The Journal of the INSTITUTE OF METALS and METALLURGICAL ABSTRACTS

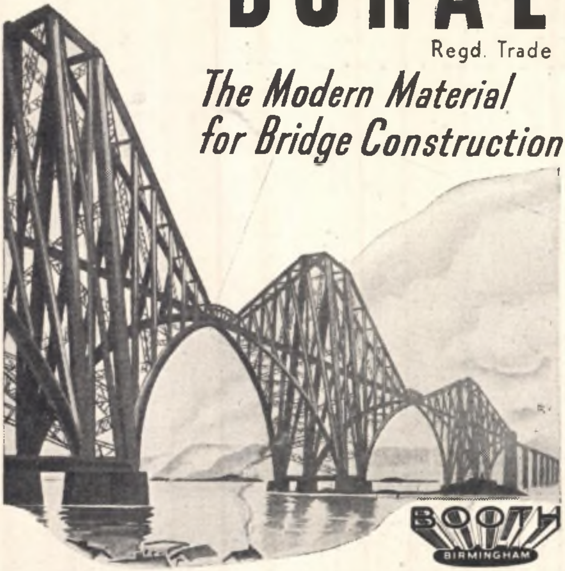
17

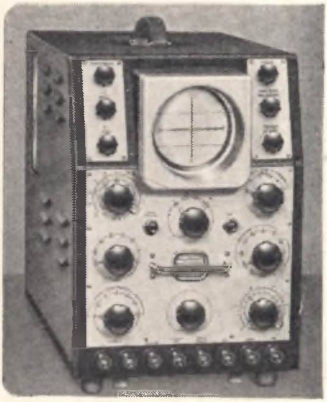
In this Issue:

