

M. Rice

DEPARTMENT OF
ENERGY, MINES AND RESOURCES

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FOREWORD

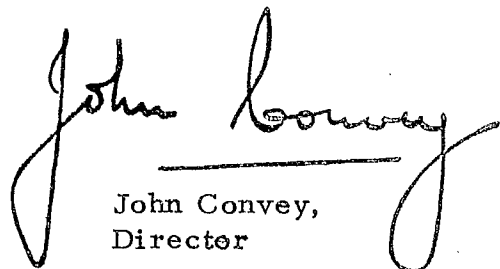
Information Circular IC 151 (June, 1963) was the first in a series of annual reviews of the scientific and technical papers published by the staff of the Mines Branch. This Information Circular is the fourth supplement to IC 151 and is divided into three sections.

Section 1 consists of the titles of papers published during 1966 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 the Queen's Printer, 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 1966 by the Mines Branch staff. The periodicals containing these papers are available in many technical libraries.

Section 3 contains a list of the 1966 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.



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, qui comprend trois sections, est le quatrième supplément à IC 151.

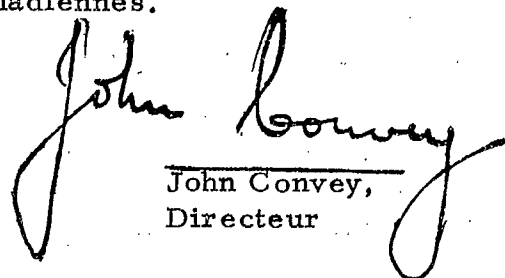
La première section comprend les titres des travaux publiés en 1966 dans les séries de la Direction des mines (monographies, rapports de recherches, bulletins techniques, et circulaires d'information), ainsi qu'un résumé ou un sommaire de chaque étude. On peut obtenir ces différents rapports chez l'Imprimeur de la Reine, 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 1966 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 depuis le début de la série en 1958 jusqu'à 1966 inclusivement. 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'Investigations 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.

juin 1967


John Convey,
Directeur

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Information Circular 151 (1962)

Information Circular 162 (1963)

Information Circular 171 (1964)

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SECTION 1 - MINES BRANCH SERIES

MONOGRAPHS

Mines Branch Monograph No. 874

Rock Mechanics Principles

by D.F. Coates*, 1965, Illus., Tables.

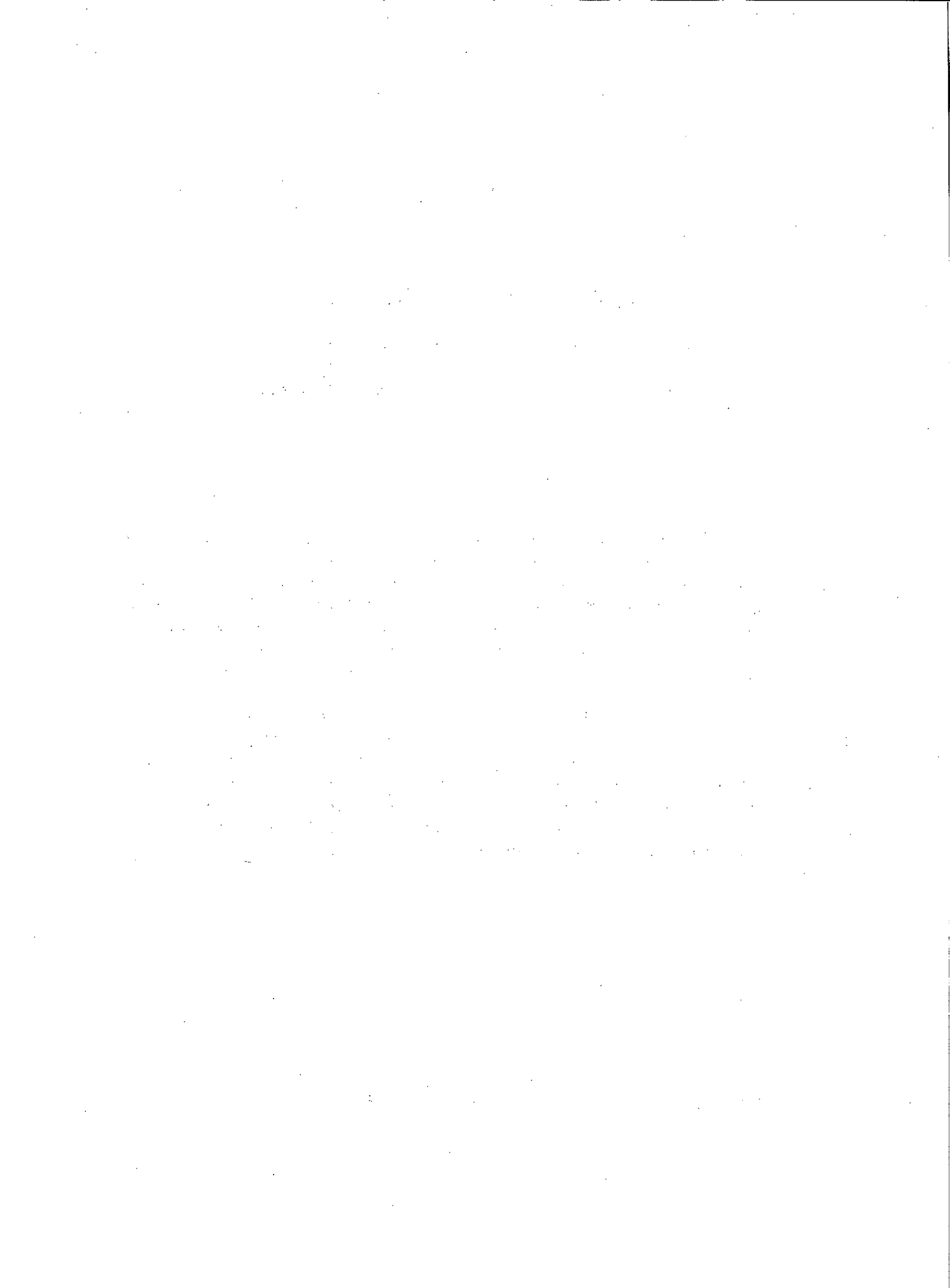
The purpose of this monograph is to provide some guidance for the young engineer or scientist entering the field of rock mechanics. The emphasis is on the application of engineering mechanics to problems arising from the needs either to prevent or to cause rock failure with particular reference to those problems encountered in mining. As the individuals entering this field are from a variety of disciplines - geology, physics, engineering - the treatment starts at a rather elementary level.

The various theories in mechanics and the rock properties that are important in this subject are reviewed for those requiring such background information. The main groups of rock problems are then examined to determine the mechanics pertinent to the various geometries and loadings of these cases. Some indication of the degree of practical applicability is also provided, although the monograph is not intended as an engineer's manual for use by planners or operators.

* Head, Mining Research Laboratories, Fuels and Mining Practice Division.

\$ 5.00

Cat. No. M32-874



RESEARCH REPORTS

R 153 Properties of Sand-Cast Magnesium Alloys Part VII: The Effect of Wall Thickness on Tensile Properties of Mg-Al-Zn Alloy Castings.

A. Couture* and J. W. Meier** March 1965 47 p., Charts, Tables.

It has been shown in earlier investigations that, under favourable solidification conditions (e.g., in premium-quality castings), high mechanical properties may be obtained regardless of wall thickness. In commercial castings, however, it is not always possible (or economical) to avoid some reduction of mechanical properties in heavier sections of the casting.

The present investigation was carried out to explore the effect of section thickness on properties of alloys AZ80, AZ91 and AZ92 in various temper conditions. To eliminate other factors affecting solidification conditions, all castings were produced using standard foundry practice for green sand casting, without the use of any chills or insulating materials.

Tensile properties of the castings were correlated with section thickness, grain size, surface area/volume ratio, cooling rate, and solidification time. It was found that tensile properties decrease gradually with decreasing surface area/volume ratio (decreasing cooling rate) until this ratio drops to about 3 (cooling rate below 30°C/min or 54°F/min); beyond this, tensile properties drop very rapidly, but specification minima can usually be met when the ratio is higher than 2 and the cooling rate exceeds 20°C/min (36°F/min).

The ratio between the diameter of round bars and the thickness of plate castings to obtain similar tensile properties is 1.4 to 1.7.

*Senior Scientific Officer and **Principal Metallurgist (Non-Ferrous Metals), Physical Metallurgy Division.

Price: 75 cents Cat. No. M38-1/153.

R 168 Pillar Loading Part I: Literature Survey and New Hypothesis.

D. F. Coates*, October 1965 94 p., Tables.

This research work on pillar loading is in what might be described as the area of engineering theory. As such, it is concerned largely with the combining of existing scientific theories into a rational hypothesis for predicting the loading of pillars. Hitherto, this has been possible only in a very crude way and only for horizontal workings using the tributary area theory.

In previous work on this subject, some workers have recognized that rock is not a fluid material applying a dead weight to pillars but, rather there will be a structural reaction of the wall rock on the excavation of the vein rock. However, no complete analysis of the mechanics of the system in producing pillar loading had been established.

The first step in this research work, therefore, has been to analyse the structural aspects of the problem by solving the statically indeterminate net deflection of the walls. This net deflection at the pillars will be a measure of the increase in pillar stress resulting from mining. The resulting equations show that not only is the extraction ratio important in determining pillar loading but that the hitherto ignored parameters of the ratio of field stress components

normal and transverse to the mining zone, the height of the pillar, the location of the pillar within the mining zone, the ratio of compressibility of pillar rock to wall rock, the number of pillars across a typical section of the mining zone, the breadth of the pillar, and the ratio of the depth from the ground surface to the span of the mining zone are all of some significance.

