is only possible to determine the capacity of a particular anchorage system in a particular rock by conducting a series of pull tests. The one general conclusion that has been established is that in weak rocks the larger the bearing length of the shell the greater its capacity.

The testing of anchorages has also shown that like other structural components, the strength of an individual bolt will be dispersed about an average value. The degree of dispersion is important, as a higher frequency of failure than is acceptable can result if roofs that have a support system designed on the basis of average strength. For example, it was found in one series of tests that the coefficient of variation of yield loads was 27%, which means that only at 65% of the average yield load ($0.65 P_y$) would 90% of the bolts have a yield load equal to or greater than this amount ($0.65 P_y$).

In soft rocks a large amount of possible expansion is desirable to prevent wedges from being pulled through the shell. In other words, relatively wide-angle wedges are more appropriate than the small-angle wedges suitable for use in hard rocks. Tests showed that for many conventional shells 100% of the possible expansion was used in installing the bolt, leaving no margin for further deformation before the wedge would be pulled through the shell. In this regard, the minimum possible hole size will provide the best anchorage conditions. In extreme cases, of course, grouted bolts or other types of support may be necessary.

It was found difficult to obtain uniform installation tensions in all bolts even when hand tightening is used. The amount of torque dissipated during installation as a result of bending of the bearing plate is responsible for much of the variation and is affected by the rock conditions at the collar of the hole. Consequently, the bearing plate size and thickness are important.

Anchorage capacity can deteriorate with time. Aside from rock that creeps under stress or that suffers deterioration from ground water, the most significant cause of such deterioration is deflection of the roof accompanied by expansion in the rock. These deflections may increase with time under static geometrical conditions but are greatly affected by the mining of adjacent openings. Measuring programs have shown that it is possible to establish a deflection number that, if exceeded, heralds the onset of additional deflection together with significant deterioration of rock conditions and the associated bolt anchorages. For example, in mines in two different areas it was found that for entries with a 5-m breadth an expansion of 6 mm within the first 210 cm into the roof was the critical amount. It has also been found that the retorquing of bolts can be beneficial, increasing the working load and presumably inhibiting the development of critical deflections in the roof.

Laboratory model tests indicate that bolt spacing should be less than 5 times the typical joint spacing in the rock mass. In addition, it was seen in these tests that the spacing should not exceed the length of the bolts.

As a result of field research on rock bolting, tentative specifications have been formulated to provide guidance for design engineers using rock bolt support for temporary openings. These specifications require classification of the rock, selection of steel for the bolt, the use of the appropriate size of bearing plate, the calculation of bolt length and spacing, limitation of the magnitudes of installed tension and torque, and monitoring under many conditions. The tentative specification can be improved by analysing the observations and criticisms from design engineers who are dealing with a wide variety of conditions.

Au cours des années, des travaux d'envergure furent accomplis par la Direction des Mines du Gouvernement canadien dans le domaine du boulonnage des roches. La plupart des travaux furent exécutés en collaboration avec des mines et on poursuivit des études dans des laboratoires. Cette communication est un choix des constatations d'importance que l'on a fait.

Nous nous sommes rendus compte, par l'expérience acquise en éprouvant la capacité d'ancrage de différents types de boulons, dans des formations, à partir de grès durs jusqu'aux schistes tendres, y compris le salpêtre, que différentes sortes de coquilles d'ancrage, de construction mécanique similaire, peuvent avoir des capacités d'ancrage assez marquées. C'est seulement par la réalisation d'une série d'essais en traction qu'il est possible d'établir la capacité d'ancrage d'un système particulier dans une roche particulière. La seule conclusion générale que l'on ait pu tirer, c'est qu'en roches tendres, plus grande est la longueur portante de la coquille, plus élevée est sa capacité d'ancrage.

Les essais effectués sur des systèmes d'ancrage ont aussi démontré que la résistance d'un boulon individuel sera dispersée autour d'une valeur moyenne, de la même manière que le cas d'autres systèmes structuraux. Le degré de dispersion est important puisqu'il peut en résulter un taux de manquements plus grand que celui qui est accepté pour le cas de toits où la résistance moyenne conditionne l'étayage. Par exemple, nous avons trouvé, à la suite d'une série d'essais, que le coefficient de variation des charges-limite était de 27%, ce qui signifie que c'est seulement à 65% de la charge-limite moyenne ($0.65 \bar{P}_y$) que 90% des boulons atteindraient une charge-limite égale à ou plus élevée que cette valeur-ci ($0.65 \bar{P}_y$).

En roches tendres, il est désirable que l'expansion possible soit grande, ce qui empêcherait les coins de passer à travers la coquille lors du serrage de l'écrou. En d'autres mots, des coins à grands angles sont plus appropriés que ceux à petits angles, employés surtout en roches dures. Des essais ont démontré que pour plusieurs coquilles de types conventionnels on faisait usage à 100% de l'expansion disponible lors de l'installation du boulon, ne laissant aucune marge pour toute autre déformation supplémentaire avant que le coin, sous traction, ne passe à travers la coquille. A cet égard, un trou de dimension aussi restreinte que possible assurera les meilleures conditions d'ancrage. Naturellement, pour les cas exceptionnels, il sera peut-être nécessaire d'employer des boulons cimentés ou tout autre mode de soutènement.

Nous nous sommes aperçus qu'il est difficile d'obtenir un serrage uniforme des boulons même lorsque celui-ci se fait manuellement. Le montant de torsion dispersé pendant l'installation, à la suite du fléchissement de la plaque portante est responsable pour la presque totalité de la variation et est affecté par les conditions de la roche à l'orifice du trou. En conséquence, la grandeur et l'épaisseur de la plaque portante sont de première importance.

La capacité d'ancrage peut diminuer avec le temps. A part la roche qui flue sous l'effet des contraintes ou qui s'altère en raison des eaux d'infiltration, la cause la plus significative d'une telle diminution est la déflexion du toit accompagnée de l'expansion de la roche. Ces déflexions qui peuvent s'accroître avec le temps dans des chantiers stationnaires, sont grandement affectées par les travaux d'exploitation adjacents. Des programmes de mesures ont démontré qu'il est possible d'établir un nombre de la déflexion lequel, lorsque dépassé, marque le début de déflexions additionnelles conjointement avec une détérioration prononcée des conditions de la roche et du boulonnage. Par exemple, dans des mines en deux endroits différents, nous avons trouvé que pour le cas d'entrées de 5 m de largeur, une expansion de 6 mm en-deçà des 200 premiers cm de pénétration du toit constituait la valeur critique. Nous avons aussi constaté que le resserrage des boulons peut avoir un effet bénéfique, augmentant ainsi la charge de travail et probablement empêchant le développement de déflexions critiques au toit.

Des essais sur modèles en laboratoire indiquent que l'espacement des boulons devrait être inférieur à 5 fois l'espacement typique des diaclases dans la masse rocheuse. En outre, ces essais ont montré que l'espacement ne devrait pas excéder la longueur des boulons.

A la suite de recherches sur le boulonnage exécutées en chantier, nous avons formulé provisoirement des spécifications qui serviraient de guides aux ingénieurs en dessins se servant de ce mode d'étaiement par boulonnage pour le cas d'ouvertures temporaires. Ces spécifications demandent la classification des roches, un choix de l'acier pour la fabrication des boulons, l'usage de plaques portantes de grandeurs appropriées, le calcul de la longueur et de l'espacement des boulons, une limite de la magnitude de la contrainte et de la torsion, et le rôle avertisseur sous des conditions importantes. Ces spécifications provisoires peuvent être précisées par l'analyse des observations et critiques énoncées par les ingénieurs en dessins qui sont occupés avec des multiples conditions.

*Head and **Manager, Mining Research Centre.

Price 75 cents

Cat. No. M38-1/224

R 225 The Thermal Destruction of DDT in an Oil Carrier

H. Whaley*, G. K. Lee*, R. K. Jeffrey** and E. R. Mitchell***

The report describes combustion tests which established that the safe disposal of DDT in an oil carrier can be achieved by thermal destruction. The tests were conducted in two laboratory pilot-scale installations to determine

- a) the nature of the combustion products produced and the completeness of thermal destruction,

- b) the extent to which any noxious products in the flue gases can be removed by scrubbing and neutralization procedures, and
- c) the design criteria necessary to construct commercial DDT/oil incinerators.

Complete combustion was readily achieved in both laboratory units, using a "blue-flame" burner with controlled flame recirculation. An important finding was that the chlorine present in the DDT formula was reduced to hydrochloric acid gas which was effectively removed and neutralized by an alkali scrubbing unit.

On the basis of the test data, design criteria were drawn up for commercial DDT/oil incinerators, using combinations of commercially available components.

Le rapport décrit des essais de combustion qui ont montré la possibilité de détruire en toute sécurité les mélanges DDT-huile par incinération. Les essais ont été effectués dans deux appareils pilotes de laboratoire afin de déterminer:

- a) la nature des produits de combustion et le degré de destruction obtenu;
- b) jusqu'à quel point on peut éliminer les produits nocifs dans les gaz de combustion par lavage et neutralisation;
- c) les normes à observer dans la construction d'incinérateurs commerciaux de mélanges DDT-huile.

Dans les deux appareils, on a aisément obtenu une combustion complète à l'aide d'un brûleur à "flamme bleue" avec recirculation sous flamme contrôlée. Il importe de noter que le chlore contenu dans le DDT s'est transformé en acide chlorhydrique gazeux qui a été complètement éliminé et neutralisé par un appareil de lavage alcalin.

Les résultats des essais ont permis d'établir des normes pour la construction d'incinérateurs commerciaux de mélanges DDT-huile, combinant des éléments d'appareils existants.