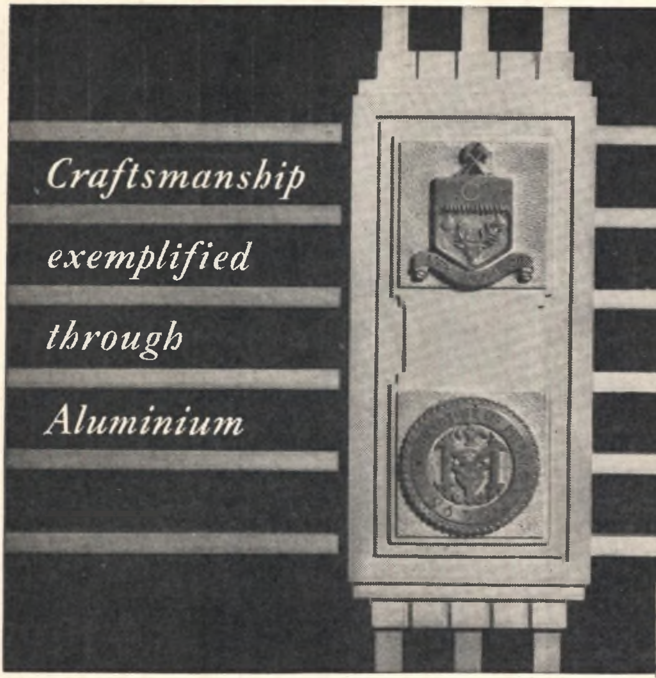
SEPTEMBER 1948

7s. 6d., *post free.*

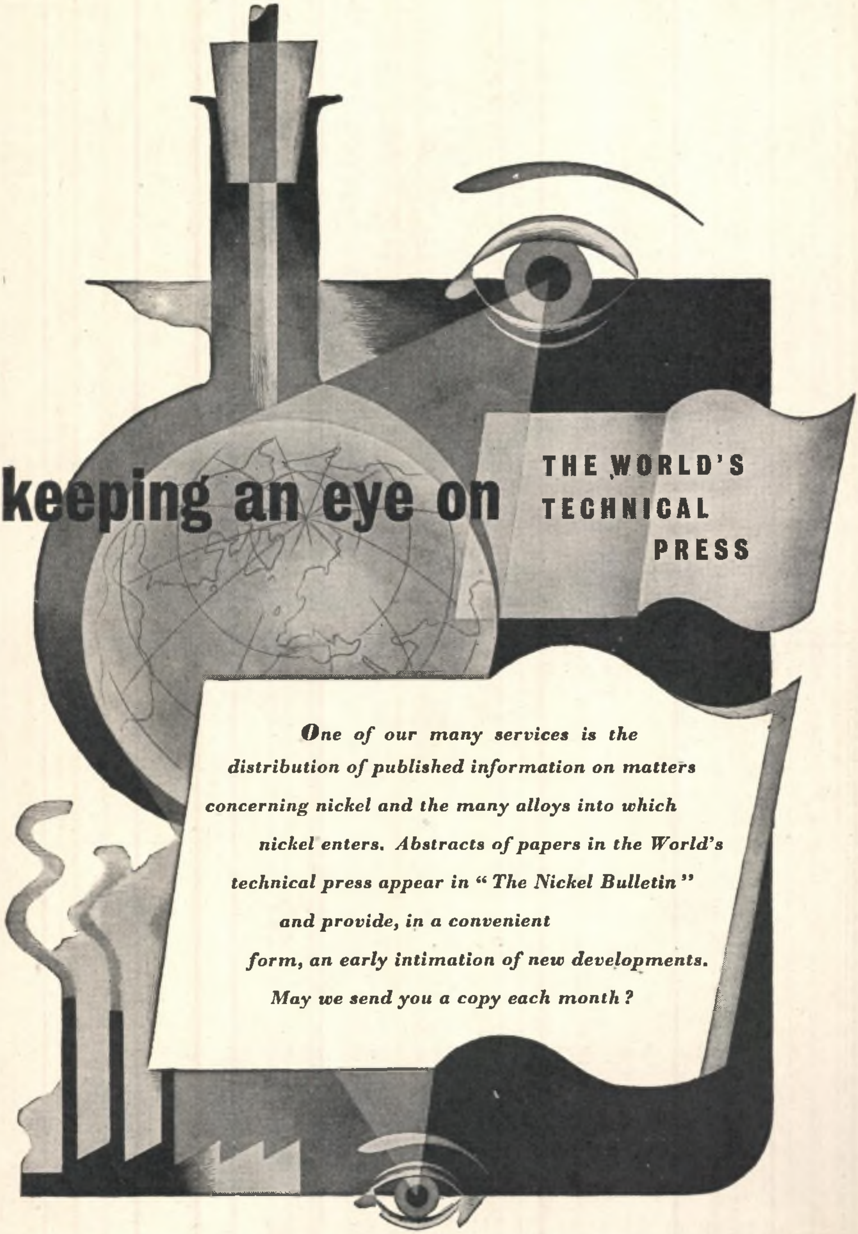
M, 16.
N-TYNE


BOOTH
BIRMINGHAM





Machined and sculptured aluminium with highlights burnished. Craftsmen: Messrs. J. Starkie Gardner Ltd.



keeping an eye on
THE WORLD'S
TECHNICAL
PRESS

"The Structure of Cast Iron"

by **ALFRED BOYLES** of United States
Pipe and Foundry Co., Burlington, New Jersey.

A series of lectures with particular emphasis on the theoretical side of cast-iron metallurgy. A great deal remains to be learned about this plebeian among metals, for the common grey iron is an alloy of great complexity and one which has been somewhat neglected by physical metallurgists in favour of the more aristocratic members of the alloy domain.

The lectures are limited to the structure of cast iron as determined by the mechanism of freezing and transformation, and the argument is frankly addressed to metallurgists familiar with the steels, but unfamiliar with cast iron. Cast iron is dealt with as a ternary alloy of iron, carbon and silicon, the structure of which is modified by the minor elements, manganese, sulphur and phosphorus. Special alloying elements, added to produce specific properties, do not come within the scope of the lectures. Attention is centred for the most part on alloys of hypo-eutectic composition, because most of the grey iron has been drawn upon freely and many references are cited.

The 124 pages of this book are well illustrated with figures and tables relating to the discussion, and the six chapters are subdivided into smaller groupings to explain thoroughly step by step in detail the various phases of cast-iron metallurgy.

154 Pages. Red Cloth Binding. Illustrations. 6 × 9. $3.25.

AMERICAN SOCIETY FOR METALS
7301 EUCLID AVENUE CLEVELAND 3, OHIO

HIGH
TEMPERATURE MEASUREMENT

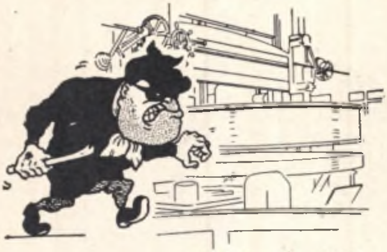
★

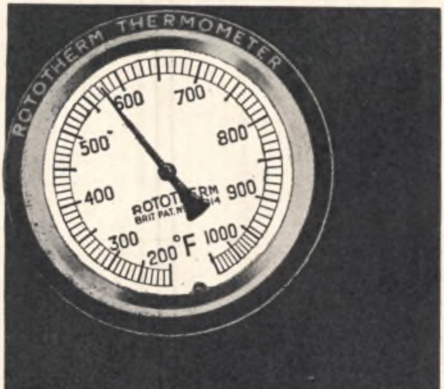
BAKER LONG LIFE Platinum v. Platinum/Rhodium Thermocouples are made to conform to N.P.L. standards of purity and accuracy.

Both 10% and 13% Rhodium/Platinum v. Platinum Couples in the usual diameters can be supplied from stock. Special sizes can be made quickly to order.

All Couples are thoroughly tested and guaranteed to agree within ± 1°C. with standard calibration curves at any temperature up to 1200°C.

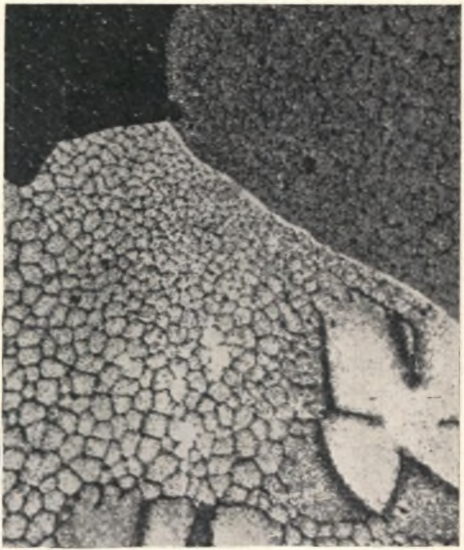
BAKER PLATINUM LIMITED, 52, High Holborn, London, W.C.1.
Chancery 8711.




ROTOTHERM THERMOMETER
200
300
400
500
600
700
800
900
1000
°F
ROTOTHERM
BRIT. PAT. No.

0.250

– the plate for PHOTOMICROGRAPHY



↑ *Cast commercially pure lead, electrolytically polished and etched. X25.*

← *The same, X1000. Photomicrographs made on 'Kodak' 0.250 Plates. (Courtesy of Ford Motor Co. Ltd.).*

'Kodak' 0.250 Metallographic Plate has a fine-grain high-contrast emulsion of high resolving power, especially colour-sensitized for photomicrography and metallography. It has its highest sensitivity in the region of maximum visual sensitivity, where most microscopes yield sharpest focus, and comparatively little speed is therefore lost when working with a green or yellow filter.