Additional analytical work has been done in examining the various alternatives to the hypothesis that is based on elastic ground. In this work it is shown that for compatible strain the loading of pillars will almost always be a phenomenon associated with elastic, or at least pre-failure, deformation in the walls. Consequently, any mechanisms based on post-failure rock properties will not be applicable to this problem, although they may be for other types of support. In this supplementary work, an elliptical arching theory has been developed that may be more valid than the various other theories hitherto available for this case of loading of yielding support.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: \$ 1.25 Cat. No. M38-1/168

R 170 Pillar Loading Part II: Model Studies.

D. F. Coates* November 1965 109 p., Charts.

The research work on pillar loading has been concerned with the combining of existing scientific theories into a rational hypothesis for predicting the loading of pillars. With the establishment of this hypothesis empirical substantiation or modification became required. The data from existing model work was analysed and supplementary experimental work conducted, so that the various parameters indicated by the hypothesis as being significant could be examined.

Measurements of pillar stresses in laboratory models of gelatin, Araldite-type materials, mortar and steel showed that it is possible to predict the variation of pillar loading with location within the mining zone, with variation of pillar height, with variation of pillar breadth, with the number of pillars across the mining zone, with the variation of the compressibility of the pillar ground with respect to that of the walls, with variation in the magnitude of the field stress component acting transversely to the mining zone or vein, and, above all, with the extraction ratio.

However, by analysing data with respect to the various parameters it was found necessary to modify the theoretical equations for the functions including the location of the pillar, the effect of the stress component acting transversely to the mining zone, and the effect of pillar breadth in a mining zone having pillars of unequal width. These modifications have been made following the traditional engineering procedure of taking into account both the empirical evidence and the mechanism (if it can be recognized but has not been included in the theory) that is causing the deviation of the data from theory.

The most significant parameters, aside from the extraction ratio, affecting the pillar loading have been shown to be the ratio of compressibility of the pillar rock to wall rock, the height of the pillar, and the breadth of the pillar in mines with pillars of unequal width.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: \$ 1.25 Cat. No. M38-1/170

R 171 The Complexometric Titration of Zirconium in Perchloric Acid Solution, and Its Application to The Analysis of Lead Zirconate-Titanate Ceramics.

A. Hitchen*, November 1965 34 p., Tables.

A rapid, simple, precise and accurate method is described for the titrimetric determination of zirconium. The sample, after a fuming with perchloric acid, is diluted with water and titrated with a standard solution of disodium ethylenediamine tetraacetate (EDTA), using Xylenol Orange as the indicator. Except for bismuth, iron (III), tin, antimony, niobium, mercury (I), arsenate, sulphate and fluoride, relatively few ions interfere; and procedures for overcoming the interferences or eliminating the interfering ions are described. Because titanium and lead do not interfere, this titration procedure has been successfully applied to the direct determination of zirconium in lead zirconate-lead titanate ceramic materials. A special fuming technique makes possible the "activation" of up to 205 mg of zirconium and is a major factor in obtaining the high precision.

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

Price: 75 cents

Cat. No. M38-1/171

R 173 The Thermal Decomposition of Pyrite.

A. W. Coats* and Norman F.H. Bright** August 1965 25 p., Figures, Tables.

A study has been made of the kinetics of the thermal decomposition of pyrite to pyrrhotite and sulphur in a dynamic argon atmosphere. The reaction was followed (a) by the rate of loss of weight as indicated by the extension of a quartz spring and (b) by the rate of progression of the pyrite/pyrrhotite interface into a polycrystalline compressed pellet. The temperature coefficient of the reaction was found to be 69.5 ± 5.9 , 64.7 ± 3.3 and 66.9 ± 5.1 kcal. mole⁻¹ when the results were processed in three different ways. The pyrite/pyrrhotite interface was found to progress at a linear rate into the pellet, and equations were derived to express the variation of reaction rate with temperature. Attempts to study the early nucleation stage of the decomposition, using mineral crystals, proved abortive.

*National Research Council of Canada Postdoctorate Fellow assigned to the Mines Branch, **Head, Physical Chemistry Section, Mineral Sciences Division, Mines Branch.

Price: 50 cents

Cat. No. M38-1/173.

R 174 The Determination of Zirconium, Niobium and Hafnium in Low Alloy Steels by X-Ray Spectrography.

Dorothy J. Reed* December 1965, 27 p., Illus., Tables.

Zirconium, niobium and hafnium have been determined in mild steels by X-ray spectrography in amounts up to 0.35, 0.30 and 0.20% respectively with errors of less than $\pm 0.01\%$.

Because suitable standards for zirconium and niobium were unavailable and no standards for hafnium existed, it was necessary to use synthetic standards. A number of samples have been set up as Mines Branch secondary standards and the validity of their use has been verified.

Using accelerating potentials of 80 or 90 kV, zirconium and niobium may be determined in the ppm range. The sensitivity for hafnium is 0.01%.

*Senior Scientific Officer, Analytical Chemistry Subdivision, Mineral Sciences Division.

Price: 75 cents

Cat. No. M38-1/174

R 178 Study of As-Rolled Carbon Steels Over Ranges of Uranium, Sulphur and Carbon Contents.

D.K. Faurschou* May 1966 63 p., Illus., Tables.

Certain ad hoc studies of uranium in carbon steels at the Mines Branch have been complemented and clarified by statistically designed and analyzed studies. The results indicate that uranium has a very limited potential usefulness as an alloying element in ferrous metallurgy. Uranium has more potential as a scavenger and sulphide former.

A factorial set of as-rolled carbon steels having four uranium levels (nil, 0.15, 0.3 and 0.6%), three sulphur levels (0.006, 0.030 and 0.14%) and two carbon levels (0.14 and 0.34%) was tested to assess the influence of uranium on impact characteristics, active-state corrosion resistance, stress-corrosion resistance, machinability, microstructure, and isothermal transformation of austenite. The sulphur and carbon levels were introduced in anticipation of interaction effects with uranium as well as for hidden replication.

Uranium was always detrimental in progressively raising C_v fracture-appearance transition temperatures. However, only uranium contents exceeding 0.15% were inherently detrimental to absorption of impact energy. At the highest sulphur level, and particularly in transverse tests, uranium beneficially raised the curves of C_v impact energy versus temperature.

The rates of active corrosion in 5% HCl and H₂SO₄ were significantly but marginally reduced by uranium. Accelerated stress-corrosion results indicate some improvement related to the presence of 0.09% uranium.

Uranium in amounts sufficient to globularize sulphides did not significantly affect machinability. Uranium makes possible the production of ultra high sulphur steels having good transverse impact toughness.

In carbon steel, uranium refined the as-cast macrostructure, promoted the formation of degenerate pearlite and slightly delayed the transformation of austenite, but had almost no effect on tensile properties.

The factorial design of the impact test program permitted quantitative determination of the effects of sulphur and carbon on C_v 15 ft-lb and C_v 50% cleavage transition temperatures.

*Senior Scientific Officer, Ferrous Metals Section, Physical Metallurgy Division.

Price: \$ 1.00

Cat. No. M38-1/178

R 179 Effect of Uranium on the Transverse Ductility of Resulphurized Chromium Stainless Steel Rolled Plate.

W.M. Crawford* July 1966 41 p., Illus., Tables.

Tensile ductility in the transverse and longitudinal direction was investigated for a group of experimental stainless steels, of AISI Types 416 and 430F, containing sulphur at levels of 0.15% and 0.30% and corresponding uranium contents to give U:S ratios of approximately 0, 1, 4, and 7.

The usual deleterious effect of sulphur on ductility was demonstrated in the uranium-free steels and, in particular, the poor transverse ductility due to the presence of the sulphides as stringers was noted.

Uranium was observed to have a pronounced effect on the morphology of the sulphides, suggesting a change in their chemical composition. At U:S ratios in the region of 4:1, globular sulphides replaced the stringers and the ratio of transverse/longitudinal ductility, as measured by per cent reduction of area, was of the order of unity. Also, in this condition, the 0.15% sulphur steels and the 0.30% sulphur steels showed similar ductilities. These beneficial effects were obtained for both grades of steel in the soft, annealed condition, and also for Type 416 quenched and tempered to a higher strength.

*Scientific Officer, Ferrous Metals Section, Physical Metallurgy Division.

Price: 75 cents

Cat. No. M38-1/179

R 180 Pillar Loading, Part III: Field Measurements.

D. F. Coates* February 1966 79 p., Illus., Tables.

This work is in the area of engineering theory. It is concerned with the combining of existing scientific theories into a rational hypothesis for predicting the loading of pillars. Hitherto, this has only been possible in a very crude way and only for horizontal workings.

Analytical work to predict pillar loadings for long mining zones in elastic ground results in equations which include, in the form of dimensionless parameters, the significant geometrical and material properties affecting pillar loading. Measurements of pillar stresses in laboratory models of gelatin, of Araldite-type materials, of mortar, and of steel show that it is possible to predict the variation of pillar loading--with location within the mining zone--with variation of pillar height--with variation in pillar breadth--with the number of pillars across the mining zone--with the variation of the compressibility of the pillar ground with respect to that of the walls--with variation in the magnitude of the field stress component acting transversely to the mining zone or vein--and, above all, with the extraction ratio.

The results of pillar stress measurements in a lead mine, two iron mines, a coal mine and a uranium mine indicate that the most significant parameter causing deviation from the predicted pillar stresses is the variation in the relative compressibility of the pillar rock.

The tributary area theory was found not to predict actual pillar loadings with an acceptable accuracy nor to account for changes in pillar loadings resulting from changes in the above factors included in the new hypothesis.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: \$ 1.25

Cat. No. M38-1/180

R 182 Laboratory Investigations of Hydrogen Explosion Phenomena Relating to Electrical Apparatus.