*Research Scientists, **Technical Officer and ***Head, Canadian Combustion Research Laboratory, Fuels Research Centre.

Price 75 cents

Cat. No. M38-1/225

R 228 Artificial Support of Rock Slopes

K. Barron*, D. F. Coates** and M. Gyenge*

Part I of this research report gives some simple analyses and establishes some guidelines for designing support for hard rock slopes. Part II describes the installation of a trial support system and gives a breakdown of construction costs. Part III considers the design and costing of support systems for some hypothetical rock slopes. It is shown that the potential profit per linear foot of pit wall, obtained by using artificial supports to safely increase the slope angle, may be optimized.

La première partie du présent rapport de recherche renferme certaines analyses simples et des directives générales sur le soutènement des parois rocheuses. La deuxième partie décrit l'installation d'un dispositif de soutènement d'essai en fait état de coût de sa construction. La troisième partie étudie le plan et le coût de dispositifs de soutènement pour diverses parois hypothétiques. Le rapport démontre que l'utilisation des supports artificiels pour accentuer l'angle de la parois des excavations permet d'augmenter le profit par pied linéaire.

*Research Scientists and **Head, Mining Research Centre.

Price \$1.25

Cat. No. M38-1/228

R 209 Studia Nad Mechanizmem Zmian Wlasnosci Plastycznych Wegli Koksujacych W Wyniku Wietrzenia

Boleslaw Ignasiak*

A study of the mechanism of changes in plastic properties of coking coals owing to weathering (Polish text).

*Post-Doctorate Fellow, Research on Bituminous Substances, Fuels Research Centre.

TECHNICAL BULLETINS

TB 104 Improvement of a Continuous Process for the Production of High-Purity Tungstic Trioxide from Scheelite: Preleaching the Scheelite with Weak Hydrochloric Acid

J. A. Vezina* and W. A. Gow**

The effect of leaching Canadian scheelite concentrates with weak hydrochloric acid at pH 1.0 prior to treatment by a previously described Mines Branch process was investigated. The work showed that the weak-acid leach removed about 25 per cent of the iron, 90 per cent of the phosphorus, 10 per cent of the calcium and 0.1 per cent of the tungsten from a scheelite concentrate analysing 54.5 per cent WO_3 , 15.8 per cent CaO, 3.9 per cent Fe, and 0.43 per cent P. The overall cost on the basis of acid consumption and tungsten loss would be about \$0.04 less per pound of tungsten than for the original Mines Branch process where the weak-acid leach was not used.

Les auteurs ont poursuivi des recherches sur l'effet de lessiver des concentrés de scheelite canadienne dans une solution de pH 1.0 en se servant d'acide chlorhydrique faible, avant de les traiter selon une méthode d'extraction de la Direction des mines, décrite précédemment. Les résultats ont démontré que le lessivage à l'acide faible libérait environ 25 p. 100 du fer, 90 p. 100 du phosphore, 10 p. 100 du calcium et 0.1 p. 100 du tungstène d'un concentré de scheelite composé de 54.4 p. 100 de WO_3 , 15.8 p. 100 de CaO, 3.9 p. 100 de Fe et 0.43 p. 100 de phosphore. Le coût global, fondé sur la consommation d'acide et la perte de tungstène, serait d'environ 4 cents de moins la livre de tungstène comparativement au coût du procédé original de la Direction des mines, lequel ne comprenait pas l'emploi du lessivage à l'acide faible.

*Research Scientist and **Head, Hydrometallurgy Section, Extraction Metallurgy Division.

Price 50 cents

Cat. No. M34-20/104

TB 110 Some Design Aspects of the Pressure-Oxidation Acid Leaching of a Canadian Uranium Ore

J. A. Vezina* and W. A. Gow**

An investigation was done to determine the amount of heat and compressed air or oxygen required to leach Elliot Lake ore by pressure-oxidation, acid leaching. The tests were done on a batch scale with the leaching being done in a 50-gallon autoclave. The results showed that 95% of the uranium was extracted from a typical Elliot Lake ore in three hours at a temperature of 302°F, a total gas pressure in the autoclave of 150 psi gauge and an oxygen partial pressure of about 9 psi absolute. To maintain these conditions when the oxygen is supplied as compressed air would require 2207 cubic feet of dry air and 310,929 BTU per ton of ore.

Conditions to obtain up to 96% uranium extraction in as little as two hours were also determined. The highest extraction rates and extractions, which were obtained with oxygen partial pressures of about 20 psi absolute, would necessitate the oxygen being supplied as compressed oxygen.

The cost of heat and compressed air or oxygen to extract 95-96 per cent uranium in 2 to 4 hours by acid pressure oxidation would be in the range of \$0.39 to \$0.57 per ton of ore treated.

*Research Scientist and **Head, Hydrometallurgy Section, Extraction Metallurgy Division.

Price 75 cents

Cat. No. M34-20/110

TB 115 An Automated System for Continuous Monitoring of CO_2 , CO and O_2 in Boiler Flue Gas

R. K. Jeffrey* and G. K. Lee**

The report describes an automated system for sampling, analyzing and recording constituents of boiler flue gases. The system employs non-dispersive infrared spectrophotometers for analyzing CO_2 and CO and a thermomagnetic sensor for analyzing O_2 . Each analyzer is supplied with a clean, dry stream of flue gas to ensure a high degree of analytical sensitivity, selectivity and accuracy. Response time between sample inlet and readout is less than 40 sec because the three analyzers require only about 2 per cent of the total sample flow.

The system has been in operation for over three years and during this time it has been proved reliable, rugged and trouble-free.

Le rapport décrit un système automatisé d'échantillonnage, d'analyse et d'enregistrement des composants des gaz des carneaux de chaudière. On emploie des spectrophotomètres à infrarouge sans dispersion pour déterminer le teneur en CO_2 et en CO , et un détecteur thermomagnétique pour déterminer la teneur en O_2 . Chaque analyseur est alimenté d'un jet pur et sec de gaz de carneau afin d'assurer un haut degré de sensibilité, de sélectivité et d'exactitude analytiques. Il ne faut que 40 secondes pour obtenir les résultats de l'analyse après l'introduction de l'échantillon dans l'appareil puisque les trois analyseurs n'utilisent qu'environ 2 p. 100 du débit total de l'échantillon.

L'appareil est en usage depuis plus de trois ans et s'est avéré fidèle, résistant et sûr.

*Technologist and **Research Scientist, Canadian Combustion Research Laboratory, Fuels Research Centre.

Price 75 cents

Cat. No. 34-20/115

TB 116 Development of an Improved Sample Control and Counting System for Activation Analysis with a Neutron Generator

D. W. Carson*

An improved sample control and counting system has been developed for activation analysis with a neutron generator, replacing the original system developed earlier (1965).

The new system, which uses low-level, low-noise, solid-state logic circuitry and includes timing, counting and readout subsystems, provides improved frequency response and eliminates spurious counts created by the original relay-controlled circuits.

L'auteur décrit la mise au point d'un système amélioré de contrôle et de comptage d'échantillons pour l'analyse par activation à l'aide d'un générateur de neutrons, remplaçant le système original mis au point en 1965.

Le nouveau système qui fait usage de circuits logiques de corps solides à faible puissance et à faible bruit et qui comprend également des sous-systèmes de minuterie, de comptage et de lecture, donne une réponse de fréquence améliorée et élimine les comptes erronés que donnaient les circuits originaux contrôlés par relais.

*Electronic Technologist, Mineral Sciences Division.

Price 75 cents

Cat. No. M34-20/116

TB 117 The Limitations of Measuring pH by Colour Indicators

B. C. Syrett* and J. G. Garrison**

Aqueous solutions containing various amounts of NaCl and FeCl_2 were prepared and their pH's estimated using pH-indicators in three forms: indicator-impregnated filter paper, indicator-coated silica gel particles, and aqueous solutions of the indicators.

It was found that silica gel was an unsuitable medium for carrying the indicator because of its own acidic nature and that the proportion of indicator to test solution can influence the accuracy of the pH estimation. It was also found that the success of the indicator-paper method depends on the concentration of the indicating solution used in the preparation of the paper and on the concentration of dissolved salts in the test solution.

Les auteurs ont préparé des solutions aqueuses contenant des quantités différentes de NaCl et de FeCl_2 et ont déterminé leur pH à l'aide d'indicateurs se présentant sous trois formes: papier-filtre imprégné d'indicateur, particules de gel de silice recouvertes d'indicateur, et solutions aqueuses des indicateurs.

Ils ont observé que le gel de silice n'est pas un véhicule convenable pour l'indicateur en raison de sa propre acidité, et que la quantité d'indicateur utilisée pour faire réagir la solution peut affecter l'exactitude de la détermination du pH. Ils ont également remarqué que le succès de la méthode

employant un papier-indicateur dépend de la concentration de la solution indicatrice utilisée pour imprégner le papier et de la concentration des sels dissous dans la solution soumise à l'essai.

*Research Scientist and **Technician, Corrosion Section, Physical Metallurgy Division.

Price 50 cents

Cat. No. M34-20/117

TB 118 Concentration of Uranium Minerals from Canadian Ores by Magnetic Means

F. H. Hartman* and R. A. Wyman**

Because previous work with a Jones Wet Magnetic Mineral Separator demonstrated the possibility of concentrating certain uranium minerals by this means, a more extensive examination was undertaken. Ores from three areas, viz. Bancroft (one mine), Beaverlodge (two mines) and Elliot Lake (three mines), were investigated, using a number of experimental conditions and procedures, with results as summarized below:

Best Over-all Results

Mine	Magnetic Concentrate			No. of Passes
	Recovery %	Weight %	U ₃ O ₈ %	
Denison	87	27	0.45	12
Rio Algom (Nordic)	86	15	0.44	10
Eldorado (Beaverlodge)	82	52	0.34	10
Canada-Met	99	85	0.28	6
Faraday	56	25	0.25	3*
Gunnar	No concentration was achieved.			