0.250 is one of a long line of special-purpose materials produced by Kodak for applied photography. For details write to :

KODAK

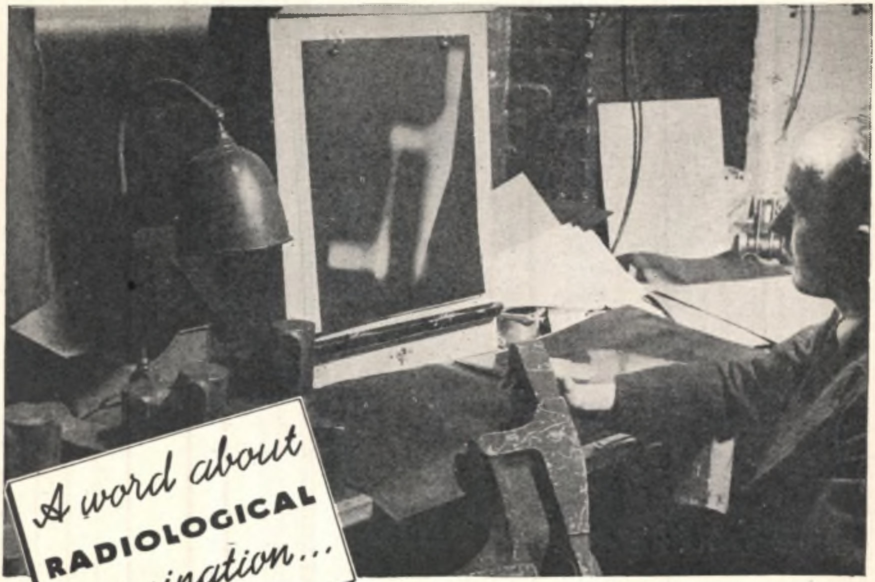
KODAK LIMITED, DEPT. 539, KODAK HOUSE, KINGSWAY, LONDON, W.C.2


Why Hind ?


out of the sea


B-I-R-S-O
TRADE MARK
B&N
NON-FERROUS CASTINGS


COPPER
FOR
COMMUNICATIONS
THOMAS
BOLTON
AND SONS LTD



...and "X-ray quality" castings

The fluorescent method of crack detection, involving the impregnation of the castings with a fluorescent material and their subsequent examination in ultra violet light, constitutes a useful supplement to X-ray inspection. The application of this method to a light alloy casting is shown above.

The radiological examination of castings, originally developed to meet the requirements of the aircraft industry for highly-stressed light alloy components, has long since been established on a routine basis. Our own very completely equipped radiological department has been in operation for more than ten years . . . Other industries have now come to recognise the value of this penetrating supplementary inspection service and, by specifying "X-ray quality", have been able with advantage to extend their use of non-ferrous castings and reap the full advantage of light alloys in their designs . . . Substantial savings can also be made by the radiological examination of castings calling for a considerable amount of machining: hidden faults are discoverable *before* the casting reaches the machine shop—not on the last operation.

J. STONE
& COMPANY LIMITED

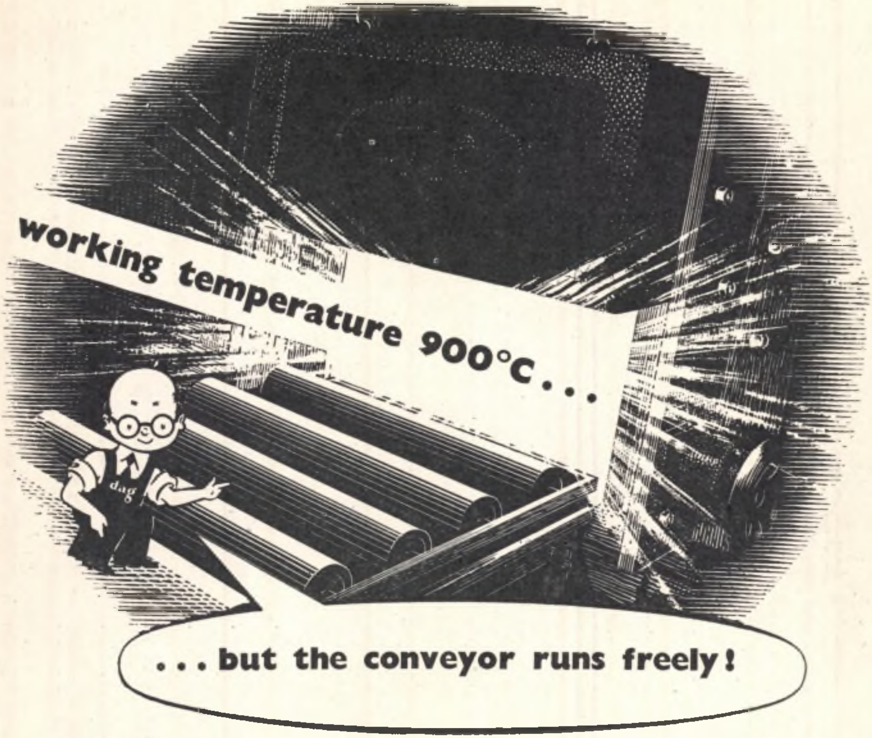
DEPTFORD & CHARLTON. *London Offices :* **OCEANIC HOUSE, 1a COCKSPUR STREET, LONDON, S.W.1**

THE JOURNAL OF THE INSTITUTE OF METALS

SEPTEMBER 1948

Contents

INDEX TO ADVERTISEMENTS


working temperature 900°C . . .
dag
. . . but the conveyor runs freely!

September 1948.

THE INSTITUTE OF METALS

President:
Sir ARTHUR SMOUT, J.P.

Secretary and Editor of Publications:
Lieut.-Colonel S. C. GUILLAN, T.D.

Assistant Editor:
Major W. G. ASKEW, M.C.

Assistant Secretary:
Major R. E. MOORE

Administrative and Editorial Offices:
4 GROSVENOR GARDENS, LONDON, S.W.1

Telephone:
SLOANE 6233

INSTITUTE NEWS AND ANNOUNCEMENTS

LIST OF MEMBERS

A new List of Members, corrected to 1 July 1948 so far as the Institute's records permit, will be distributed to all members, who are requested to use the special forms (bound in the list) for notifying all changes of particulars.

It is the Council's hope that the distribution of this list may enable members very largely to increase the Institute's membership during the current financial year. Most members will find, after studying the list, that they have qualified acquaintances in the fields of science and industry who should support the Institute's work and benefit from its publications and services. Invitations sent to such persons to apply for membership could result in a large accession of strength to the Institute.