G. K. Brown* E. D. Dainty** and S. Silver** April 1966 79 p., Illus., Tables.

The relative ease of ignition of mixtures of hydrogen and

air throughout the flammable range by electric spark was found and compared to the ignition of pentane and air mixtures. A determination was made of the relationship of percentage by volume of hydrogen in air to explosion pressure in a small cubical enclosure, one quarter of a cubic foot in volume; and also of the time to reach peak pressure in the same enclosure. A study was made of the transmission of hydrogen explosions through flat joints by means of apparatus which permitted variation of the gap size, the joint width and the free volume. As the apparatus for this study was such that the gap could not expand due to explosion pressure, a further study was made of explosion transmission through the shimmed flat joints of several commercial-type, explosion-proof enclosures and an experimental enclosure, all of which had bolted covers and for which the gap changed due to pressure during an explosion. Experiments were also conducted on diffusion of hydrogen into enclosures and the possibility of transmitting hydrogen explosions through threaded joints. The results of the various studies are presented, discussed, and, in some cases, related to theoretical equations or otherwise interpreted.

*Head and **Senior Scientific Officers, Electrical Equipment Certification and Safety Research Section, Fuels and Mining Practice Division.

Price: \$ 1.00

Cat. No. M38-1/182

R 183 Effect of Heat Treatment on the Corrosion Behaviour of Two Zirconium-Copper-Molybdenum Alloys.

C. F. Dixon* H. M. Skelly** March 1966, 18 p. Illus., Tables.

The effect of heat treatment on the corrosion properties of Zr-1.0% Cu-1.5% Mo and Zr-0.5% Cu-0.5% Mo alloys was investigated.

The heat treatment found to give optimum corrosion resistance in steam was, for the Zr-1.0% Cu-1.5% Mo alloy, 1000°C (1830°F) for one hour, then water quench, followed by ageing at 500°C (930°F) for 32 hours; and, for the Zr-0.5% Cu-0.5% Mo alloy, 1000°C (1830°F) for one hour, water quench, then age at 500°C (930°F) for 24 hours.

Over-ageing of the alloys resulted in growth of the intermetallic phase particles, which then caused cracking of the corrosion film.

Preparation of an experimental alloy, namely Zr-3.0% Cu-4.5% Mo, which contained a larger percentage of the intermetallic phase, made it possible to identify, by X-ray diffraction methods, that phase as being a cubic structure with a unit cell of 4.999 Å.

*Scientific Officer and **Senior Scientific Officer, Nuclear and Powder Metallurgy Section, Physical Metallurgy Division.

Price: 50 cents

Cat. No. M38-1/183

R 184 Hypereutectic Aluminum-Silicon Alloys Produced by Hot Compaction of Atomized Powder.

H. M. Skelly* and C. F. Dixon** May 1966 21 p., Illust., Tables.

The main objects of this investigation were: (1) to de-

termine whether a fine dispersion of primary silicon phase could be obtained in hypereutectic aluminum-silicon atomized powder without adding nucleation catalysts to the melt; (2) to determine whether the atomized powders could be consolidated by hot pressing.

Atomized powders of Al-25%Si, Al-35%Si and Al-45%Si alloys containing a fine dispersion of silicon were successfully produced without the use of nucleation catalysts. The powders were consolidated to densities close to theoretical by hot pressing at temperatures of 400°C (750°F) and 550°C (1020°F) and pressures of 38,000 psi and 81,000 psi.

Some properties of the powders and of the compacts produced from them were determined.

*Senior Scientific Officer and **Scientific Officer, Nuclear and Powder Metallurgy Section, Physical Metallurgy Division.

Price: 50 cents

Cat. No. M38-1/184

R 158 Changed to Reprint Series RS19.

R 159 Changed to PMM 66,25.

TECHNICAL BULLETINS

TB 67 An All-Solid-State Ultrasonic Power Oscillator.

R. H. Goodman* and A. H. Bettens** March 1966, Charts., Illus., 9 pages.

This report describes a versatile all-solid-state power oscillator originally designed for use with an ultrasonic agitating system.

The unit produces a variable frequency sine wave (25 to 100 kc) with a power output of 20 watts into output impedances of 8, 8,000 and 10,000 ohms. The circuit is completely protected from short circuiting of the output.

*Senior Scientific Officer and **Senior Technician, Mineral Physics Section, Mineral Sciences Division.

Price: 50 cents Cat. No. M34-20/67.

TB 76 A Comparison of Manual and Automatic Control of the Grinding Circuit at East Malartic Mines Limited, Norrie, Quebec.

F. J. Kelly* and W. A. Gow** September 1966, 24 p., Illus., Tables.

Surveys were made of the East Malartic Mines Limited grinding circuit while it was under manual control and when it was under automatic control. The automatic control system used involved the measurement of the intensity of a narrow frequency range of the sound emanating from the grinding units, and control of the feed rate so as to maintain the sound intensity at a pre-set value. Eighty per cent of the control signal came from the primary open-circuit rod mill, and the remaining twenty per cent from one of two secondary ball mills operating in parallel in closed circuit with hydraulic cyclones.

The surveys showed that the application of automatic control resulted in a significant reduction in the variability of the fineness of grind, and in the variability of the screen analyses, of all the products from the grinding circuit. For example, under manual control the 50% passing size of the rod mill discharge varied from 48 mesh to 150 mesh, while under automatic control the variation was within one Tyler screen size, i. e. from just less than 28 mesh to just more than 35 mesh.

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

Price: 50 cents Cat. No. M38-20/76.

TB 77 Determination of Silicon by Measurement of the Absorbance of the *N*-Amyl Alcohol Extract of α -Silicomolybdic Acid (Application to High-Purity Copper Metal and Brasses).

Elsie M. Donaldson* and W. R. Inman** September 1965, 21 p., Charts, Tables.

A procedure involving *n*-amyl alcohol extraction of α -silicomolybdic acid and spectrophotometric measurement of the extract (at 350 m μ) has been applied to the determination of trace amounts of silicon in high-purity copper metal and brasses. Interference from phosphorus and arsenic is eliminated by the selective destruction of their heteropoly

complexes in a 3N sulphuric acid medium prior to the extraction of the silicon complex.

*Senior Scientific Officer and **Chief Chemist, Analytical Chemistry Sub-division, Mineral Sciences Division.

Price: 50 cents Cat. No. M34-20/77.

TB 78 Pilot Plant for Low and High-Pressure Fluid-Catalyst-Bed Reactions.

J. P. Mogan*, R. W. Taylor** and F. L. Booth***, November 1965, 35 p., Figures.

The construction details of a high-pressure fluid-catalyst pilot-plant are described in this report. This versatile unit will be used to study a variety of fluid-bed reaction schemes (cracking, hydrofining, . . .) for the beneficiation of crude oils and bitumens. Of side-by-side configuration, the plant can operate from 15 to 1500 psi at up to 1200°F. The charge oil rate can be varied from 0.08 to 1.75 imp. gph. The oil reacts in the presence of a continuously regenerated recirculating catalyst flow of 7 to 25 lb per hour from a 6-lb inventory. An alternate once-through catalyst system circulates 32 lb of catalyst through the reactor from pressure storage vessels.

The ancillary equipment—connecting lines, heaters, safety equipment, supports, and insulation—is also described.

*Senior Scientific Officer, **Technician, and ***Head, Petroleum Process Engineering Section Fuels and Mining Practice Division.

Price: 75 cents Cat. No. M34-20/78

TB 79 Analytical Procedures for a Vanadium Recovery Process.

R. J. Guest* and J. C. Ingles** February 1966 68 p., Illus., Tables.

Analytical procedures are described for the determination of a number of elements in connection with a process for the recovery of high-purity vanadium compounds from vanadium-bearing boiler fly ash. Although the basic procedures used are standard ones, a number of modifications have been made where necessitated by the nature of the sample material. A discussion of the reason for these modifications is included and the experimental work carried out on several procedures is described.

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

Price: \$ 1.00 Cat. No. M34-20/79

TB 80 A Survey of the Titanium Alloys, Their Applications and Their Processing and Manufacturing Technology.

H. V. Kinsey* March 1966, 94 p., Tables.

The characteristics, properties, areas of application, and processing and manufacturing techniques of the titanium alloys are all reviewed in this "state of the art" survey, which is based on information available in the open literature that

appeared between 1959 and 1965. This information is nearly all related to the aeronautical field.

The only major fabrication area not covered in this report is welding. Welding has been dealt with separately in Mines Branch Technical Bulletin TB 71 (April 1965) by Dr. K. Winterton.

* Head, Refractory Metals Section, Physical Metallurgy Division.

Price: \$ 1.25

Cat. No. M34-20/80.

TB 81 Simple, Low-Rate Feeder For Water-Insoluble Flotation Reagents.

L. L. Sirois* and T. Takamori** February 1966, 13 p., Illus.

A simple feeder to deliver water-insoluble flotation reagents in very small quantities was built. The action of this feeder is based on the regulated production of gases from the hydrolysis of water, to exert a positive pressure on a reagent and thus expel it at the required rate through a suitable feed arrangement.

The accuracy of the feeder depends on the stability of the direct current produced, on the large quantities of minute gas bubbles formed at the electrodes in the hydrolysis cell, and on the formation of small drops of reagent at the feeding end.

This feeder will deliver from 0.026 to 0.250 cc of solution or liquid per minute, with actual reagent-feed rates depending on dilution or specific gravity of liquid reagents.

* Head, Metallic Minerals Research Laboratory, Mineral Processing Division. ** Associate Professor, Hokkaido University, Sapporo, Japan; formerly National Research Council Fellow, attached to the Mines Branch, 1963-1965.

Price: 75 cents

Cat. No. M34-20/81.