*Screen fractions

Best Single-Pass Results

Mine	Magnetic Concentrate		
	Recovery %	Weight %	U ₃ O ₈ %
Denison	71	7	1.19
Rio Algom (Nordic)	68	5	1.14
Eldorado (Beaverlodge)	50	24	0.44
Canada-Met	95	73	0.31

Sur la base d'un travail antérieur effectué avec la Séparateur Magnétique Jones par voie humide, la possibilité de concentration de certains minéraux uranifères par ce moyen a été démontrée et un examen plus approfondi a été entrepris. Les minerais de trois régions, c'est-à-dire de Bancroft (une mine), de Beaverlodge (deux mines) et du Lac Elliot (trois mines), ont été étudiés dans des conditions expérimentales et par des méthodes différentes dont les résultats sont résumée ci-dessous:

Meilleurs Résultats Totaux

Mine	Concentré Magnétique			Nb de passages
	Rendement %	Poids %	U ₃ O ₈ %	
Denison	87	27	0.45	12
Rio Algom (Nordic)	86	15	0.44	10
Eldorado (Beaverlodge)	82	52	0.34	10
Canada-Met	99	85	0.28	6
Faraday	56	25	0.25	3*
Gunnar	Pas de concentration obtenue			

*Parties tamisées

Meilleurs Résultats d'un Seul Passage

Mine	Concentré Magnétique		
	Rendement %	Poids %	U ₃ O ₈ %
Denison	71	7	1.19
Rio Algom (Nordic)	68	5	1.14
Eldorado (Beaverlodge)	50	24	0.44
Canada-Met	95	73	0.31

*Research Scientist and **Head, Industrial Minerals Milling Section, Mineral Processing Division.

Price 75 cents

Cat. No. M34-20/118

TB 119 The Measurement of the Surface Area of Minerals with a Modified Perkin-Elmer Sorptometer

C. M. Lapointe*

The performance of a Model 212-D Perkin-Elmer Sorptometer has been studied for the measurement of surface areas in the range of specific surface areas between 200 cm²/g and 1000 cm²/g. It was found that, with some modifications to the instrument with regard to the transfer of the desorbed gas from the sample to the detector, the Sorptometer could be used for the surface area measurement of relatively large samples of mineral particles.

This Bulletin describes a simplification of the BET method that can be used for the routine measurement of surface areas on samples of similar characteristics by the one-point determination. The method can be extended to a two-point or a three-point determination in order to obtain a conventional BET plot.

A standard procedure is outlined for the calibration of the instrument, for the sample preparation, for the adsorption measurement, and for the calculation of the specific areas.

L'auteur évalue la performance d'un sorptomètre Perkin-Elmer, Modèle 212-D, pour la mesure des aires de surface de poudres allant de 200 cm²/g à 1000 cm²/g. Il a trouvé qu'après quelques modifications au mode de transport du gas désorbé de l'échantillon au détecteur, le sorptomètre convient à la mesure de l'aire de surface d'assez gros échantillons de minerais.

On décrit dans ce bulletin une simplification de l'équation BET que l'on peut utiliser au cours de mesures de routine sur une série d'échantillons semblables après détermination d'un seul point de l'isotherme. Cette technique peut aussi être employée afin de tracer l'isotherme conventionnel en effectuant deux ou trois mesures.

On trouvera en appendice descriptions 1) des techniques de calibration de l'instrument, 2) de la préparation des échantillons, et 3) du calcul des aires de surface.

*Research Scientist, Mineral Sciences Division.

Price 75 cents

Cat. No. M34-20/119

TB 120 Methods for the Analysis of Ilmenite, Titanium-Bearing Slags and other Electric Furnace Slags Part I: A Review and Comments on some Typical Methods for the Determination of Titanium and Iron

A. Hitchen*

A review has been made of some typical methods for the determination of titanium and iron. Comments on these methods have been made with the view of deciding on their applicability to the determination of titanium and iron in ilmenite ores and slags. The advantages and disadvantages of some of the methods are discussed.

L'auteur passe en revue quelques méthodes-type de titrage du fer et du titane. Il discute ces méthodes en vue de déterminer leurs possibilités d'application au titrage du fer et du titane dans les minerais d'ilménite et les laitiers.

*Senior Scientific Officer, Chemical Analysis Section, Extraction Metallurgy Division.

Price 50 cents

Cat. No. M34-20/120

TB 121 Methods for the Analysis of Ilmenite, Titanium-Bearing Slags and other Electric Furnace Slags
Part II: Rapid Methods for the Determination of Iron and Titanium in Ilmenite Ores and Slags

A. Hitchen*

Procedures are described for the rapid determination of titanium and iron in ilmenite ores and slags. Three fusion procedures are described which are suitable for decomposing the material and taking it into solution. Iron is determined by dichromate titration after reduction in a silver reductor. The combined titanium and iron titre is determined by dichromate titration after reduction with liquid zinc amalgam and the titanium is then found by difference. The accuracy and precision of the methods were satisfactory for routine control purposes and technicians may easily be trained in their use. A single analysis for both titanium and iron may be completed in between 45 and 60 minutes.

L'auteur examine certaines méthodes de titrage rapide du fer et du titane dans les laitiers et les minerais d'ilménite. Il décrit trois méthodes de fusion qui peuvent servir à décomposer le matériau en vue d'en faire une solution. La teneur en fer est établie par titrage au bichromate après réduction dans l'argent. La teneur combinée en fer et en titane est déterminée par titrage au bichromate après réduction dans un amalgame de zinc liquide, et on obtient ensuite la teneur en titane par soustraction. Ces méthodes sont assez précises pour les vérifications ordinaires et les techniciens peuvent facilement en apprendre l'usage. Un seul titrage de fer et de titane peut être effectué en 45 à 60 minutes.

*Senior Scientific Officer, Chemical Analysis Section, Extraction Metallurgy Division.

Price 75 cents

Cat. No. M34-20/121

TB 123 Quantitative X-ray Determination of Quartz and Pyrite in Dusts

H. Machacek*

This investigation concerns the quantitative direct X-ray determination of quartz and pyrite in airborne mine dusts. A new technique developed by Leroux and Powers has been successfully applied and some new details have been found. The method provides reproducible analyses of quartz and pyrite in dust samples. When the calibration curves of the pure components have been made and certain sources of error are kept within appropriate limits, quartz and pyrite can be determined down to $30 \mu\text{g}/\text{cm}^2$ when deposited on appropriate filters.

Cette étude a trait à la détermination radiologique directe des quantités de quartz et de pyrite contenues dans les poussières atmosphériques des mines. Une nouvelle technique mise au point par Leroux et Powers a été appliquée avec succès et quelques nouveaux détails ont été décelés. La méthode en question permet d'effectuer des analyses contrôlées du quartz et de la pyrite dans des échantillons de poussière. Lorsque les courbes de calibration des composants purs ont été tracées et que certaines sources d'erreurs sont maintenues dans des limites convenables, il est possible de mesurer les quantités de quartz et de pyrite avec une précision de $30 \mu\text{g}/\text{cm}^2$ lorsqu'ils sont déposés sur des filtres appropriés.

*NRC Postdoctorate Fellow assigned to the Crystal Structure Group, Mineral Sciences Division.

Price 50 cents

Cat. No. M34-20/123

TB 124 Methods for the Analysis of Ilmenite, Titanium-Bearing Slags and other Electric Furnace Slags
Part III: A Review and Comments on some Typical Methods for the Separation and Determination
of Aluminum

A. Hitchen*

A review of some typical methods for the separation and determination of aluminum in a variety of materials is presented. A discussion is given of the nature of interferences and sources of error likely to be encountered in the application of several of the methods. For application to the analysis of ilmenite and titanium-bearing slags, the simplest and most attractive methods appear to be those which involve an extraction step followed by a chelometric titration using EDTA or DCYTA.

L'auteur passe en revue quelques méthodes types utilisées pour séparer l'aluminium et en déterminer la quantité contenue dans divers matériaux. Il examine la nature des interférences et les causes d'erreurs susceptibles de se produire lors de l'application de plusieurs de ces méthodes. Pour l'analyse de l'ilménite et des laitiers titanifères, les méthodes qui paraissent les plus simples et les plus pratiques sont celles qui comportent une phase d'extraction suivie d'un titrage chéломétrique à l'aide d'EDTA ou de DCYTA.

*Senior Scientific Officer, Chemical Analysis Section, Extraction Metallurgy Division.

Price 75 cents

Cat. No. M34-20/124

TB 126 The Effect of pH on the Free-Corrosion Characteristics of 18% Ni(250) Maraging Steel in
3.5% NaCl Solutions

B. C. Syrett*

The free-corrosion characteristics of 18% Ni(250) maraging steel in 3.5% NaCl solutions have been studied, using tests in which the ratio of specimen area to solution volume was high (about 0.15 cm²/ml). Initial pH values lay in the range of about 1 to 12, and both aerated and de-aerated solutions were employed.

The observations were consistent with the established behaviour of many iron alloys in aqueous media.