Copies of forms of application will be found in many issues of the monthly *Journal*. The Secretary will be glad to supply additional copies on demand. Elections take place frequently.

ELECTION OF ORDINARY MEMBERS AND STUDENT MEMBERS

The following 18 Ordinary Members and 16 Student Members were elected on 16 August 1948:

As Ordinary Members

Baron, Jean Jacques, Directeur des Services Techniques de l'Aluminium Français, 23 bis rue Balzac, Paris 8e, France.

Bhatawadekar, Raghunath Govind, B.A., B.Sc., B.Met., Metallurgist and Chemist, Central Standards Office, Ministry of Railways, New Delhi, India.

Boas, Walter, Dr.-Ing., M.Sc., Principal Research Officer, Division of Tribophysics, Council for Scientific and Industrial Research, University of Melbourne, Victoria, Australia.

Carpenter, Otis R., M.S., Engineer, Babcock and Wilcox Co., Barberton, Ohio, U.S.A.

CHIPPS, Charles Richard, Foundry Manager (Non-Ferrous), 18 Evelyn's Villas, Hillingdon, Middlesex.

DALLAS, Hughes, Vice-President and General Manufacturing Manager, Revere Copper and Brass, Inc., 230 Park Avenue, New York, N.Y., U.S.A.

DREBLOW, E. S., Controller of Production (Hilger Division), Hilger and Watts, Ltd., 97 St. Pancras Way, London, N.W.1.

FELLOWS, John Albert, A.B., M.S., Sc.D., Assistant Chief Metallurgist, American Brake Shoe Co., Mahwah, N.J., U.S.A.

HANSTOCK, Raymond Ford, Ph.D., Chief Physicist, High Duty Alloys, Ltd., Slough, Buckinghamshire.

HARRIS, Herbert Roland, Technical Representative, Shaw and McInnes, Ltd., Beckville, Albion Rd., Chalfont St. Giles, Buckinghamshire.

JACKSON, Frank, Chief Chemist and Technical Manager, Mansons, Ltd., Glasgow.

LOEWY, Erwin, M.E., President, Hydropress, Inc., 570 Lexington Avenue, New York, U.S.A.

RAO, Tanguturi Narasimha, Automobile Engineer, Cincinnati Milling and Grinding Machines, Inc., Cincinnati 9, Ohio, U.S.A.

RIZK, Ahmed Mohammed (Bey), B.Sc., Chief Inspecting Engineer, Egyptian Government, 41 Tothill Street, London, S.W.1.

SARANTIS, John S., B.A., Managing Director, Industrie Hellénique du Cuivre S.A. Resmadjoglou 14, Athens, Greece.

WAINWRIGHT, Hector Aitken, M.Met., B.Eng., Director, Birmetals, Ltd., Birmingham 32.

WASILEWSKI, Roman Jerzy, B.A., Metallurgist, Murex, Ltd., Rainham, Essex.

WILKINSON, John, Director and Chief Metallurgist, The Yorkshire Copper Works, Ltd., Leeds.

As Student Members

ACKROYD, Dennis, Metallurgist, David Brown and Sons (Huddersfield), Ltd., Park Works, Lockwood, Huddersfield, Yorkshire.

AINSWORTH, Patrick Arthur, Student of Metallurgy, Sheffield University.

BURKE, James, Student of Metallurgy, University of Liverpool.

CATTERALL, John Ashley, Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

DEMAIN, William, Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

DUNMORE, Owen J., Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

ENTWISLE, Anthony Roger, B.A., Student of Metallurgy, Cambridge University.

EVANS, David John Ivor, Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

FARMERY, Harold Keith, Student of Metallurgy, Cambridge University.

GRASSAM, Bryan William, B.A., Student, Cambridge University.

HUGHES, James Ernest, Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

KILLINGTON, Albert James, Student of Metallurgy, Royal School of Mines, South Kensington, London, S.W.7.

Littlewood, Geoffrey, Metallurgist, David Brown and Sons (Huddersfield), Ltd., Park Works, Lockwood, Huddersfield, Yorkshire.

Porter, Frank Cecil, B.A., Student of Metallurgy, Cambridge University.

Slate, Paul Martin Biers, Student of Metallurgy, Sheffield University.

Young, Kenneth Owen, Junior Metallurgist, David Brown and Sons (Huddersfield), Ltd., Park Works, Lockwood, Huddersfield, Yorkshire.

PERSONAL NOTES

Professor Leslie Aitchison, D.Met., M.Sc., has been seriously ill and had an urgent operation.

Dr. H. J. Axon, B.Met., has become engaged to be married to Miss Elisabeth Ellis.

Mr. F. M. Davis, L.I.M., has joined the staff of Messrs. Swan, Hunter and Wigham Richardson, Ltd., Wallsend, as a Metallurgical Chemist.

Mr. A. Duckworth, B.Sc., has been appointed a Technical Officer (Metallurgist) in the Engineering Department of the Dyestuffs Division, Imperial Chemical Industries, Ltd., Manchester 9.

Mr. S. K. Ghaswala, B.E., has been admitted to the membership of the following institutions : Institution of Engineers (India) (Associate Member) ; Société des Ingénieurs Civils de France (Member) ; International Association for Bridge and Structural Engineering (Zürich) (Member) ; International Association for Hydraulic Structures Research (Stockholm) (Member) ; and the British Interplanetary Society (Fellow). He has also been appointed a reviewer for *Applied Mechanics Reviews*.

Dr. F. R. Morral, B.S., has been appointed Associate Professor of Materials Engineering at the College of Applied Science, Syracuse University, Syracuse, N.Y., U.S.A. For the past four years he has been Group Leader of the Metal Trades Laboratory of the Technical Service and Development Division, American Cyanamid Co., Stamford, Conn.

Mr. M. C. Nickson was recently awarded the M.Sc. degree of London University.

Mr. W. D. Robertson was awarded the degree of Doctor of Science of the Massachusetts Institute of Technology in June. He has since taken up a post on the staff of the Institute for the Study of Metals, at the University of Chicago, where he will study various aspects of surface chemistry pertaining to the corrosion of metals.