TB 82 The Application of Electronic Sorting to Minerals Beneficiation.

R. A. Wyman*, July 1966, 47 p., Charts, Tables.

Developments during the past twenty years have made electronic sorting techniques potentially valuable for solving many mineral beneficiation problems. Pertinent information on the subject is presented, available equipment is described, further development possibilities are indicated, and examples of separations are given.

* Head, Industrial Minerals Milling Section, Mineral Processing Division.

Price: 75 cents

Cat. No. M34-20/82.

INFORMATION CIRCULARS

IC 177 Bibliography of High-Temperature Condensed States Research Published in Canada, October - December 1965.

Norman F.H. Bright* January 1966, 12 p.

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from October 1 to December 31, 1965.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price: 50 cents Cat. No. M38-3/177.

IC 178 Bibliography of High-Temperature Condensed States Research Published in Canada, January - March 1966.

Norman F.H. Bright* April 1966, 11 p.

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from January 1 to March 31, 1966.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price: 50 cents Cat. No. M38-3/178

IC 179 Preliminary Mineralogical Study of the Silver Deposits in the Cobalt Area, Ontario.

W. Petruk* June 1966, 44 p., Illus., Tables.

The silver deposits in the Cobalt area in Ontario consist of mineralized carbonate veins in the Cobalt series sediments, Keewatin rocks, Nipissing diabase, and lamprophyre. The central portions of the mineralized veins consist largely of cobalt-nickel arsenides and native silver in carbonate, and the terminal portions consist of arsenopyrite and sulphides in carbonate. The minerals in these veins occur in a variety of ways, but most of the cobalt-nickel arsenides occur as rosettes and masses. The rosettes in silver-bearing veins contain cores of native silver, and the masses contain irregular aggregates, disseminations and veinlets of native silver but are richer in native bismuth.

*Senior Scientific Officer, Mineralogy Section, Mineral Sciences Division.

Price: 75 cents Cat. No. M38-3/179.

IC 180 Filtration (A Literature Survey).

N. Nemeth* March 1966, 19 p.

Research up to the present on the theoretical aspects of filtration is reviewed. Major phases of work and respective schools of thought are summarized, and samples of the views of various workers are given. Outlines for future research are indicated, with special attention to the more neglected areas.

* Scientific Officer, Metallic Minerals Research Section, Mineral Processing Division.

Price: 50 cents Cat. No. M38-3/180

IC 181 An Index of the Scientific and Technical Papers Published by The Staff in 1966.

Price: 50 cents Cat. No. M38-3/181

IC 182 Analyses of Coal and Coke During 1965.

W. J. Montgomery* and G. C. Behnke** June 1966, 20 p.

The Solid Fuels Laboratory of the Fuels and Mining Practice Division is responsible for all analytical work on coal and coke encompassed by this publication, including that reported in the official "Analysis Directory of Canadian Coals" (which is published by the Mines Branch, but only at intervals of five or more years). This information circular, issued as the sixth of an annual series, tabulates the analyses of coal and coke samples analysed by the Division during 1965.

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

*Head and **Technician, Solid Fuels Laboratory, Fuels and Mining Practice Division.

Price: 50 cents Cat. No. M38-3/182.

IC 183 Directory of High-Temperature Condensed States Research in Canada, July 1966.

Norman F.H. Bright* July 1966, 20 p.

A list is given of establishments in Canada in which research on high-temperature condensed states is currently being conducted. The names of the researchers involved and an indication of their specific fields of interest are also included.

*Head, Physical Chemistry Section, Mineral Sciences Division.

Price: 50 cents Cat. No. M38-3/183

IC 184 Bibliography of High-Temperature Condensed States Research Published in Canada, April - June, 1966.

Norman F.H. Bright* July 1966, 12 p.

This report contains bibliographic information concerning research work on high-temperature condensed states published in Canadian journals from April 1 to June 30, 1966.

*Head, Physical Chemistry Section, Mineral Sciences
Division.

Price: 50 cents

Cat. No. M38-3/184

IC 185 Bibliography of High-Temperature Condensed
States Research Published in Canada, July -
September, 1966.

Norman F.H. Bright* October 1966 12 p.

This report contains bibliographic information concern-
ing research work on high-temperature condensed states
published in Canadian journals from July 1 to September 30,
1966.

*Head, Physical Chemistry Section, Mineral Sciences
Division.

Price: 50 cents

Cat. No. M38-3/185.

REPRINT SERIES

RS 1 Making Decomposition Rate Measurements on Simple Inorganic Chemical Powders by TGA.

T. T. Ingraham* Reprinted from Proceedings of The First Toronto Symposium on Thermal Analysis, Toronto Section, Chemical Institute of Canada, February 1965.

When studying the rates of thermal decomposition of inorganic materials, it is usual for the observed reaction rates to appear to vary with the state of subdivision of the material. Rather than use the complex and time consuming techniques of surface area measurement, a new technique of pelletizing powdered materials has been developed for use in flowing gas streams. It has been shown that the energy parameters resolved by this technique are identical with those obtained for solid specimens. The technique has made it possible to make critical kinetic examinations of materials which are available only as powders.

*Head, Research Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/1

RS 2 An Investigation of Gas-Explosion Transmission Through Short Cylindrical Channels of Varying Length and Diameter.

E. D. Dainty* and G. K. Brown** Presented to Restricted International Conference of Directors of Safety in Mines Research, July 12th to 16th, 1965.

The Mines Branch of the Canadian Department of Mines and Technical Surveys recently began a series of studies on gaseous explosion transmission through various types of channels. The results of the initial stage which was concerned with transmission of explosions through cylindrical channels, are presented in this paper.

The experimental results are presented in the form of a diameter versus length characteristic for a 9.5% methane-air mixture. This characteristic is the transition line between a non-ignition transmission region and an ignition transmission region. In addition it is suggested that there is an optimum length at a minimum diameter on this transition characteristic. Consequently, reducing the length below the optimum would require an increase in diameter for ignition transmission to occur.

It is believed that this peculiar reversal is due to an "orifice effect", which differentiates this phenomenon from the behaviour of flat joints. A discussion of this effect suggests that the aerodynamic flow configuration through a round channel is the most important factor determining the location of the optimum length. Also, the discussion suggests an explanation for the reversal effect for cylindrical channels.

*Research Scientist and **Head, Electrical Equipment Certification Section, Fuels and Mining Practice Division.

Price: 25 cents Cat. No. M38-8/2

RS 3 Flotation of Uranium From Elliot Lake Ores.

W. R. Honeywell* and S. Kalman** Reprinted from Canadian Mining and Metallurgical Bulletin, March 1966.

This paper describes flotation test work conducted over the past several years at the Mines Branch, Ottawa, on the radioactive quartz-pebble conglomerate ores of the Elliot Lake area of Ontario. The purpose of this work has been to

produce a uranium flotation concentrate for subsequent leaching operations. The results of earlier investigations are summarized and correlated with the results of mineralogical studies of the ores and flotation products. The results of recent pilot-plant investigations by flotation, as well as by gravity concentration followed by flotation of the gravity tailings, are given. The principal collector used for uranium flotation was a tall oil fatty acid, and the indicated total cost of all reagents ranged from 21 to 31 cents per ton of ore treated.

*Senior Scientific Officer, Hydrometallurgical Section, **Head, Mineralogy Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/3

RS 4 Leaching of Uranium From Elliot Lake Ore in the Presence of Bacteria.

V. F. Harrison*, W. A. Gow** and K. C. Ivarson*** Reprinted from Canadian Mining Journal, May 1966.

Testing by the Departments of Mines and Technical Surveys and of Agriculture showed that mine water and stope ore from Denison Mines contained bacteria belonging to the Ferrobacillus - Thiobacillus group. Percolation leach tests showed that the bacteria promote the production of an acid-oxidizing solution effective in leaching, whereas in the absence of bacteria no leaching of the uranium occurred.

*Senior Scientific Officer, **Head, Hydrometallurgy Section, Extraction Metallurgy Division, and ***Senior Research Officer, Soil Research Institute, Department of Agriculture, Ottawa.

Price: 25 cents Cat. No. M38-8/4

RS 5 Stable Copper Cyanide Plating Baths.

W. Dingley*, J. Bednar* and R. R. Rogers** Reprinted from Plating, May 1966.

Stable copper cyanide plating baths which can be operated at 25°C (77°F) have been developed. These conform to both of the following relationships:

- (1) OH^- normality = "free" CN^- normality, and
- (2) $\frac{\text{total NaCN normality}}{\text{Cu normality}}$ varies between 2.6 and 2.9,

depending on the bath concentration.

Advantage of these baths include: (1) comparatively simple control of bath compositions. (2) improvement in the nature and adhesion of the copper deposits, and in the plating-cell operating conditions. (3) ability to use higher cathode current densities. (4) ability to copper plate high-strength steel such as Type 4037 without embrittling the steel. (5) ability to plate comparatively thick copper coatings directly on steel without the use of a "strike" bath.

*Technical Officers and **Head of Corrosion Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/5

RS 6 Sulfurous Acid Corrosion of Low Carbon Steel at Ordinary Temperatures - 1. Its Nature.

W. McLeod*, R.R. Rogers**, Reprinted from Corrosion, Vol. 22, No. 5, May 1966.

Corrosion rate data are presented for low carbon steel in (1) a combination of sulfur dioxide, water vapor and air, and (2) aqueous solutions of sulfurous acid in the absence of air, at ordinary temperature. Information as to the nature of the corrosion products is presented and it is shown that this depends on the place in which the corrosion takes place to an important extent.

*Senior Scientific Officer, and **Head, Corrosion Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/6.

RS 7 Excited X-Rays Identify Minerals as Ore Moves Down Conveyor Belt.