L'auteur a étudié les caractéristiques de corrosion ordinaire de l'acier martensitique à 18 p. 100 de nickel (250) dans des solutions à 3.5 p. 100 de NaCl, au moyen d'essais dans lesquels le rapport entre la surface de l'échantillon et le volume de la solution était élevé, soit environ 0.15 cm² par ml. La valeur initiale du pH se situait entre 1 et 12, et l'auteur a employé des solutions aérées aussi bien que non aérées.

Les observations concordaient avec le comportement classique de nombreux alliages de fer en milieu aqueux.

*Research Scientist, Corrosion Section, Physical Metallurgy Division.

Price 50 cents

Cat. No. M34-20/126

INFORMATION CIRCULARS

IC 219 Some Comments on the Interpretation of Response Surfaces

F. D. Friedrich*

In the application of statistical analysis to industry and research, a response surface is the geometric rendition of an equation or set of equations describing the relationship between a dependent variable and a number of independent variables. The present report briefly outlines various techniques for determining the physical meaning of a response surface, assuming that the defining equations have already been obtained by statistical techniques.

Contour plots are briefly described, and an example shows how a computer can be used to extend them to three or more factors and three or more responses. The technique of ridge analysis is explained without mathematical proof. An example involving three independent variables is worked out. Finally, canonical analysis is discussed, and a brief example is given.

Dans les applications de l'analyse statistique à l'industrie et à la recherche, on appelle surface de réponse la représentation géométrique d'une équation ou d'une série d'équations décrivant la relation entre une variable dépendante et un certain nombre de variables indépendantes. Le présent rapport expose brièvement diverses méthodes de détermination de la signification physique d'une surface de réponse, en supposant que les équations de définition ont déjà été obtenues par des méthodes statistiques.

L'auteur décrit brièvement les tracés équiscalaires et donne un exemple de l'utilisation d'un ordinateur pour les étendre à trois facteurs ou plus, et à trois réponses ou plus. Il explique la technique d'analyse des pointes sans en faire la preuve mathématique, et traite un exemple à trois variables indépendantes. Enfin, il discute l'analyse canonique et en donne un bref exemple.

*Senior Scientific Officer, Canadian Combustion Research Laboratory, Fuels Research Centre.

Price 75 cents

Cat. No. M38-3/219

IC 226 LiF(220) Conversion Tables for X-ray Spectrography

Dorothy J. Reed* and Phillip Bretzloff**

Tables are presented of the 2θ angles for the principal X-ray lines of elements diffracted by the 220 plane of a lithium fluoride crystal.

Les auteurs présentent des tableaux des angles 2θ des principales raies X d'éléments diffractés par le plan 220 d'un cristal de fluorure de lithium.

*Research Scientist and **Summer Assistant, Spectrochemistry Section, Mineral Sciences Division.

Price 75 cents

Cat. No. M38-3/226

IC 227 Neutralization and Aeration of Acid Mine Waters (A Literature Survey)

V. F. Harrison*

Research and development work performed in the United States during the past twenty years or more on the neutralization of waste solutions containing sulphuric acid and dissolved iron is reviewed. The chemistry of mine water is explained, and the chemical properties of various types of limestone and lime are discussed. Also, methods of applying these reagents to coal mine drainage and industrial effluents to obtain clean water and of disposing of the precipitated sludge are outlined. It is suggested that mine water from some Canadian mines might be amenable to a limestone treatment process.

Le présent rapport passe en revue les travaux de recherche et de développement entrepris aux États-Unis depuis vingt ans et plus dans le domaine de la neutralisation des solutions résiduelles contenant de l'acide sulfurique et du fer dissous. Il examine la composition chimique des eaux de mines et étudie les propriétés chimiques de divers genres de calcaires et de chaux. De plus, le rapport fait un exposé général des méthodes d'application de ces réactifs aux eaux de houillères et aux effluents industriels.

en vue de leur épuration, ainsi que des méthodes d'évacuation des sédiments accumulés. Il a été proposé que l'eau de certaines mines du Canada pourrait se prêter à un traitement au calcaire.

*Research Scientist, Hydrometallurgy Section, Extraction Metallurgy Division.

Price 75 cents

Cat. No. M38-3/227

IC 230 Transport of Solids in Pipelines, with Special Reference to Mineral Ores, Concentrates, and Unconsolidated Deposits (A Literature Survey)

A. L. Job*

Pipelines offer significant possibilities for improved transport in the less developed areas of the world. The advantages and disadvantages of transport by pipeline are considered and comparisons made with rail transport. The application of transport by pipeline to the following industries is briefly reviewed: crude oil and natural gas, coal, mineral ores, industrial minerals, and wood pulp. Sand fill in mines, vertical hydraulic transport in mines, and dredging operations requiring the use of long pipe-lines, are reviewed.

The economics of various lines are reviewed and costs are given for transport of coal, rock phosphates and gilsonite. Transport by pipeline is used extensively in the Florida phosphate fields and practice in that area is also reviewed.

Vertical transport, as applied to mineral ores and coal, is examined in some detail and feeders are described. Large-scale dredging operations are further described. Pipeline wear, deflocculants, friction-reducing agents, and rifled pipes are mentioned. Centres for research in hydraulics and pipelining are listed and the work of the Alberta Research Council is described.

Tables include a list of mines using vertical transport and a list of pipelines, transporting solids in various parts of the world, over 2 miles in length. The technical terms commonly used in the literature dealing with hydraulic transport are defined. A bibliography of 383 references is included.

Les pipe-lines offrent d'excellentes possibilités d'améliorer le transport dans les régions sous-développées du globe. L'auteur passe en revue les avantages et les désavantages du transport par pipe-line par opposition au transport ferroviaire. Il examine brièvement l'application de ce mode de transport aux industries du pétrole brut et du gaz naturel, de la houille, des minerais, des minéraux industriels, du bois et de la pâte de bois. Il mentionne le remblayage au sable des vides d'exploitation minière, le transport hydraulique vertical dans les mines et le dragage nécessitant l'emploi de longs pipe-lines.

L'étude examine les aspects économiques de plusieurs genres de pipe-lines et les coûts de transport pour le charbon, la roche phosphatée et la gilsonite. Vu l'emploi généralisé des pipe-lines dans les mines de phosphate de Floride, elle passe en revue les méthodes appliquées dans cette région.

L'auteur étudie en détail le transport vertical, appliqué au minerai et au charbon, et décrit les conduites d'alimentation. Il donne plus de précisions sur le dragage à grande échelle. Il mentionne l'usure des pipe-lines, les produits de défloculation, les agents antifricition et les conduites à rainures. Il énumère les centres de recherche en hydraulique et en canalisations et décrit les travaux du Conseil de recherches de l'Alberta.

Dans les tableaux, on trouve une liste des mines qui utilisent le transport vertical et une liste des pipe-lines de plus de 2 milles de longueur transportant des produits solides dans diverses parties du monde. L'étude comprend également un glossaire des termes techniques couramment employés dans les ouvrages traitant du transport hydraulique, ainsi qu'une bibliographie de 383 ouvrages.

*Senior Scientific Officer, Mining Research Centre.

Price \$1.25

Cat. No. M38-3/230

IC 231 Analyses and Characteristics of Oil Samples from Saskatchewan

R. P. Charbonnier*, R. G. Draper*, W. H. Harper** and A. Yates*

The 83 oil analyses gathered in this publication have been performed in the Fuels Research Laboratories of the Mines Branch in Ottawa, according to the U. S. B. M. Routine Method of Distillation. Some reservoir characteristics are also included.

Les 83 analyses de pétrole rassemblées dans cette publication ont été faites aux laboratoires de recherches sur les combustibles de la Direction des mines, à Ottawa, suivant la méthode U. S. B. M. de distillation. On a aussi inclus quelques caractéristiques des gisements.

*Senior Scientific Officers and **Technical Officer, Fuels Research Centre.

Price \$1.25

Cat. No. M38-3/231

IC 232 Analyses and Characteristics of Oil Samples from Alberta

R. P. Charbonnier*, R. G. Draper*, W. H. Harper** and A. Yates*

The 198 oil analyses gathered in this publication have been performed in the Fuels Research Laboratories of the Mines Branch in Ottawa, according to the U. S. B. M. Routine Method of Distillation. Some reservoir characteristics are also included.

Les 198 analyses de pétrole rassemblées dans cette publication ont été faites aux laboratoires de recherches sur les combustibles de la Direction des mines, à Ottawa, suivant la méthode U. S. B. M. de distillation. On a aussi inclus quelques caractéristiques des gisements.

*Senior Scientific Officers and **Technical Officer, Fuels Research Centre.

Price \$3.00

Cat. No. M38-3/232

IC 233 Guide to Engineering Statistics

J. Visman* and Jacqueline L. Picard**

This text provides guidelines for the selection and the application of statistical techniques that are commonly used in science and industry.

The emphasis is on how to solve statistical problems and, by conveying the basic concepts of variability, to prepare the reader for further study of textbooks in his or her particular field.

Instructions in the form of a Summary of Operations, presented in Section 1, are recommended to those readers for whom the application of statistical analysis is not a daily routine. A tabular listing of statistical problems and procedures provides a short-cut to the practical application of techniques. A general sampling theory for segregated populations is introduced with condensed instructions that cover most of the variates.

Definitions of terms and symbols are presented in an appendix preceding the alphabetic register of subjects.

Many techniques in this guide can only be applied legitimately for calculating first-order estimates of a variance, a probability, a ratio, etc. For more critical situations where specific conditions - too complicated to be mentioned here - have to be satisfied, the reader is well advised to obtain the assistance of a professional statistician. Between this high level of perfection and that of the "educated guess" there is scope for a guide to statistics which it is hoped this volume will provide for its readers.