Dr. H. McK. Skelly, B.Sc., is now engaged on metallurgical work in the research laboratories of the Aluminum Company of Canada, Ltd., Kingston, Ont. His private address is 145 Colborne St., Kingston, Ont., Canada.

Mr. O. Thomas recently left the Imperial Smelting Corporation, Ltd., to take up an appointment as Assistant Manager with Treharne and Davies, Ltd., Analysts and Chemical Consultants, at their Swansea branch. His new private address is 2 Bath Rd., Morriston, Swansea, Glam.

Mr. A. W. Town has left Cambridge University after having obtained First Class Honours in Metallurgy (Part II), and has been appointed to a post in the steel melting shop of Messrs. Hadfields, Ltd., Sheffield.

Mr. D. W. Wakeman, B.Sc., has been awarded the degree o Ph.D. of Birmingham University.

Mr. B. C. Woodfine has been awarded the degree of B.Met. (Ferrous) with First Class Honours of Sheffield University, and, subsequently, the Robert Styring Postgraduate Research Scholarship in the University of Sheffield and also a D.S.I.R. grant to carry out two years' postgraduate research at the University.

DEATH

The Editor regrets to announce the death, in Edinburgh on 14 August 1948, of **Dr. William Cullen**, who was elected a member of the Institute in 1929.

Note : Will members (in addition to informing the Institute's administrative departments of changes of address, occupation, &c.) kindly notify the Editor, separately, of all changes of occupation, appointments, awards of honours and degrees, &c., as these matters interest their fellow members. Such notes should reach the Editor not later than the 21st day of each month, for publication in the next month's issue of the *Journal.*

LOCAL SECTIONS NEWS

SESSION 1948–1949

Members are reminded that (free) membership of the Local Sections—Birmingham, London, Scottish, Sheffield, and South Wales—and the right of attendance at all meetings of the two Associated Societies—the Leeds Metallurgical Society and the Manchester Metallurgical Society—is a privilege of membership, but that, *at the commencement of each session*, it is necessary to notify the Honorary Secretary of the section or society that membership and the right of attendance are claimed.

The names and addresses of the Honorary Secretaries are :

Birmingham : Mr. E. H. Bucknall, M.Sc., F.I.M., 53 Halesowen Rd., Quinton, Birmingham 32.

London : Dr. E. C. Rhodes, F.I.M., Development and Research Department, The Mond Nickel Co., Ltd., Bashley Rd., London, N.W.10.

Scottish : Mr. Matthew Hay, Craigton Industrial Estate, Barfillan Drive, Glasgow, S.W.2.

Sheffield : Dr. W. R. Maddocks, B.Sc., Department of Applied Science, The University, Sheffield 1.

South Wales : Mr. K. M. Spring, 36 Beechwood Rd., Uplands, Swansea, Glam.

Leeds Metallurgical Society : Mr. W. J. G. Cosgrave, 24 Wellhouse Rd., Leeds 8.

Manchester Metallurgical Society : Mr. J. A. Tod, B.Sc., F.I.M., Imperial Chemical Industries, Ltd., Metals Division, Broughton Copper Works, Manchester.

Programmes of the Local Sections and of the Associated Societies are in course of completion, and will be distributed to members in the form of a folding card.

OTHER NEWS

JOINT COMMITTEE ON METALLURGICAL EDUCATION

Report on Progress for the period from 1st January 1947 to 30th June 1948

Nine meetings of the Committee were held during the period under review, including a Special Meeting held on 7 May 1948, to enable members to meet and interchange views with Dr. Robert F. Mehl of the Carnegie Institute of Technology, Pittsburgh, Chairman of the Advisory Committee on Metallurgical Education of the American Society for Metals.

The following is a list of members as at 30 June 1948, representing industry, the Iron and Steel Institute, the Institution of Mining and Metallurgy, the Institute of British Foundrymen, the Institute of Metals, the Institution of Metallurgists, Universities, the City and Guilds of London Institute, the Association of Technical Institutes, and the Association of Principals of Technical Institutes :

Professor Leslie Aitchison, D.Met., M.Sc. (*Chairman*).
Professor G. Wesley Austin, O.B.E., M.A., M.Sc.
Mr. G. L. Bailey, M.Sc.
Professor C. W. Dannatt, A.R.S.M., D.I.C.
Dr. C. H. Desch, F.R.S.
Mr. J. W. Gardom.
Dr. E. Gregory, M.Sc., Assoc.Met.
Mr. R. A. Hacking, O.B.E.
Dr. J. E. Hurst, J.P.
Mr. J. Sinclair Kerr.
Mr. E. J. Lawford.
Mr. E. D. McDermott.
Mr. W. A. C. Newman, O.B.E., B.Sc., A.R.S.M., A.R.C.S.
Mr. G. Patchin.
Dr. L. B. Pfeil, O.B.E., A.R.S.M.
Sir Arthur Smout, J.P.
Mr. R. B. Templeton.
Mr. D. R. O. Thomas.
Professor F. C. Thompson, D.Met., M.Sc.
Dr. A. M. Ward.
Mr. J. Wilson.

Dr. C. H. Desch, while continuing his membership of the Committee, resigned the Chairmanship on 3 June 1947, and Professor Leslie Aitchison was appointed Chairman from that date.

During 1947 the Committee continued to give assistance to parents and students seeking information about facilities for metallurgical education, to compile information on metallurgical films, and to arrange for their loan to colleges, schools, local societies, and works.

A second and revised edition of the brochure " Metallurgy—A Scientific Career in Industry " has been prepared and was published in May 1948; it contains the latest available information about courses in metallurgy at Universities and Technical Colleges. Copies have been sent, among others, to all Local Education Authorities, the Principals of Technical Colleges, and Headmasters of Secondary Technical Schools. Over 6000 copies of this brochure have been distributed.

The work of the Committee includes:

(1) Consideration of the general requirements for providing education for metallurgists of all grades.

(2) Assisting in every way possible in the provision of the means by which these requirements can be secured at the different levels.