R. H. Goodman*, A. H. Bettens* and C. A. Josling** Reprinted from Canadian Electronics Engineering, June 1966.

In the uranium mining industry, the presence of uranium ore can be detected through its natural radioactivity but there are few techniques which allow detection of non-radioactive elements. An electronic ore-sorting system using X-ray fluorescence has been developed at the Department of Mines and Technical Surveys, Ottawa, to allow the extension of sorting techniques to other minerals.

This system operates on ore sizes from 2 to 10 inches. Rejection of waste material before much effort has been spent in processing means that for a given grinding capacity and reagent quantity, a greater output of final product can be obtained.

*Research Scientist and **Technicians, Mineral Physics Section, Mineral Sciences Division.

Price: 25 cents Cat. No. M38-8/7.

RS 8 Symposium on the Preparation and Properties of Lead Zirconate-Lead Titanate Piezoelectric Ceramics.

Foreword by I. F. Wright, Co-ordinator of Mines Branch Electronic Ceramics Programme, Senior Scientific Officer, Ceramics Section, Mineral Processing Division. Reprinted from the Journal of the Canadian Ceramic Society, Volume 34, February, 1965.

a) The System PbO-ZrO₂-TiO₂ at 1100°C.

A. Hubert Webster*, Ronald C. MacDonald** and William S. Bowman**.

The system PbO-ZrO₂-TiO₂ has been examined with particular emphasis on the sub-solidus phase relationships at 1100°C. The PbZrO₃-PbTiO₃ solid solution series has been found to exhibit smaller deviations from the ratio:

$$\frac{\text{PbO}}{\text{ZrO}_2 + \text{TiO}_2} = 1 \text{ than had been previously reported.}$$

Zirconium dioxide containing titania in solid solution, the compound ZrTiO₄ and titania have been found to co-exist with various ranges of the PbZrO₃-PbTiO₃ solid-solution series. Zirconia can take up to about 14 mol % of titania

into solid solution. The general form of the diagram, however, agrees with the results of previous work by Ikeda et al.

*Senior Scientific Officer and **Summer Student Assistants, Physical Chemistry Section, Mineral Sciences Division.

b) A Wet Chemical Method for the Preparation of Oxide Mixtures Applicable to Electronic Ceramics.

V. M. MacNamara*

A method is described for effecting the complete coprecipitation of the basic carbonates or hydroxides of lead, zirconium and titanium from a stoichiometric, acid-nitrate solution of the metals. The acidic solution containing the metal nitrates is sprayed onto the surface of dilute ammonium nitrate solution. Ammonia gas diluted with nitrogen is used to maintain the pH of the neutralizing solution above seven. This procedure results in the instantaneous neutralization of the individual droplets, thus each particle of precipitate has the desired stoichiometry. The effects of pH, temperature and agitation method are discussed and the spray technique described. Methods used for washing, settling and drying the precipitate are also described and evaluated.

The method yields, with good reproducibility, powders that are non-segregating with respect to the components and are of high purity. Upon calcination at 650°C the powders react completely to give the solid solution lead zirconate-lead titanate.

*Senior Scientific Officer, Hydrometallurgy Section, Extraction Metallurgy Division.

c) Some Ceramic and Electrical Properties of Bodies Fabricated from Co-precipitated Lead-Zirconium-Titanium Hydroxide.

A. H. Webster*, T. B. Weston**, and R. R. Craig***.

Co-precipitated lead-zirconium-titanium hydroxides, with and without the presence of carbonate, have been successfully fabricated into lead zirconate-titanate ceramic test pieces. The effects of certain processing variables during the precipitation and drying stages on the structural, chemical and electrical properties of the ceramic bodies are described. Some difficulties, encountered during preliminary work in this investigation and found to be caused by the presence of impurities, led to an examination of the effects of various constituents when added to the calcined precipitates prior to sintering. In particular, the presence of small amounts of fluorine and of alumina were found to be very detrimental to the electro-mechanical properties of the sintered ceramic body.

*Senior Scientific Officer, Physical Chemistry Section, Mineral Sciences Division **Senior Scientific Officer, Ceramic Section, Mineral Processing Division and ***Scientific Officer, Analytical Chemistry Sub-division, Mineral Sciences Division.

d) Chemical Determination of Lead, Titanium and Zirconium in Precipitates used for Production of Homogenous Lead Zirconate-Lead Titanate Solid Solutions.

D. J. Barkley*, A. Hitchen**, G. Zechanowitsch***, J. B. Zimmerman****, and J. C. Ingles*****.

Methods are described for the determination of lead, zirconium and titanium in precipitates containing all three of these elements as major constituents. Lead is determined

by titration with EDTA, using Xylenol Orange as indicator, after isolation from the other constituents by a solvent extraction step employing sodium diethyl-dithiocarbamate. Titanium is determined by differential absorptiometry of the titanium-hydrogen peroxide compound, in the raffinate from the lead removal step. Zirconium is determined conventionally on a separate aliquot of the sample solution, by the gravimetric mandelic acid procedure, after prior removal of lead as sulphate.

Data on the precision and accuracy of the methods are also presented.

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

Price: 25 cents Cat. No. M38-8/8

RS 9 Theory and Experiment in Methods for the Precision Measurement of Viscosity.

H. R. Thresh*, Reprinted from Transactions ASM 55(3) 790-818 (1962).

Methods of measuring viscosity are appraised for their suitability to liquid metals at elevated temperatures. Selected methods are examined for their potential sources of error, and means are discussed for eliminating, minimizing or correcting for error.

*Senior Scientific Officer, Metal Physics Section, Physical Metallurgy Division.

Price: 25 cents Cat. No. M38-8/9

RS 10 Ejection of Atoms from Metallic Single Crystals.

R. L. Cunningham* and Joyce Ng-Yelim**. Reprinted from American Journal of Physics, Vol. 33, No. 12, 1064-1069, December 1965.

The unique characteristics of experimental data obtained from the directional ejection of atoms from metallic single crystals subjected to ion bombardment are discussed. The advantages, for instructional purposes, are outlined. Simple experiments are described that are designed to give the beginner in crystallography a working familiarity with (1) crystal directions, (2) techniques for orientation determinations, and (3) anisotropic characteristics of crystals. All experiments described maybe performed with simple and inexpensive equipment.

*Principal Scientist and **Technical Officer, Physical Metallurgy Division.

Price: 25 cents Cat. No. M38-8/10

RS 11 Some Observations on Niobium in Steel.

D. R. Bell* and G. P. Contractor**. Reprinted from Tetsu-to-Hagane, Vol. 52, No. 1, Jan. 1966, pp. 42-54.

The effects of niobium on silicon-killed, low carbon steel were investigated. Most of the data relate to 450-lb laboratory melts, forged and rolled to 3/4-in. plate. Data from one heat of commercial steel were also examined.

In the as-rolled condition, it was found that small additions of niobium increased the yield strength and raised the transition temperature markedly, but that larger additions were less effective. In the normalized condition, the effects on yield strength were similar to those in the as-rolled condition but the changes were less marked. The transition temperature was improved with all levels of niobium, the smallest additions (up to 0.04%) being most effective.

Commercial plate of a similar composition to the laboratory steel was procured with niobium contents of approximately zero, 0.010% and 0.023%, in 1/4-in., 3/4-in., and 1 1/2-in. thickness. The yield strength and transition temperature results obtained on the commercial material qualitatively corroborated the findings of the laboratory steels. Niobium was most effective in increasing the yield strength in the 1/4-in. plate, the effectiveness decreasing as the plate thickness increased. Rotating beam fatigue tests showed that niobium slightly increased the fatigue limit of smooth bars and had no effect on the fatigue limit of notched bars. The fatigue ratio was unaffected by niobium for smooth bars and decreased somewhat for notched bars.

Limited data, based on electrolytically extracted residues, indicated that the major bulk of the niobium added to the steels was partitioned to the carbide phase. Similarly, much of the nitrogen present in the steels was found to occur in the residues.

The evidence indicated that the effects of niobium on the yield strength and notch ductility of normalized carbon steel were qualitatively explicable in terms of grain refinement, and precipitation strengthening. The evidence did not account for the pronounced effects of small quantities of niobium on as-rolled steel.

*Senior Scientific Officer**Head, Ferrous Metals Section, Physical Metallurgy Division.

Price: 25 cents Cat. No. M38-8/11

RS 12 Instrumentation in the Cyanidation Process.

W. A. Gow*, H. H. McCreedy** and F. J. Kelly***. Reprinted from the Canadian Mining and Metallurgical Bulletin, July 1966.

It is believed that many of the problems encountered in the operation of gold cyanidation plants are difficult to resolve due to the lack of sufficient and reliable information regarding the variations and actual values of operating variables at any given time. The application of instruments to monitor the more important variables in the cyanidation process should result in more efficient plant operation and a better understanding of the process. The use of pH and conductivity sensing devices for alkalinity measurements, a monitor to determine the dissolved oxygen content of plant solutions, a continuous cyanide titrator and sonic control of grinding circuits are discussed. Although the discussion is oriented toward the cyanide process, much of the paper is applicable to other ore treatment operations.

*Head, **Senior Scientific Officer and ***Scientific Officer, Hydrometallurgy Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/12

RS 13 Synthetic Wodginite, Tapiolite and Tantalite.

A. C. Turnock*, Reprinted from the Canadian Mineralogist, Vol. 8, Part 4, 461-470, 1966.

Solid phases in the systems $MnTa_2O_6-FeTa_2O_6-O$ and $MnTa_2O_6-FeTaO_4$ have been synthesized at various temperatures and partial pressures of oxygen.

In the binary system $MnTa_2O_6-FeTa_2O_6$, the two solid phases produced were: (i) orthorhombic $Mn_{1-x}Fe_xTa_2O_6$ (tantalite), and (ii) tetragonal $Fe_{1-y}Mn_yTa_2O_6$ (tapiolite). The maximum amounts of substitution at 1200°C were $x=0.18$, $y=0.62$.