Ce texte a l'objet de servir de guide à la sélection et à la mise en oeuvre de techniques statistiques qui s'utilisent souvent dans les divers domaines des sciences et de l'industrie.

Il s'agit ici surtout de souligner la manière par laquelle se résolvent les problèmes statistiques. Par ailleurs, ce guide servira de préparatif à l'étude de la statistique dans le domaine particulier du lecteur en lui donnant des notions élémentaires de la variabilité.

Aux lecteurs pour lesquels l'utilisation de l'analyse statistique n'est pas une pratique journalière, la méthode est présentée sous forme de mode opératoire. Un résumé de divers problèmes et de procédés statistiques en forme de tableau sert de raccourci pour l'emploi de ces techniques. Une théorie générale de l'échantillonnage pour les populations ségréguées est présentée avec un précis de la technique qui traite de la plupart des variates. La définition des termes et caractères se trouve dans un appendice qui précède la table alphabétique des matières.

Les techniques dont on parle ne peuvent légitimement être utilisées que pour le calcul d'estimations de premier ordre, par exemple d'une variance, d'une probabilité, d'une proportion, etc. Lorsqu'il s'agit de situations plus difficiles où nous devons satisfaire à certaines conditions précises, trop compliquées pour être discutées ici, le lecteur devrait bien obtenir l'aide d'un statisticien. Entre ce niveau élevé de perfection et celui du jugement pratique, il y a de la place pour un guide à la statistique et c'est ce que nous espérons avoir ici fourni au lecteur.

*Head and **Technical Officer, Western Regional Laboratory, Metals Reduction and Energy Centre.

Price \$1.25

Cat. No. M38-3/233

IC 235 Superplasticity

H.M. Weld*

The superplasticity phenomenon, which is characterized by a metal's capacity for a large degree of relative uniform extension, is reviewed for the purpose of assessing both its potential applicability to practical metallurgical operations and the possible benefits to be derived from further research and development. Detailed are the requirements for a metal to be superplastic, as well as the conditions necessary for the phenomenon to occur. Twenty-nine metal systems reported to be superplastic are listed, including pure metals and single-phase and multi-phase alloys. A number of the methods are reviewed that are employed to generate the required fine grain structure--in the order of a micron--mechanically by extrusion or rolling, or thermally by eutectoid decomposition or compact sintering. It is concluded that superplasticity may be found in many other metal systems that possess a stable micrograin size within the limited temperature and strain-rate range in which a high strain-rate sensitivity can exist. Potential applications of superplastic metals by extruding, rolling, deep forming, coining, bulge-forming, and die-less wire drawing are reported. Possible problems in connection with the use of superplastic metals--such as oxidation, formation of voids, and strain-rate control--are discussed. Many of the commercial alloys reported to be superplastic will owe their acceptance to their improved mechanical and chemical properties rather than to their remarkable high-temperature ductility. The future application of the superplastic effect is viewed as being most successful when used to form large parts that are beyond the capabilities of most presses.

L'auteur étudie le phénomène de la superplasticité, qui se caractérise par l'aptitude d'un métal à s'allonger fortement d'une manière assez uniforme, afin d'évaluer à la fois son application possible aux travaux de métallurgie courante et les avantages éventuels à retirer de recherches ultérieures. Il décrit les paramètres de superplasticité d'un métal, ainsi que les conditions requises pour que le phénomène se produise. Il énumère vingt-neuf systèmes de métaux qui sont considérés comme superplastiques, y compris des métaux purs et des alliages à une ou plusieurs phases. Il passe en revue un certain nombre de méthodes employées pour produire la texture voulue à grain fin (de l'ordre d'un micron), soit mécaniquement par extrusion ou par laminage, soit thermiquement par décomposition eutectoïde ou par agglomération des compacts. Il conclut que le phénomène de superplasticité peut se produire dans de nombreux autres systèmes de métaux dont la taille des micrograins est stable dans la limite de température et de vitesse de déformation où il peut exister une grande sensibilité à la vitesse de déformation. L'auteur énumère les applications des métaux superplastiques à l'extrusion, au laminage, à l'emboutissage profond, à la frappe de la monnaie, au bombage et à l'étirage des fils sans filière. Il examine divers problèmes que peut poser l'utilisation des métaux superplastiques, notamment l'oxydation, la formation de cavités et le contrôle de la vitesse de déformation. Un bon nombre des alliages commerciaux considérés comme superplastiques seront acceptés en raison de leurs propriétés mécaniques et chimiques améliorées plutôt que de leur remarquable ductilité à haute température. L'auteur juge que l'application éventuelle de la superplasticité atteindra sa plus grande efficacité dans la formation de grosses pièces qui dépassent les capacités de la plupart des presses.

*Research Advisor, Physical Metallurgy Division.

Price 75 cents

Cat. No. M38-3/235

IC 236 Individual Consumption and Utilization of Energy in Canada, USA, Britain, France, Germany and Sweden 1950-1965

R. P. Charbonnier*

Eleven graphs present, for Canada and five other comparable countries, the trends of their per-capita consumption of total energy, hydro-electricity, and separately: liquid, solid and gas fuels, and of their per-capita energy utilization (usable consumption based on estimated conversion efficiencies).

Onze graphiques présentent, pour le Canada et cinq autres pays comparables, les tendances de leur consommation per-capita d'énergie totale, d'hydro-électricité, et séparément: de combustibles liquides, solides et gazeux, ainsi que de leur utilisation d'énergie per-capita (consommation utile basée sur des estimations des efficacités de conversion).

*Chief Scientist (Programs), Metals Reduction and Energy Centre.

Price 50 cents

Cat. No. M38-3/236

IC 236F Consommation et Utilisation Individuelles d'Énergie au Canada, aux États-Unis d'Amérique, en Grande Bretagne, en France, en Allemagne et en Suède 1950-1965

R. P. Charbonnier*

Onze graphiques présentent, pour le Canada et cinq autres pays comparables, les tendances de leur consommation per-capita d'énergie totale, d'hydro-électricité, et séparément: de combustibles liquides, solides et gazeux, ainsi que de leur utilisation d'énergie per-capita (consommation utile basée sur des estimations des efficacités de conversion).

Eleven graphs present, for Canada and five other comparable countries, the trends of their per-capita consumption of total energy, hydro-electricity, and separately: liquid, solid and gas fuels, and of their per-capita energy utilization (usable consumption based on estimated conversion efficiencies).

*Scientifique principal (Programmes), Centre d'énergie et de réduction des métaux.

Prix 50 cents

No. de Cat. M38-3/236F

IC 238 Bibliography of High-Temperature Condensed States Research Published in Canada, October-December, 1969

Norman F. H. Bright*

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from October 1 to December 31, 1969.

Le présent rapport contient des renseignements bibliographiques sur les recherches effectuées sur les états condensés aux températures élevées, publiées dans les revues scientifiques canadiennes au cours de la période d'octobre 1 à décembre 31, 1969.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price 50 cents

Cat. No. M38-3/238

IC 240 Stability of Waste Embankments (A Report by the Canadian Advisory Committee on Rock Mechanics)

This report, prepared by a Subcommittee of the Canadian Advisory Committee on Rock Mechanics, reviews the status of knowledge on the stability of waste dumps and the like structures and suggests research to close the gap in the knowledge of the subject. While not dealing with land pollution directly, the report discusses the broad design criteria required to ensure maximum safety in regard to waste dumps, ore piles, and tailings dams. This report is published in the interests of dissemination of scientific knowledge and to encourage further discussion of this important subject.

Le présent rapport, rédigé par un sous-comité du Comité consultatif canadien de la mécanique des roches, passe en revue les connaissances actuelles sur la stabilité des terrils et autres dépôts de résidus et recommande certaines recherches en vue de combler les lacunes d'information en cette matière. Bien qu'il ne traite pas directement de la pollution du sol, le rapport étudie les critères techniques généraux

devant assurer la sécurité des terrils, des dépôts de minerai et des barrages de retenue des stériles. Le rapport vise à diffuser les connaissances scientifiques et à encourager l'échange d'idées sur cet important sujet.

Price \$1.25

Cat. No. M38-3/240

IC 241 Bibliography on Rock Bolting Methods in Mining Practice. Part II: Abstracts from World Literature, 1958 to End of 1967

A. E. Gardner*

Issued as Part II of a series, this information comprises a further installment to assemble all published information on rock bolting methods in mining practice. Both publications now cover to the end of 1967.

In this information circular are 256 additional abstracts grouped as before and numbered from 281 to 536. The Authors Index includes abstracts 1-280 in brackets as well as references by number from 281 to 536 to the current volume. Chronology is from late to earlier.

Three appendices list Conferences, Suppliers of Equipment, and Sources of Information. Indexes are included of Authors, of Companies and Other Public Bodies, and of Subjects.

Ce recueil, qui constitue la 2^e partie d'une série, forme une nouvelle étape dans la compilation de tous les ouvrages de référence sur les méthodes de boulonnage employées dans les exploitations minières. Les deux publications donnent la bibliographie jusqu'à la fin de 1967.

La présente circulaire d'information contient 256 résumés nouveaux, classés dans le même ordre que dans l'ouvrage précédent et numérotés de 281 à 536. L'index des auteurs comprend les références des résumés 1 à 280 (entre parenthèses) et des résumés 281 à 536 contenus dans le présent volume. L'index chronologique va des plus récents aux plus anciens ouvrages.

La liste des conférences, des fournisseurs de matériel et des sources d'information est donnée dans trois appendices. Les index indiquent les noms des auteurs, des sociétés et autres corps publics, et les sujets.