(3) Making known throughout the Secondary and Public Schools the opportunity offered by metallurgy as a career.

(4) Providing parents, guardians, careers masters, and others with full details of the educational facilities available to fit boys for various careers in metallurgy.

(5) Keeping continuous touch with industry in order to ascertain in what respects the young metallurgist is considered to fall short of the appropriate standard when he enters the metallurgical industry with: (*a*) a University degree; (*b*) a National Certificate in Metallurgy or qualification of a similar standard; (*c*) other qualifications from a Technical School or College. Ascertaining how far his falling short of the highest standard can be laid at the door of metallurgical education and taking such remedial steps as may be possible.

(6) Taking appropriate steps for carrying its policy into effect, including: (*a*) discussions and meetings with the interested people in industry, schools, technical colleges, universities, and Government departments, in order that views may be exchanged. (*b*) The preparation of memoranda addressed to the various bodies which may be concerned and the publication of the Committee's views and suggestions.

(7) The consideration of special matters of an important nature, such as entrance qualifications to University Schools of Metallurgy. A pamphlet giving the Committee's " Recommendations on Qualifications for Entrance to University Schools of Metallurgy " was published in April 1948 and widely circulated to the various interested bodies, and the recommendations have been published in the Press and in the Journals of the participating Institutes.

NEWS AND ANNOUNCEMENTS

INTER-SERVICE METALLURGICAL RESEARCH COUNCIL

The Admiralty and Ministry of Supply have set up an Inter-Service Metallurgical Research Council to advise them on metallurgical problems of importance to the Services. It will provide for the interchange of ideas on common metallurgical problems and avoid overlap between research programmes, and should also ensure that balance is maintained between fundamental and *ad hoc* research, and that the long-term research necessary for the provision of new alloys is embarked upon.

The Research Council includes representatives of the Admiralty and Ministry of Supply, and a number of distinguished metallurgists from the universities, industry, and other Governmental departments. The independent members are: Professor L. Aitchison, Professor of Industrial Metallurgy, University of Birmingham (Chairman); Professor E. N. da C. Andrade, Quain Professor of Physics, University College, London; Professor G. Wesley Austin, Goldsmiths' Professor of Metallurgy, Cambridge University; Mr. G. L. Bailey, Director, British Non-Ferrous Metals Research Association; Dr. R. W. Bailey, Research Consultant, Metropolitan-Vickers Electrical Co., Ltd.; Mr. H. H. Burton, Director of Research, English Steel Corporation, Ltd.; Dr. W. Hume-Rothery, Lecturer in Chemistry, Oxford University; Dr. H. Moore; Mr. A. J. Murphy, Research Director, J. Stone & Co., Ltd.; Mr. D. A. Oliver, Director of Research, B.S.A. Group; Dr. C. J. Smithells, Director of Research, The British Aluminium Co., Ltd.; Dr. C. Sykes, Director of Research, Firth–Brown Research Laboratories; Dr. W. H. J. Vernon, Chemical Research Laboratory, Teddington. The Secretary is Mr. A. H. Waterfield of the Ministry of Supply.

LIVERPOOL METALLURGICAL SOCIETY

The Society has published a very interesting programme for its first session, which commences on Thursday, 7 October 1948, when Professor J. H. Andrew, D.Sc., F.I.M., will lecture on "New Lamps for Old". The meeting will be held in the rooms of the Liverpool Engineering Society, 9 The Temple, 24 Dale St., Liverpool, at 7 p.m. A hearty invitation to attend this meeting is extended by the Society to all members of the Institute of Metals who can attend. Professor Andrew will present, in terms acceptable to an audience including chemists and engineers, some of the new concepts in metallurgy which are leading to fresh developments in this field.

Particulars of the Society may be obtained from the Honorary Secretary, Mr. C. W. J. Gellatley, 7 Woolacombe Road, Liverpool 16.

CONFERENCE ON THE FILM IN SCIENTIFIC RESEARCH

The Sciences Committee of the Scientific Film Association has arranged a one-day Conference on "The Film in Scientific Research", to be held on Tuesday, 12 October 1948, at The Royal Institution, London. The Chair will be taken by Mr. J. E. Cummins, Chief Scientific Liaison Officer in London of the Australian Government, and the Conference will be opened by Sir Robert Watson-Watt, C.B., F.R.S.

The business of the Conference will be:

(i) Discussion by British and Foreign scientists as to the value of scientific films as a research tool in various branches of science: astronomy, biology, chemistry, physics, &c., during which suitable examples will be shown.

(ii) Discussion as to the function which the research film can play in giving up-to-date information to scientists working in a particular field.

(iii) Scientific films as an aid to the training of scientists.

(iv) Scientific films as a medium for explaining to the general public important results of scientific research.

(v) The technical aspects of the use of films in scientific research.

It is hoped that there will be time for a general discussion, when any points not previously mentioned can be raised. The Conference will conclude with a two-hour showing of British and foreign research films.

Material suggested for discussion and any information as to the existence or availability of any research films suitable for showing at the Conference, should be sent to the Hon. Secretary, Sciences Committee, Scientific Film Association, 34 Soho Square, London, W.1, as soon as possible; tickets and further information regarding the Conference can be obtained from the same address.

POLISH ENGINEERING SOCIETY

The Stowarzyszenie Techników Polskich w Wielkiej Brytanii (Association of Polish Engineers in Great Britain) has changed its Bye-laws to conform to the Companies Acts, 1929 and 1947, and has been incorporated as the "Institution of Polish Engineers in Great Britain".

The new Institution will conform to the pattern of similar British institutions. It has more than 600 members, who are divided into various professional "sections". The headquarters of the Society is at 146 Holland Road, London, W.14.

AUSTRALIAN JOURNAL OF SCIENTIFIC RESEARCH

The Council for Scientific and Industrial Research, in collaboration with the Australian National Research Council, has decided to take responsibility for the establishment in Australia of a new scientific journal, the *Australian Journal of Scientific Research*, as a medium for the publication of research papers of outstanding merit. This journal is open to receive contributions from research workers, irrespective of country or of the organization to which they are attached.