The oxidation of these tantalites and tapiolites (the system $MnTa_2O_6-FeTa_2O_6-O$) produced solid phases with compositions that are on the join $MnTa_2O_6-FeTaO_4$, plus dissolved Ta_2O_5 .

In the system $MnTa_2O_6-FeTaO_4$, the three solid phases [produced] were; (i) orthorhombic $MnTa_2O_6$ (tantalite), (ii) monoclinic $Mn_{2-2w}^{+2}Fe_{3w}^{+3}Ta_{4-w}O_{12}$ with $0.08 < w < 0.29$ at 1200°C (wodginite), and (iii) tetragonal $Fe_{3-3z}^{+3}Mn_{2z}^{+2}Ta_{3+z}O_{12}$ with $0 < z < 0.57$ at 1200°C (a compound with a rutile-type structure).

It has been shown that in wodginite (i) the iron is trivalent and the manganese divalent, and that (ii) tin is not an essential component.

* Senior Scientific Officer, Physical Chemistry Section, Mineral Sciences Division. Present address: Geology Department, University of Manitoba, Winnipeg.

Price: 25 cents

Cat. No. M38-8/13

RS 14 Prevention of Significant Embrittlement in Certain Types of High-Strength Steels; Prior to and During Cadmium Electroplating.

J. Bednar*, W. Dingley*, R. R. Rogers**. Reprinted from Electrochemical Technology September-October, 1966.

In the past, high-strength steels have become seriously embrittled during surface pretreatment and during subsequent cadmium electroplating. During this research, a method of chemical pretreatment was discovered by means of which the surfaces of Type 1062 and 4037 steels may be smoothed to eliminate sharp edges and cleaned for plating without introducing a significant amount of embrittlement. It also was found that specimens pretreated in this manner and plated with cadmium by a procedure previously developed by the authors are essentially free from embrittlement. Considerable success also has been obtained with Type 4340 steel. A chemical method of removing embrittlement and plating without introducing further embrittlement also was discovered. Evidence is presented to suggest that this type of embrittlement is primarily a surface phenomenon.

* Technical Officers and ** Head of Corrosion Section, Extraction Metallurgy Division.

Price: 25 cents

Cat. No. M38-8/14

RS 15 Glass Insert Stress meters.

K. Barron*, Reprinted from Society of Mining Engineers, December 1965.

The glass-insert stressmeter, or photoelastic stressmeter, is an instrument designed to determine stress changes occurring in rocks. It has several potential advantages over other such devices in that it is a biaxial device, it is simple and it is cheap to make.

The object of this study was to assess the behaviour of the meter under biaxial loads and to examine some of the problems associated with measurement and interpretation of the fringe pattern. This assessment has been carried out by comparing theoretical and laboratory behaviour of the meter.

It has been shown that:

- a) There are certain optimum measuring points in the meter at which measurements should be made for best accuracy. The position of the points depends on the ratio, η , of the biaxial stresses.
- b) The meter's sensitivity can be assumed to be independent of the rock modulus E provided that the rock modulus is $< 2.5 \times 10^6$ psi and not, as previous workers have assumed, if $E < 5 \times 10^6$ psi.
- c) There are several methods of separating the principal stresses; some of these are unsatisfactory. A new method is proposed and discussed.
- d) The meter sensitivity decreases as the ratio of the biaxial stresses approached unity; the accuracy thus also decreases.
- e) The axes of symmetry of the fringe pattern give an excellent indication of applied stress direction.
- f) Laboratory calibrations are in good agreement with theory.

*Senior Scientific Officer, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: 25 cents

Cat. No. M38-8/15

RS 16 Classification of Rocks for Rock Mechanics.

D. F. Coates*, Reprinted from Rock Mechanics and Mining Sciences, Vol. 1, pp 421-429, 1964.

In the field of rock mechanics efficient communication between the laboratory and the field engineers, operators and contractors is important. For example, a rock may be described as a Cretaceous shale with quartz and pyrite, etc. However, some of the principal factors of practical interest would be: (a) is it jointed, badly fractured, distinctly layered or massive; (b) does it fail in a brittle or plastic manner; (c) is it viscous before failure; (d) can the information be interpolated between boreholes, etc.? Hence it is important that the significant properties of both the substance and the mass be recognized and the appropriate information obtained so that an initial appraisal can be made of any potential problems.

Classification can be on the basis of natural, inherent characteristics or on the basis of purpose. The classification of rocks for rock mechanics problems should be functional, and the words used for communication between groups should be defined, widely recognised and related to the use of the information.

A classification system would principally be of value to engineers or those concerned with applied problems. At the same time, it has always been the concern of scientists to group or systematise and thus explain knowledge. In this way, scientists can point out similarities or differences which are not otherwise apparent. For the engineer, the appropriate classification of a rock mass would greatly assist in making the initial appraisal of any problem and in pointing to the areas where additional engineering information must be obtained for the final resolution of the matter. A review of rock mechanics' applications, of important properties and of other classifications are presented. A proposal is then made for a classification system to be used initially in this field.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: 25 cents

Cat. No. M38-8/16

RS 17 Some Case of Residual Stress Effects in Engineering Work.

D. F. Coates*, Reprinted from State of Stress in the Earth's Crust, 1964.

The paper describes and analyses the cases of: (1) the upheaval of the floor of an open pit in component rock at shallow depth, (2) the horizontal deformation of a power tunnel at shallow depth, and (3) a rockburst of unusual magnitude in an underground mine. These are all cases of conspicuous effects of the presence of residual stresses at the locations of mining and construction projects.

In the case of the open pit, after stripping approximately 50 ft of waste rock over a width of 625 ft the floor of the excavation suddenly cracked and heaved 8 ft upwards. The analysis indicated that the remaining 45 ft of layered waste rock would require a residual, horizontal stress of approximately 400 psi to cause such buckling and upheaval.

In the case of the power tunnel with a diameter of 51 ft, the crown was approximately under 175 ft of overlying rock plus 130 ft of soil. During the eight months subsequent to excavation horizontal closure of close to 2 inches occurred. A large residual, horizontal stress would be required to produce this amount of deformation. The creep properties of the rock indicated that little additional closure would occur after the first year.

The unusually large rockburst occurred in a mine where stoping had proceeded to below the 4000 ft depth. As a result of the burst, the shaft was closed completely from the 1400 ft to the 2800 ft level. By analysing the energy content of the seismic wave that was detected as far away as 600 miles, it seemed that a residual, horizontal stress of 2500 psi would be required to produce the strain energy in the volume of ground that suddenly failed explosively.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: 25 cents

Cat. No. M38-8/17

RS 18 The Stability of Slopes in Open Pits

D. F. Coates*, Reprint No. 42 of the Eighth Commonwealth Mining and Metallurgical Congress Australia and New Zealand - 1965, 13th Technical Session.

In rock slopes it is difficult to follow traditional design procedures as there are no theoretical analyses that can be used for the determination of stresses. Furthermore, the prediction of effective strength in a rock slope is not easy.

After considering the various types of rock slope failures and the limited theory that is available for predicting behaviour, it is suggested that for the planning of slopes in rocks, the practical procedure is to concentrate on monitoring deformation rather than analysing stress. In this way, empirical information is obtained that might indicate that the initial selection is satisfactory or that further excavation is required for stability. In addition, guidance is then obtained for further slope excavations in the same formation.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: 25 cents

Cat. No. M38-8/18

RS 19 Analyses of Pit Slides in Some Incompetent Rocks.

D. F. Coates*, K. L. McRorie** and J. B. Stubbins***. Reprinted from Trans. of the Society of Mining Engineers of AIME, pp. 94-101, March 1963.

Twenty-two pit slides that occurred in two Canadian open pit mining properties are analyzed. Information on the results of laboratory tests of the rocks and a brief description of the geological environment are also presented. One deduction from the study is that slides seem to be predictable by using established theory. This corroboration indicates that, contrary to normal mining practice, the appropriate slope angle should vary with the height of the wall. In addition, if the general ground water level around an open pit can be reduced, the appropriate slope angles of the walls could then be increased by a determinable amount. The ultimate objective of these investigations is to determine the relationship between the percentage probability of failure of any slope designed with specific strength parameters. With this relationship it would then be possible to determine optimum slope angles.

*Head, Mining Research Laboratories, Fuels and Mining Practice Division, **Assistant Manager, Steep Rock Iron Mines Limited, Atikokan, Ontario, ***Chief Engineer, Knob Lake Operation, Iron Ore Company of Canada, Schefferville, Quebec.

Price: 25 cents

Cat. No. M38-8/19

RS 20 The Mechanics of Support and Caving in Longwall Top Slicing.

D. F. Coates* and M. Gyenge**. Reprinted from the Proceedings of the Fourth International Conference on Strata Control and Rock Mechanics; Columbia University, New York, pp. 70-84, May 1964.

In studying the feasibility of mining with a longwall top slicing method in iron ore measurements were taken to obtain information on the distribution of stress around the mine openings together with its effects on the prop loads, the stability of the underdrift and the caving in the tail area.

As a result of these measurements, increased understanding was obtained on the ground reaction to be expected from mining excavations in this ore. It was shown that the loads on props being used for the support of the back could be predicted based on laboratory tests of the caved material. It was also found that the structural requirements for the mat supporting the caved back material could be predicted. Also, the location of the underdrifts could be determined to avoid fracturing of the walls resulting from the increased stresses under the longwall face.

*Head, Mining Research Laboratories and **Senior Scientific Officer, Mining Research Laboratories, Fuels and Mining Practice Division.