*Technical Officer, Mining Research Centre, seconded (August 1969) to the Mining Information Centre, Mines Branch.

Price \$1.25

Cat. No. M38-3/241

IC 242 The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides. Part I: The Generation of H₂S from Base Metal Sulphides

H. W. Parsons* and T. R. Ingraham**

Papers and patents published in the past sixty years have been selectively reviewed as part of a project for determining the feasibility of recovering hydrogen sulphide from base metal sulphides. The most promising reactions involve pyrrhotite and a warm aqueous solution of hydrochloric acid. Simultaneous separate reviews have been made of means for converting hydrogen sulphide to elemental sulphur and of recovering an iron product from the ferrous chloride solutions.

Les auteurs ont étudié une sélection de mémoires et de brevets publiés au cours des 60 dernières années en vue de déterminer la possibilité de récupérer l'acide sulfhydrique à partir des sulfures de métaux communs. Les réactions les plus prometteuses sont obtenues à l'aide de la pyrrhotine et d'une solution aqueuse chaude d'acide chlorhydrique. D'autres études complémentaires ont porté sur divers moyens de transformer l'acide sulfhydrique en soufre élémentaire et de récupérer un produit du fer des solutions de chlorure ferreux.

*Research Scientist and **Head, Research Section, Extraction Metallurgy Division.

Price \$1.00

Cat. No. 38-3/242

IC 243 The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides. Part II: The Recovery of Sulphur from Gases Containing H₂S

R. F. Pilgrim* and T. R. Ingraham**

A review has been made of the many variations of the Claus reaction for recovering sulphur from hydrogen sulphide. The variations include wet and dry processing in the presence and absence of a variety of catalysts. Simultaneous separate reviews have also been made of means for generating hydrogen sulphide from pyrrhotite and for recovering an iron product from the ferrous chloride solutions.

Les auteurs ont étudié les nombreuses variantes de la réaction de Claus, qui sert à récupérer le soufre de l'acide sulfhydrique, y compris le traitement à sec ou par voie humide, avec ou sans divers catalyseurs. Ils ont aussi passé en revue les moyens de produire de l'acide sulfhydrique à partir de la pyrrhotine et de récupérer un produit de fer des solutions de chlorure ferreux.

*Research Scientist and **Head, Research Section, Extraction Metallurgy Division.

Price \$1.00

Cat. No. M38-3/243

IC 244 The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides. Part III: The Recovery of Iron Products from Ferrous Chloride Solutions

D. A. Reeve* and T. R. Ingraham**

A review has been made of the methods that may be used to recover hydrogen chloride and iron products from aqueous acidic solutions of ferrous chloride.

Simultaneous separate reviews have been made of means for recovering hydrogen sulphide from pyrrhotite and for converting hydrogen sulphide to elemental sulphur.

Les auteurs ont étudié les méthodes qui peuvent servir à récupérer l'acide chlorhydrique et les produits de fer des solutions aqueuses acidiques de chlorure ferreux.

Ils ont également passé en revue les moyens de récupérer l'acide sulfhydrique de la pyrrhotine et de transformer l'acide sulfhydrique en soufre élémentaire.

*Research Scientist and **Head, Research Section, Extraction Metallurgy Division.

Price \$1.00

Cat. No. M38-3/244

IC 245 English-French Glossary of Mining and Related Terms

A. S. Romaniuk*

The Mines Branch has a special interest in communicating information of use to the Canadian mineral industry. To facilitate the translation of technical and scientific information from English to French, the Branch initiated a project with staff members of the Mining Engineering Department, Ecole Polytechnique. The product of this effort is this English-French glossary of mining and related terms.

La Direction des mines s'intéresse particulièrement à communiquer des renseignements utiles à l'industrie minière canadienne. Afin de faciliter la traduction des textes techniques et scientifiques de l'anglais au français, la Direction a mis sur pied un programme spécial avec le concours du département de génie minier de l'Ecole polytechnique. Le fruit de ce travail est un glossaire anglais-français des termes miniers et du vocabulaire connexe.

*Head, Mining Information Centre, Mines Branch.

Price \$1.25

Cat. No. M38-3/245

IC 246 Bibliography of High-Temperature Condensed States Research Published in Canada,
January-March, 1970

Norman F. H. Bright*

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from January 1 to March 31, 1970.

Le présent rapport contient des renseignements bibliographiques sur les recherches effectuées sur les états condensés aux températures élevées, publiées dans les revues scientifiques canadiennes au cours de la période de janvier 1 à mars 31, 1970.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price 50 cents

Cat. No. M38-3/246

IC 247 An Index of the Scientific and Technical Papers Published by the Staff in 1969

Price \$1.00

Cat. No. M38-3/247

IC 248 Chemical Analyses of the Ash of Canadian Coals

W. J. Montgomery*, J. Z. Skulski**, G. C. Anderson*** and J. G. Jorgensen**

The Solid Fuels Laboratory of the Fuels Research Centre is responsible for all the analytical work required for this publication. Analytical data on samples analysed during a given year have been published in Mines Branch Information Circulars, "Analyses of Coal and Coke During the Year _____", from 1960 to the present. This Information Circular deals specifically with the chemical composition of coal ash, and includes, where available, data on ash fusibility.

The analyses are arranged by Province, Area, and Mine, from east to west. The exact seam or location is indicated, when that information is available. The percentage of ash in the dry coal is indicated. The analyses are from samples concerned with specific projects collected by Divisional Officers or mine officials from 1964 to 1968.

Le Laboratoire des combustibles solides du Centre de recherche sur les combustibles est responsable de tous les travaux d'analyse nécessaires à la présente publication. Les résultats des analyses pratiquées sur divers échantillons sont publiés annuellement depuis 1960 dans les circulaires d'information de la Direction des mines intitulées "Analyses de houille et de coke effectuées en _____". La présente circulaire traite plus particulièrement de la composition chimique de la cendre de houille et donne, dans la mesure du possible, des données sur la fusibilité des cendres.

Les analyses sont réparties selon la province, la région et la mine, de l'est à l'ouest. Quand c'est possible, on indique également l'emplacement et la couche précise. Est également indiquée la teneur en cendre de la houille à l'état sec. Les analyses portent sur des échantillons recueillis aux fins d'études particulières par des agents de la division ou des employés de mines entre 1964 et 1968.

*Head, Solid Fuels Laboratory, **Scientific Officers and ***Technician, Fuels Research Centre.

Price 75 cents

Cat. No. M38-3/248

IC 249 Analyses of Coal During 1969

W. J. Montgomery* and G. C. Behnke**

The Solid Fuels Laboratory of the Fuels Research Centre is responsible for all analytical work on coal encompassed by this publication. This information circular, issued as the ninth of an annual series, tabulates the analyses of coal samples analysed by the Centre during 1969.

It must be clearly understood that no responsibility is taken by the Centre for the accuracy of the sampling procedures adopted for procuring the samples for which analyses are reported in this circular, excepting those taken by Centre officers.

Proximate analysis and sulphur values are reported on the "as received" basis only, whereas calorific values are reported on the "as received" as well as the "dry" basis. As an easy reference, the analyses are arranged by province and state.

Le laboratoire des combustibles solides, au Centre de recherches des combustibles, s'occupe de tous les travaux analytiques sur le charbon mentionnés par la présente publication. Cette circulaire d'information, la neuvième d'une série qui doit paraître annuellement, traite des analyses d'échantillons de charbon analysés par le Centre au cours de 1969.

Il faut bien se rappeler que, sauf pour les échantillons prélevés par ses propres fonctionnaires, le Centre n'assume aucune responsabilité en ce qui concerne l'exactitude des techniques d'échantillonnage adoptées pour obtenir les échantillons dont les analyses sont considérées dans la présente circulaire.

On indique les analyses quantitatives approximatives et les teneurs en soufre des échantillons "tels qu'ils nous sont parvenus" seulement, tandis qu'on mentionne les valeurs calorifiques des échantillons "tels qu'ils sont recus" et aussi "à sec". Pour les fins de référence, les analyses sont classées par province et par état.

*Head, Solid Fuels Laboratory and **Technician, Fuels Research Centre.

Price 75 cents

Cat. No. 38-3/249

IC 250 Bibliography of High-Temperature Condensed States Research Published in Canada,
April-June, 1970

Norman F. H. Bright*

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from April 1 to June 30, 1970.

Le présent rapport contient des renseignements bibliographiques sur les recherches effectuées sur les états condensés aux températures élevées, publiées dans les revues scientifiques canadiennes au cours de la période d'avril 1 à juin 30, 1970.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price 50 cents

Cat. No. M38-3/250

IC 252 Ion-Exchange Recovery of Copper, Zinc and Nickel from Acid-Sulphate and Alkaline-Cyanide
Waste Water

A. J. Gilmore*

The literature of the past twenty years describing the use of ion-exchange methods for the treatment of copper-, zinc- and nickel-bearing acid-sulphate or alkaline-cyanide wastes is reviewed. Applications of sulphonic, carboxylic, and weak-base ion-exchange resins to the treatment of a variety of base-metal-bearing waste solutions from industrial plants and mines are described. One investigation of the treatment of alkaline cyanide solution containing base-metal-cyanide complexes with a strong-base ion-exchange resin is reviewed. The literature suggests that an ion-exchange process based on a sulphonic-type resin could be useful for the treatment of acid-sulphate mine or metallurgical waste, but further work to develop design criteria is necessary. Further work of a more preliminary nature is needed to determine whether present ion-exchange media have a potential application to the treatment of alkaline-cyanide waste solutions.