Dr. N. S. Noble has been appointed as Editor of the new journal. Editorial policy will be determined by an Editorial Board under the chairmanship of the Editor and comprising as members: Professor W. J. Dakin (Department of Zoology, University of Sydney), Professor E. J. Hartung (Department of Chemistry, University of Melbourne), Professor L. H. Martin (Department of Physics, University of Melbourne), and Professor J. G. Wood (Department of Botany, University of Adelaide). The Board aims to achieve a high standard of quality in papers accepted, and a strict refereeing system has been instituted.

The journal will be printed in two series: Series A (Physical Sciences) and Series B (Biological Sciences). Initially, each series will be issued quarterly and will cost 30*s.* per annum.

THE DESIGN AND OPERATION OF FUEL-FIRED FURNACES, WITH SPECIAL REFERENCE TO RECENT DEVELOPMENTS

A course of 20 lectures on this subject will be delivered in the Department of Applied Chemistry (Head: Dr. J. E. Garside), Northampton Polytechnic, St. John St., London, E.C.1, on Tuesday evenings at 7 p.m., commencing on 5 October 1948. The fee for the course is 21*s.*; admission to the course is effected by personal enrolment at the office of the Polytechnic on any weekday between 10 a.m. and 7 p.m.

TECHNOLOGY OF REFRACTORY MATERIALS

A course of ten lectures on this subject by Mr. L. R. Barrett, B.A., B.Sc., M.S., will be delivered in the Department of Applied Chemistry (Head: Dr. J. E. Garside), Northampton Polytechnic, St. John St., London, E.C.1, on Wednesday evenings at 7 p.m., commencing on 6 October 1948. The fee for the course is 12*s.* 6*d.*; admission to the course is by personal enrolment at the office of the Polytechnic on any weekday between 10 a.m. and 7 p.m.

DIARY FOR OCTOBER

LOCAL SECTIONS MEETINGS

Birmingham Local Section.—Open discussion on Controlled Atmospheres; opening speakers, Mr. P. F. Hancock, B.A., F.I.M., and Mr. W. B. Morrison, F.I.M. (Sir James Watt Memorial Institute, Great Charles St., Birmingham, Thursday, 7 October, at 6.30 p.m.)

London Local Section.—Chairman's lecture, by Mr. W. F. Randall, B.Sc., A.R.S.M., M.I.E.E., F.I.M.: "Alloys of Special Physical Characteristics Used for Instrument Manufacture". (4 Grosvenor Gardens, London, S.W.1, Thursday, 7 October, at 7 p.m.)

Scottish.—Mr. D. S. Burwood: "Technique of Extraction Processes". (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C2, Monday, 11 October, at 6.30 p.m.)

South Wales.—Chairman's Address, by Mr. D. W. Hopkins, B.Sc. (Royal Institution, Victoria Rd., Swansea, Tuesday, 12 October, at 6.30 p.m.)

NEWS AND ANNOUNCEMENTS

OTHER MEETINGS

THURSDAY, 7 OCTOBER

Leeds Metallurgical Society.—Mr. G. A. Jones: "High-Speed Photography". (Chemistry Department, The University, Leeds, at 7.30 p.m.)

Liverpool Metallurgical Society.—Professor J. H. Andrew: "New Lamps for Old". (Rooms of Liverpool Engineering Society, 9 The Temple, 24 Dale St., Liverpool, at 7 p.m.)

TUESDAY, 12 OCTOBER

Egypt Exploration Society.—Professor V. G. Childe: "Metallurgy in the Ancient East". (4 Chesterfield Gardens, London, W.1, at 8 p.m.)

Institution of Mechanical Engineers, Automobile Division.—Annual General Meeting; Induction of New Chairman; Chairman's Address. (The Institution, Storey's Gate, London, S.W.1, at 6 p.m.)

WEDNESDAY, 20 OCTOBER

Manchester Metallurgical Society.—Presidential Address by Mr. A. H. Goodger, M.Sc., A.R.I.C. (Engineers' Club, Albert Sq., Manchester, at 6.30 p.m.)

APPOINTMENTS VACANT

To conform to the requirements of the Control of Engagements Order, 1947, these advertisements are published for the information only of those who are "excepted persons" under the Order.

CHIEF INSPECTOR, to take charge of existing inspection organization. Knowledge of aluminium alloys, brass, and copper essential, and experience of A.I.D. methods and procedure preferred. Write fully to Secretary, James Booth & Company, Limited, Argyle Street, Birmingham 7.

METALLURGIST, or Mineralogist, required for laboratory controlling and developing manufacturing process using metals (mainly non-ferrous) and minerals. The works are on the N.E. Coast. A university degree in metallurgy or natural science is essential, and some experience of scientific control or research in industry is desirable. Age 25–35. Write giving details of training, experience, and salary to Box No. 241, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

TECHNICAL MANAGER required for important zinc oxide factory in the Midlands. Necessary qualifications include preferably actual experience of this manufacture, or suitable academic qualifications together with considerable metallurgical smelting works experience. Manager would also be required to have or acquire, full knowledge of technique of paint and rubber applications of oxide and be able to organize the necessary research into these aspects. This is not an advertisement for a laboratory man, but for a very experienced metallurgist or metallurgical engineer of the highest grade who can hold a highly responsible senior managerial position, and for whom the post is consequently one carrying an exceptional remuneration. Fullest typed details please to Box No. 242, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

THE CIVIL SERVICE COMMISSIONERS invite applications for a permanent post as PRINCIPAL SCIENTIFIC OFFICER or SENIOR SCIENTIFIC OFFICER in the Ministry of Supply Headquarters in London. Candidates must have been born on or before 1 August 1917, and must possess a First or Second Class Honours degree in Metallurgy. Experience in the metallography of light alloys is required. Inclusive salary scales: Principal Scientific Officer, £900–£1220 (men); Senior Scientific Officer, £650–£850 (men); rates for women are somewhat lower. Further particulars and application forms from the Secretary, Civil Service Commission, Scientific Branch, 27 Grosvenor Square, London, W.1, quoting No. 2279. Completed application forms must be returned by 8 October 1948.