Price: 25 cents Cat. No. M38-8/20

RS 21 Mécanique du soutènement et du foudroyage dans l'exploitation en tranche unidescendante par longue taille.

D. F. Coates* and M. Gyenge**. French version of paper reprinted from the Proceedings of the Fourth International Conference on Strata Control and Rock Mechanics, Columbia University, New York, May 1964.

Les travaux décrits dans cette communication entrent dans le cadre d'un programme de recherches réalisé avec la collaboration d'une compagnie minière qui poursuivait l'étude de diverses méthodes d'exploitation en profondeur. Comme conséquence de la modernisation du matériel de mine, il fut décidé d'expérimenter le découpage en tranches unidescendantes par longue taille.

Ces nouvelles connaissances devraient permettre d'élaborer, avec une meilleure compréhension des réactions probables du terrain, tant les futures opérations par tranche unidescendante que celles d'autres méthodes d'exploitation, tout particulièrement dans le cas de la propriété qui a fait l'objet de cette étude. Les essais de laboratoire pratiqués sur le matériau du toit permettent de prévoir l'ordre de grandeur des charges que supporteraient des étançons utilisés en tranche supérieure. On peut définir les exigences imposées au garnissage afin qu'il puisse résister à la pression d'arrière-taille pourvu que l'analyse tienne compte de l'effet de voûte locale qui se forme entre les têtes des étançons. La cassure dans les parois des voies inférieures est possible de prédire.

*Head and **Senior Scientific Officer, Mining Research Laboratories, Fuels and Mining Practice Division.

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RS 22 Loads on Friction Props on a Longwall Face.

H. Zorychta* and G. S. Merrill**. Reprinted from the Canadian Mining and Metallurgical Bulletin, Vol. 58, No. 634, pp. 175-181, February, 1965.

Based on underground measurements made at the Nova Scotia coal mines of the Dominion Coal Company, Limited, this paper presents a comparison between the physical properties of hardwood packs and steel friction props when used for longwall support. The probable loads supported by steel friction props on a longwall face at both the Dominion No. 20 Colliery and the Princess Colliery are delineated, and the results of the tests are presented in graphical form. It is concluded that the steel friction props are more efficient than the hardwood packs that they replaced as roof supports.

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RS 23 Effect of Xanthate in Cyanidation.

H. H. McCreedy and W. R. Honeywell*. Reprinted from the Canadian Mining Journal, August 1966, pp. 66-69.

The results of the work have shown that the presence of xanthate in a cyanide circuit retards the dissolution rate of gold and therefore it would be to the operator's advantage to keep the xanthate added to a minimum required for successful flotation.

It has also been shown that the residual xanthate in the flotation water can be used as an indication of the amount added.

A suitable analytical technique has been tested for the determination of residual xanthate and therefore the means are available which would allow an operator to control the xanthate addition to a predetermined level.

*Senior Scientific Officers, Hydrometallurgy Section, Extraction Metallurgy Division.

Price: 25 cents Cat. No. M38-8/23

RS 24 The Production of High-Purity Niobium Oxide from Pyrochlore-Perovskite Concentrate.

F. J. Kelly* and W. A. Gow**. Reprinted from the Canadian Mining and Metallurgical Bulletin, August, 1965.

A chemical process, based on laboratory investigations, is proposed for the production of high-purity niobium oxide from a pyrochlore-perovskite flotation concentrate produced from ore obtained at the Oka, Quebec, property of Columbium Mining Products Limited.

The method developed included the decomposition and dissolution of the flotation concentrate with hot, concentrated sulphuric acid. The dissolved niobium was purified and concentrated by a solvent extraction step, using methyl isobutyl ketone as the extractant. The niobium was recovered from the extractant with ammonium fluoride solution from which niobium oxide was precipitated with ammonia. Finally, the

filtered and washed precipitate was calcined. Ninety-six per cent of the niobium was recovered in a product analysing 99.9 per cent Nb_2O_5 . The reagent cost was in the range of \$1.00 to \$1.25 per pound of niobium recovered.

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

Price: 25 cents

Cat. No. M38-8/24

RS 25 Système de Détermination à Distance de la Vitesse de Détonation de Fortes Charges Explosives.

G. E. Larocque*, F. Kapeller** and A. Darling***. Ré-imprimé de Explosifs, N°3-1966, pp. 81-89.

Les auteurs décrivent brièvement un ancien système utilisé par les Laboratoires de recherche en génie minier pour mesurer la vitesse de détonation explosive au cours d'essais sur le terrain. On souligne les faiblesses mécaniques et les défauts de ce système, qui empêchant son usage pour le contrôle robuste et d'une source de courant constant à transistors, mis au point pour remplacer l'appareil à source de courant constant, qui faisait partie de l'ancien système. Une nouvelle sonde d'explosif de remplacement est aussi décrite, et l'on donne un résumé des divers essais faits au cours de la mise au point des deux appareils mentionnés précédemment. Le nouveau a été utilisé avec succès avec 2000 pieds de câble entre la sonde d'explosif et l'appareil de contrôle, fournissant un signal en forme de gradins, ayant un temps de montée de 2 à 3 microsecondes par gradin.

*Chargé de recherches principal, **Technicien, Laboratoire de recherche en génie minier ***Chargé de recherches principal, Laboratoire de recherche sur les explosifs, Division des Combustibles et du génie minier.

Price: 25 cents

Cat. No. M38-8/25

RS 26 Experimental Criteria for Classification of Rock Substances.

D. F. Coates* and R. C. Parsons**, Reprinted from International J. Rock Mech. Min. Sci. Volume 3, pp. 181-189.

The classification system previously suggested for consideration used categories describing both the rock substance and the rock mass. The rock substance was to be classified with respect to strength, pre-failure deformation characteristics and failure characteristics. The divisions within these categories were to be kept to a minimum owing to the much greater importance of structural features in determining the behaviour of most rock masses. Also, the detailed rock properties appropriate for specific problems cannot be considered in a classification system which must be based on information that can be easily obtained.

Since the original proposal, many research workers have offered criticisms and alternate suggestions. Also, extensive testing has been done on a wide range of rock substances to determine if the previously suggested criteria produced classifications that are acceptable from a common sense point of view.

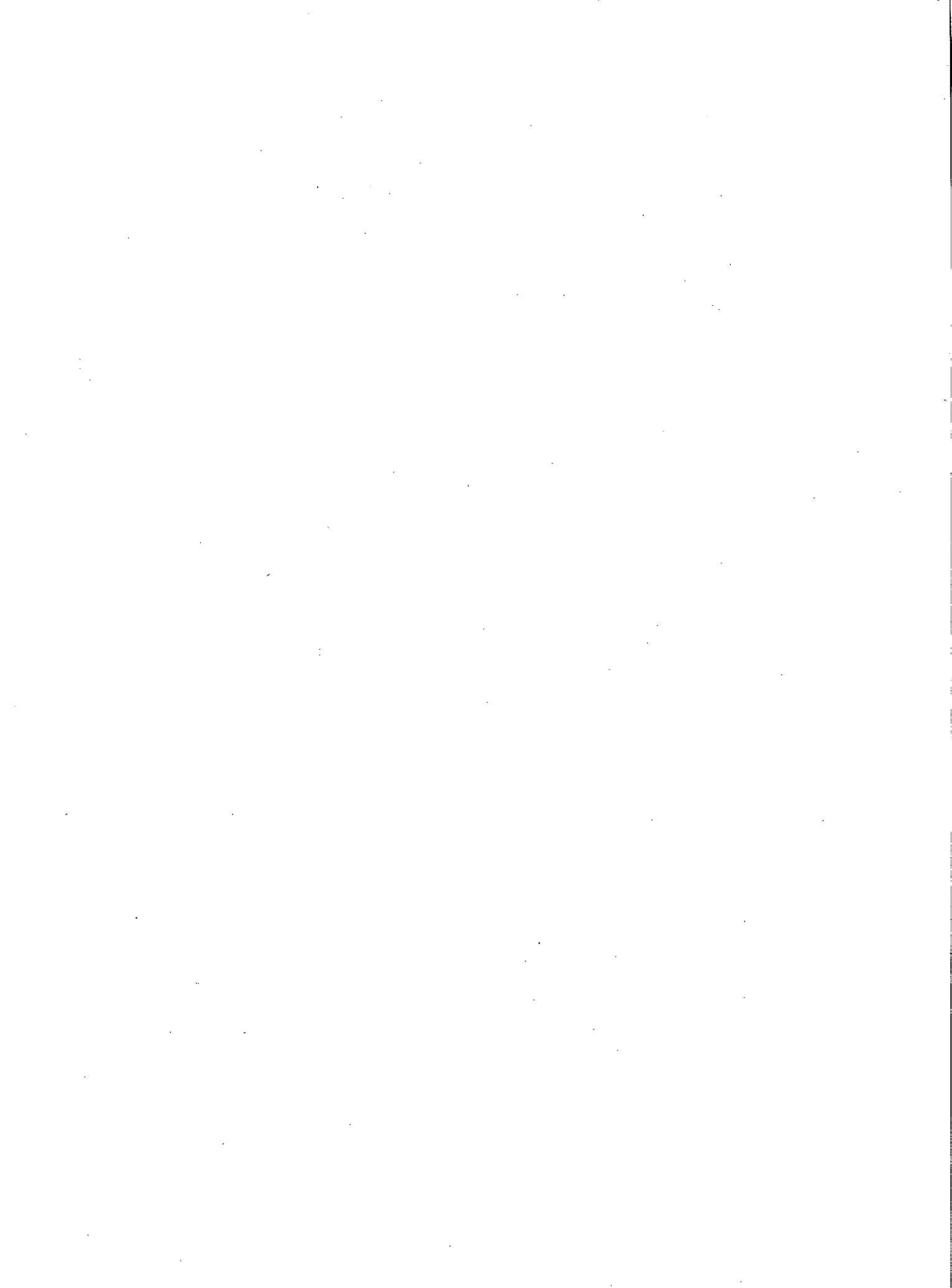
As a result of the suggestions by others and the classification testing, it is now recommended that the previous proposal be modified to include the geological name of the rock and to change the dividing line between weak and strong to 700 ksc (10,000 psi). In addition, owing to the variety of

patterns of rheological behaviour, it is thought that instead of trying to distinguish between elastic and viscous substances and plastic and brittle failure based on deformation characteristics, it might be better simply to classify the substance as either elastic or yielding with the term yielding meaning a certain minimum time-dependent strain rate or a certain proportion of total strain being permanent. Further criticisms and suggestions are invited.