L'auteur passe en revue les travaux publiés au cours des vingt dernières années sur l'emploi des méthodes d'échange d'ions pour la récupération du cuivre, du zinc et du nickel des eaux résiduelles à base de sulfate acide ou de cyanure alcalin. Il décrit les applications des résines échangeuses d'ions sulfoniques, carboxyliques et faiblement basiques au traitement de divers effluents miniers et industriels contenant des métaux communs. Il relève en particulier une étude du traitement des solutions de cyanure alcalin contenant des complexes de cyanures de métaux communs à l'aide d'une résine échangeuse d'ions fortement basique. Les ouvrages étudiés laissent croire qu'un procédé à échanges d'ions fondé sur une résine de type sulfonique pourrait servir utilement au traitement des effluents miniers ou métallurgiques

à base de sulfate acide, mais qu'il faut en approfondir l'étude avant de mettre au point des critères de conception. De même, il faudra d'autres travaux préliminaires pour déterminer si les échangeurs d'ions peuvent servir au traitement des solutions résiduelles à base de cyanure alcalin.

*Research Scientist, Hydrometallurgy Section, Extraction Metallurgy Division.

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IC 253 An Indexed List of References on Continuous Casting

R. Thomson*

A list of references to the technical literature on continuous casting, covering the period - 1940 to 1969, is presented and indexed with respect to subject matter and author.

L'auteur présente une liste des références techniques sur la coulée continue publiées durant la période 1940 à 1969. L'index réfère au sujet et aux auteurs.

*Research Scientist, Non-Ferrous Metals Section, Physical Metallurgy Division.

IC 254 Evaluation of Canadian Commercial Coals: Saskatchewan, Alberta and British Columbia - 1968

T. E. Tibbetts*

The physical and chemical analyses of fifty-three coal samples are reported. In addition, the chemical analyses of ash of most of the same coals are reported in a separate section.

The samples were taken and analysed by the Fuels Research Centre during the year 1968. They represent the production on a specified day of the coals as commercially prepared at the mine or, referring to the channel samples, the coal seam where mining was in progress or planned.

Coals from twenty mining operations in the three coal mining provinces of western Canada, namely Saskatchewan, Alberta and British Columbia, are represented; they include lignite, subbituminous and bituminous coals.

L'auteur décrit les résultats d'analyses physiques et chimiques de 53 échantillons de houille. Il donne de plus les résultats de l'analyse chimique de la cendre de la plupart de ces charbons dans une section séparée.

Les échantillons ont été prélevés et analysés en 1968 par le Centre de recherche sur les combustibles. Ils sont représentatifs de la production journalière de la houille préparée commercialement à la mine, ou, dans le cas des échantillons de veines, de la couche de houille où l'extraction était en cours ou projetée.

Les échantillons proviennent de 20 charbonnages dans trois provinces de l'Ouest, soit la Saskatchewan, l'Alberta et la Colombie-Britannique; ils comprennent de la lignite, de la houille maigre et de la houille grasse.

*Head, Coal and Peat Resources Evaluation Section, Fuels Research Centre.

Price 75 cents

Cat. No. M38-3/254

IC 255 Evaluation of Canadian Commercial Coals: Nova Scotia and New Brunswick - 1969

T. E. Tibbetts* and D. J. O'Brien**

Physical and chemical analyses of seventy-seven coal samples are reported, representing the eleven operating mines in Nova Scotia and six operating mines in New Brunswick.

The samples were taken and analysed by the Fuels Research Centre during the year 1969. They represent the production on a specified day of the coals as commercially prepared at the mine or the coals as delivered to thermal electric generating stations.

Les auteurs donnent les résultats des analyses chimiques et physiques de 77 échantillons de houille provenant des 11 mines en exploitation en Nouvelle-Ecosse et de six mines du Nouveau-Brunswick.

Les échantillons ont été prélevés et analysés en 1969 par le Centre de recherche sur les combustibles. Ils sont représentatifs de la production journalière de la houille préparée commercialement à la mine ou livrée aux centrales thermiques.

*Head and **Technician, Coal and Peat Resources Evaluation Section, Fuels Research Centre.

Price 75 cents

Cat. No. M38-3/255

IC 257 Bibliography of High-Temperature Condensed States Research Published in Canada,
July-September, 1970

Norman F. H. Bright*

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from July 1 to September 30, 1970.

Le présent rapport contient des renseignements bibliographiques sur les recherches effectuées sur les états condensés aux températures élevées, publiées dans les revues scientifiques canadiennes au cours de la période de juillet 1 à septembre 30, 1970.

*Head, Physical Chemistry Section, Mineral Sciences Division.

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REPRINT SERIES

RS 89 Dynamic Recovery of Aluminum during Hot Rolling

J. P. Immarigeon* and H. J. McQueen**. Reprinted from the Canadian Metallurgical Quarterly, Vol. 8, No. 1, January - March 1969.

Superpurity aluminum was rolled at 235 and 315°C to 90 per cent reduction in a single pass. The changes in microstructure arising from the deformation were examined by polarized-light and transmission-electron microscopy. The original grains were elongated in the direction of rolling and contained an equiaxed polygonized substructure. The subgrains were larger and more perfect at the higher rolling temperature. The extent of dynamic recovery is compared with that of commercial-purity aluminum and with that of other face-centred cubic metals.

Un taux de réduction de 90% par laminage en une seule opération a été effectué sur de l'aluminium à 99,99% de pureté à 235 et à 315°C. Les modifications de la structure dues à cette déformation ont été examinées en lumière polarisée et par microscopie électronique en transmission. Les grains originaux sont allongés dans le sens de la déformation et présentent une sous-structure polygonalisée équiaxiale. Des sous-grains plus réguliers et plus gros ont été obtenus à la température la plus élevée. L'importance de la restauration dynamique est comparée avec celle de l'aluminium de pureté commerciale et avec celle d'autres métaux cubiques à faces centrées.

*Student Assistant and **Research Scientist, Physical Metallurgy Division.

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Cat. No. M38-8/89

RS 90 Heterogeneous Chemical Kinetics by Gas Effluent Analysis - The Unzipping of Paraform

T. R. Ingraham* and D. Fraser**. Reprinted from the Chemical Institute of Canada, Toronto Section, February 25-26, 1969, Proceedings of the Third Toronto Symposium on Thermal Analysis.

Most metallurgical processes occur through heterogeneous chemical reactions involving two phases. Often it is difficult to delineate the variables that control the rate of reaction. In this instance an ore-roasting reaction was simulated with the depolymerization of an organic material and a computer model was constructed for the processes. The model was extended to ore roasting and methods were developed for optimizing the effects of temperature change, particle size, gas flow and the other variables that affect the rate of roasting. It will be appreciated that when rapid rates are attained, the capital cost for plant installation is smaller than when a slow reaction rate prevails.

*Head and **Scientific Officer, Extraction Metallurgy Research Section, Extraction Metallurgy Division.

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Cat. No. M38-8/90

RS 91 The Determination of Some X-ray Attenuation Coefficients in the Range 26.3 to 2.3 keV

J. L. Dalton* and J. Goldak**. Reprinted from Canadian Spectroscopy, Vol. 14, No. 5, pp. 171-173, 1969.

Mass attenuation coefficients have been determined for titanium, vanadium, iron, nickel, and copper over an energy range 17.5 to 2.3 keV and for praseodymium, gadolinium and erbium over the range 26.3 to 4.5 keV. Agreement within experimental error with recent measurements on the transition metals was obtained. There appears to be no published experimental data in the pertinent energy range for comparison with the coefficients determined for the rare earth elements. The precision of the measurements as determined by the relative standard deviation varied from 0.5 per cent to 2.4 per cent. The variation in the precision can be accounted for by non-uniform absorbing foils. The accuracy of the measurements was judged to be in the range two to four per cent of the coefficients reported.

*Scientific Officer, Mineral Sciences Division and **Associate Professor, Faculty of Engineering, Carleton University.

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RS 92 Control of Oil Ash Deposits and Pollution Abatement by an Additive

G. K. Lee*. Reprinted from the Fuel Society Journal, Volume 20, 1969.

The formulation and principal properties of a fuel-oil additive developed by the Canadian Combustion Research Laboratory are described. The effectiveness of the additive in controlling problems that are universal to boilers burning high vanadium, high-sulphur residual oil is discussed together with a detailed explanation of the additive's physico-chemical interactions with oil ash and combustion products. Results of additive trials in both operating boilers and combustion research rigs are presented.

*Research Scientist, Canadian Combustion Research Laboratory, Fuels Research Centre.

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RS 93 The Mechanism of the Formation of Lead Hexaferrite

W. S. Bowman*, Sutarno**, Norman F. H. Bright*** and J. L. Horwood****. Reprinted from the Journal of the Canadian Ceramic Society, (1969), Vol. 38, pp. 1-8.

Studies of the mechanism of the formation of lead hexaferrite from its constituent oxides have been conducted. The reactions were studied by differential thermal analysis, thermogravimetric analysis, X-ray diffraction procedures and by magnetic susceptibility measurements. It was found that the nature of the intermediate product(s) was dependent upon the technique of mixing, and the time and temperature of heating. There is an indication that there may be considerable variations in the temperature dependence of the various possible intermediate reactions. A kinetic model describing the behaviour of the system is postulated. The intermediate compounds observed were $2\text{PbO} \cdot \text{Fe}_2\text{O}_3$ and $\text{PbO} \cdot 2\text{Fe}_2\text{O}_3$. The latter can be distinguished from the structurally-similar $\text{PbO} \cdot 6\text{Fe}_2\text{O}_3$ by the use of magnetic susceptibility measurements.