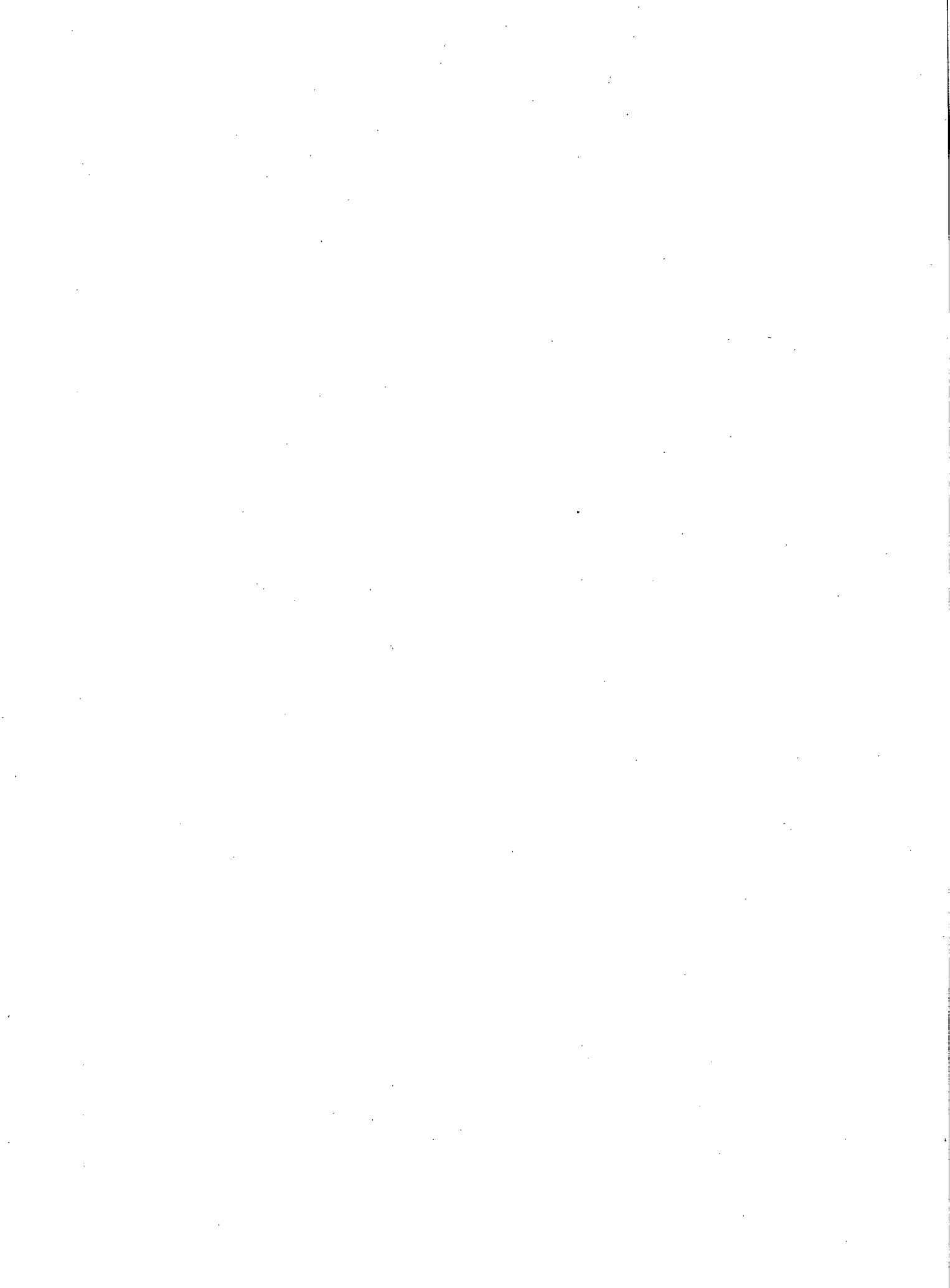
*Head and **Scientific Officer, Mining Research Laboratories, Fuels and Mining Practice Division.

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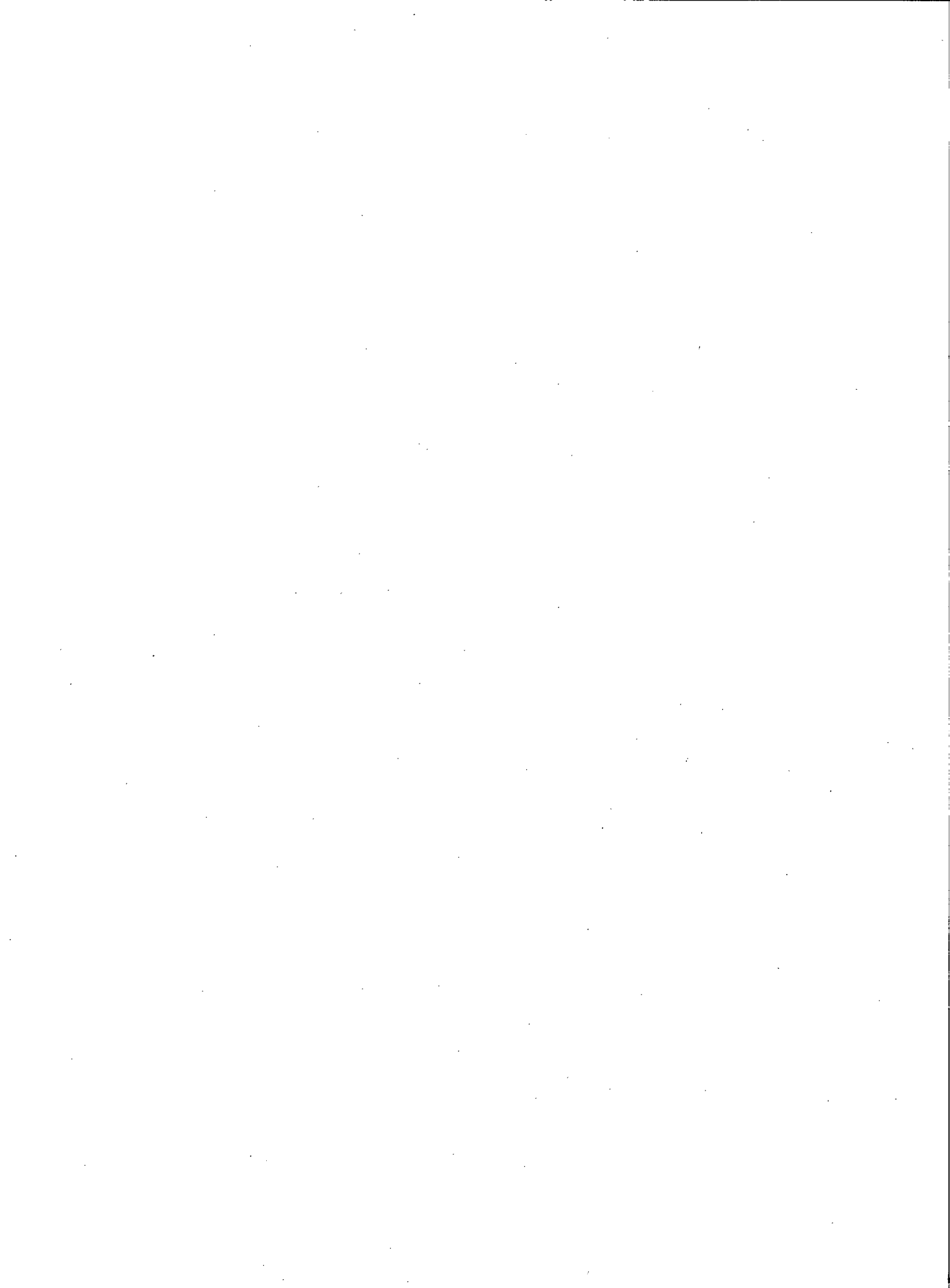
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- IR 65-109 "Mineralogical Investigation of a Copper-Nickel Ore from Axis Lake, Saskatchewan", L. J. Cabri, December 30, 1965.
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- IR 66-19 "Preliminary Considerations in the Design of a Protective Wall for the Proposed Hydrogenation Laboratory, Corkstown Road, Ottawa", K.W. Bowles, August 1965.

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- IR 65-108 "Examination of 155 mm Howitzer Driver Casting", D.E. Parsons and D.A. Munro, January 19, 1966.
- IR 66-16 "Examination of Failed Propeller-Tap-Bolt from M.S. 'Prince Nova'", R. Thomson, February 18, 1966.
- IR 66-47 "Room Temperature Tensile Tests of 15CDV6 (Vascojet 90) Steel Sheet Material", J. Harbec, June 14, 1966.
- IR 66-56 "Comparison of Two Quenched Steel-Bar Samples", D.A. Munro and D.E. Parsons, June 30, 1966.
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- IR 66-102 "Uranium Alloy Development for Non-Nuclear Application: Progress Report No. 4", H.M. Skelly, C.F. Dixon and N.S. Spence, December 13, 1966.