*Technical Officer; **Research Scientist and ***Head, Physical Chemistry Section; ****Research Scientist, Solid State Studies Group, all of Mineral Sciences Division.

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RS 94 Variations in the Ceramic and Magnetic Properties of Barium Hexaferrite Samples made from Iron Oxides Prepared by Different Methods

W. S. Bowman*, G. E. Alexander**, J. M. Jaworski*** and G. A. Ingham****. Reprinted from the Journal of the Canadian Ceramic Society, Vol. 38, (1969), pp. 171-175.

Physico-chemical properties of iron oxides produced by two different methods and the ceramic and magnetic properties of unoriented and oriented barium hexaferrite specimens prepared from these oxides are presented. The influence of calcination temperature on the grain growth of the polycrystalline barium hexaferrite during subsequent sintering is shown. Differences found in the reactivity, grain growth and magnetic properties suggest the use of different technological procedures for the production of barium ferrite from different iron oxides.

*Technical Officer and **Technologist, Mineral Sciences Division; ***Representative and ****Research Manager, Northern Pigment Company Limited, Toronto, Ontario.

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Cat. No. M38-8/94

RS 95 The Effect of Some Operational Variables on the Properties of Strontium Hexaferrite

Sutarno*, W. S. Bowman**, G. E. Alexander*** and J. D. Childs****. Reprinted from the Canadian Ceramic Society, (1969), Vol. 38, pp. 9-13.

Strontium hexaferrite with the composition $\text{SrO} \cdot 5.5 \text{Fe}_2\text{O}_3$ has been prepared by precipitating strontium carbonate in an iron-oxide slurry. The precipitated powders were calcined at various temperatures up to 1300°C and ball-milled for various lengths of time up to 32 hours. The resulting alcoholic slurries were pressed to discs under the influence of a magnetic field and then sintered at temperatures of $1100\text{-}1300^\circ\text{C}$. The surface area of the powders, and the ceramic and magnetic properties of the discs

were measured. It was found that the magnetic properties of strontium hexaferrite are sensitive, not only to the sintering temperature, but also to changes in calcination temperature and milling time. Under the most favourable combination of treatment conditions and composition, energy products of 3.9×10^6 gauss-oersted have been achieved.

*Research Scientist, **Technical Officer, ***Technologist and ****Summer Student Assistant, all of Mineral Sciences Division.

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RS 96 X-ray Spectrographic Analysis at Low Two-Theta Angles

Dorothy J. Reed*. Reprinted from the Canadian Spectroscopy, Vol. 15, Issue No. 2, March 1970, Pages 49-51 inclusive.

Undifferentiated radiation has been removed from the continuum at low 2θ angles by inserting a lead shield at the end of the receiving collimator to remove the upper third of the collimated X-ray beam before it strikes the analyzing crystal. The removal of this radiation caused no decrease in analytical sensitivity although counting rates were reduced. Results are presented for the determination of tungsten and hafnium in steels and tantalum in high temperature alloys.

À des angles 2θ petits, les radiations non différenciées ont été éliminées par l'introduction d'un écran de plomb à l'extrémité du collimateur récepteur. L'écran est placé de façon à éliminer le tiers supérieur du faisceau collimé de Rayons-X avant qu'il ne frappe le cristal analyseur. L'élimination de cette radiation ne réduit pas la sensibilité analytique, malgré une légère diminution du taux de comptage. On présente les résultats obtenus pour la détermination du tungstène et de l'hafnium dans l'acier ainsi que du tantale dans des alliages à haute résistance thermique.

*Research Scientist, Spectrochemistry Sub-Division, Mineral Sciences Division.

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Cat. No. M38-8/96

RS 97 The Application of Dark-Field Electron Microscopy to the Determination of Crystallite Size in Ferrites

E. Smith* and Sutarno**. Reprinted from the Canadian Ceramic Society Journal, Vol. 37, 1968.

Barium and strontium ferrites were prepared by coprecipitation from nitrate solutions, filtering and calcining at 1100°C or 1300°C . The calcined powders were ground in a steel mortar. A method was developed for supporting the powders in thin plastic films for electron microscopy. Powders were examined by electron microscopy in bright and dark fields, and by electron diffraction.

Three types of particle in the micron range of size were found, two being monocrystalline and one finely polycrystalline with a crystallite size of about 500 Å. It was not possible to distinguish between these particles without the use of electron diffraction.

It was found that the grains of the barium ferrites were generally smaller than those of the strontium ferrites prepared under similar conditions, and that the grain sizes of both increased with calcining temperature.

*Research Scientist, Metal Physics Section, Physical Metallurgy Division and **Research Scientist, Physical Chemistry Section, Mineral Sciences Division.

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Cat. No. M38-8/97

RS 98 Some Field Experience in the Use of an Accelerated Method of Estimating 28-Day Strength of Concrete

V. M. Malhotra* and N. G. Zoldners**. Reprinted from the Journal of the American Concrete Institute, November 1969, No. 11 Proceedings, V. 66 and Reprinted from the Journal of the American Concrete Institute, May 1970, No. 5 Proceedings, V. 67.

Statistically analyzes field strength data supplied by various organizations using the accelerated method of estimating 28-day strength of concrete. Briefly, the accelerated method consists of initial

standard moist-curing of test specimens for 24 hr, followed by boiling for 3-1/2 hr, and testing in compression 1 hr later. The analyses of the test data indicate that the accelerated test method under discussion is an excellent means for rapid strength determination of concrete, and its use by the concrete industry is recommended.

*Research Scientist and **Head, Construction Materials Section, Mineral Processing Division.

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Cat. No. M38-8/98

RS 99 Electron-Probe Microanalysis of Alloyed Galvanized Coatings

R. H. Palmer*, H. R. Thresh** and J. J. Sebisty***. Reprinted from the Proceedings of the Ninth International Galvanizing Conference, Dusseldorf, Germany, June, 1970.

The distribution of several bath alloying elements in galvanized coatings was determined with an electron-probe microanalyser and the results are interpreted in terms of the changes in the metallographic structure and iron-zinc reaction rates caused by alloying. The iron and zinc contents of the phases were measured together with the alloying elements.

Manganese in the experimental coatings prepared on a normal-activity steel was concentrated basically in the zeta phase although the delta also had an appreciable manganese content. It appears that the zeta phase has a high affinity for manganese although the thickness of this phase was not appreciably affected. The manganese in the coating was derived from the bath addition, and not from the steel base.

The nickel, titanium and vanadium bath additions were concentrated at the zinc-zeta interface in the form of Zn-Fe-Ni, Zn-Fe-Ti and Zn-Fe-V ternary compounds. It is speculated that these compounds at the interface reduced the supply of zinc for further reaction with the steel base by acting either as a mechanical or a diffusion barrier, and that this reduced the total thickness of the alloy layers, favoured the growth of delta at the expense of zeta, and produced more uniform alloy layers.

Chromium could not be detected by the microprobe, and lead was shown to be present in the outer zinc layer as discrete globules.

*Research Scientist, **formerly Research Scientist and ***Research Scientist, Physical Metallurgy Division.

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Cat. No. M38-8/99

RS 100 Iron-Iron Interaction in Iron-Containing Zinc Sulphide

J. D. Keys*, J. L. Horwood, T. M. Baleshta, L. J. Cabri and D. C. Harris**. Reprinted from The Canadian Mineralogist, Vol. 9, Part, 1968.

The behaviour of iron in ZnS has been studied through the effect of iron concentration on magnetic and electrical properties. Specimens containing iron in amounts varying from 0.09 to 16.16 atom per cent have been synthesized. These were found to be homogeneous by electron-probe microanalysis and under the reflecting microscope.

At lower iron concentrations the synthetic and natural iron-bearing sphalerites are paramagnetic and their magnetic susceptibilities vary with the iron content in a linear manner. At higher iron concentrations these iron-bearing sphalerites become increasingly antiferromagnetic and their magnetic susceptibilities vary in a non-linear manner. The antiferromagnetic behaviour may be comparable to that observed in Mn-bearing ZnS and is probably the result of similar magnetic ordering of the substantial iron.

Electrical conduction for a natural iron-bearing sphalerite has been found to result from migration of low-mobility holes rather than by electrons. This observation is consistent with the mechanism known as d-band conduction, which attributes electrical current to the flow of holes in the d-bands of transition metals. This type of conduction is possible in iron-containing ZnS through the interaction of Fe³⁺ with Fe²⁺, with the Fe³⁺ in either the tetrahedral or the octahedral position.

*Present address: Hydrologic Sciences Division, Inland Waters Branch and ** Research Scientists, Mineral Sciences Division.

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Cat. No. M38-8/100

RS 101 The Stability of the Polymorphs of Titanium Monoxide *

H. Iwasaki** and N. F. H. Bright***. Reprinted from the Journal of the Less-Common Metals, 21 (1970), 353-363.

A study has been made of the compositional and temperature stabilities of the high- and low-temperature modifications of titanium monoxide. The low-temperature form appears to exist as a single phase in the Ti-O system over only a narrow range of composition near $\text{TiO}_{0.84}$. It can be formed in equilibrium with the high-temperature form by prolonged annealing; the high-temperature form has the composition $\text{TiO}_{1.09 \pm 0.02}$ when the annealing is conducted at 900°C . The upper temperature limit of stability of the low-temperature form is somewhat in excess of 900°C , in agreement with earlier work. There is an indication that the high-TiO-Ti₂O₃ boundary should be placed at a higher oxygen content than has been given in earlier publications. Some consideration is given to the kinetic mechanism of the high-low transformation; it would appear to be diffusion-dependent.

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***Head, Physical Chemistry Section, Mineral Sciences Division.

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