YOUNG METALLURGIST with degree, preferably with some knowledge and experience of welding, required for development work on welding of light alloys in North-West Area. Knowledge of chemistry up to Pass Degree standard desirable. Position requires initiative and ability. Apply stating age, qualifications, and experience to Box H.4489, W. H. Smith & Son, Ltd., Manchester 3.

W. A. NEWARK

2, CLERKENWELL GREEN
LONDON, - - E.C.1.

Will bind Members' Monthly Journals and Metallurgical Abstracts in Binding Cases supplied free on application to the Institute. Please send issues and cases direct to W. A. Newark.

PRICE : 4*s.* 9*d.* per volume ; 9*s.* 6*d.* per two annual volumes, inclusive of postage to members' addresses.

AN INTRODUCTION TO THE
ELECTRON THEORY OF METALS

by G. V. RAYNOR, M.A., D.Phil.

Research Fellow in Theoretical Metallurgy, Birmingham University

Bound in cloth. 98 pages, with 62 figs.

7s. 6d. post free. (3s. 9d. post free to members)

Specially commissioned by the Institute of Metals, this book has been written for the older metallurgist whose knowledge of pure physics is insufficient to enable him to come readily to terms with the modern theoretical work on the metallic state. ● The author deals with the new approach to metallurgy, some basic principles of atomic theory, the Bohr theory of the atom, the probability conceptions, application to metals, the effect of crystal structure, application to alloy structures, approximations involved in the results of the electron theories, insulators and conductors, magnetic properties of metals and alloys, and the cohesion of metals.

This is a book which should be read by every metallurgist.

INSTITUTE OF METALS
4 GROSVENOR GARDENS, LONDON, S.W.1.

THE STRUCTURE OF METALS AND ALLOYS

By WILLIAM HUME-ROTHERY, M.A., D.SC., F.R.S.

Fifth (revised) Reprint

Cloth. Pp. 137 with 61 Figures
Price: 4s. 6d., post free (members 2s. 3d., post free)

CONTENTS: The Electronic Background to Metallurgy: The Structure of the Atom; The Structure of the Molecule; The Structure of the Crystal. The Crystal Structure of the Elements. The Atomic Radii of the Elements. Primary Metallic Solid Solutions: The Conception of Atomic Size Factor; The Electronegative Valency Effects; The Form of Liquidus Curves; The Form of Solidus Curves; The Form of Primary Solid Solubility Curves; Superlattice Structures. Intermediate Phases in Alloy Systems: Normal Valency Compounds: Electron Compounds and the Electron Concentration Rule; Interstitial and Other Structures Determined by the Size Factor. Imperfections in Crystals and Deviations from the Ideal Lattice. Index.

Press Opinions of Previous Editions

Journal of the Franklin Institute: " . . . one is impressed with the masterly co-ordination of the text with the illustrations, their arrangement and structure. The book can benefit a large number of scientific men of widely diversified interests."

Nature: " . . . a really authoritative account of pioneer work which may well indicate an entirely new era in fundamental, theoretical metallurgy."

Chemistry and Industry: "We consider the book an admirable one for its purpose."

THE INSTITUTE OF METALS
4 Grosvenor Gardens, London, S.W.I.

THE WORKING BEHAVIOUR OF PHOSPHORUS-DEOXIDIZED COPPERS CONTAINING BISMUTH.*

By A. P. C. HALLOWES,† B.Sc., A.I.M., Member.

(Communication from the British Non-Ferrous Metals Research Association.)

Synopsis.

The paper describes a study of the hot and cold working behaviour of bismuth-bearing phosphorus-deoxidized coppers. Non-arsenical coppers containing up to 0·1% bismuth were rolled in laboratory trials, and arsenical and non-arsenical coppers containing up to 0·01% bismuth were fabricated into tubes and strips on a works scale.

An earlier study of the mechanism of bismuth embrittlement of deoxidized coppers indicated that bismuth contents higher than those usually tolerable would not introduce fabricating difficulties if the temperature of hot working, or of annealing prior to cold work, was substantially increased and if intermediate annealing was followed by quenching.

Accordingly, two working schedules were adopted in the works trials, one being representative of the normal practice of the works concerned and the other modified as indicated above. It is shown that the modified schedule permits satisfactory working with bismuth contents considerably higher than would otherwise be permissible, and practical recommendations are made indicating the heat-treatment necessary to avoid embrittlement with deoxidized coppers of various bismuth contents. The bismuth limits are also dependent, in lesser degree, on the severity of the working operations involved.

Laboratory tests on the semi-fabricated coppers illustrate the re-embrittling effect of subsequent heat-treatment or hot working at temperatures lower than those required to retain the bismuth in a harmless condition.

I.—Introduction.

A paper on the theoretical aspect of the Association's research into the bismuth embrittlement of phosphorus-deoxidized copper has already been published.[1] The present account describes a study of the working behaviour of bismuth-bearing phosphorus-deoxidized coppers and confirms that higher bismuth contents can be tolerated if the working schedule is modified in the light of the research on the mechanism of embrittlement.

An account of some small-scale laboratory rolling trials of deoxidized non-arsenical coppers containing up to 0·1% bismuth is given in Section III. Section IV describes industrial-scale trials of the manufacture

---

* Manuscript received 26 January 1948.

† Investigator, British Non-Ferrous Metals Research Association, London.

of tubes and strips from deoxidized arsenical and non-arsenical coppers containing up to 0·01% bismuth. In these trials, hot-working temperatures and intermediate annealing temperatures, followed by quenching, were (*a*) similar to the normal practice of the works concerned, and (*b*) increased, to minimize bismuth embrittlement.

Section V describes laboratory tests designed to reveal any embrittlement in the semi-finished products and to demonstrate the harmful effect of subsequent hot working at unduly low temperatures or cold working after annealing at similar temperatures.

Further experiments, described in Section VI, illustrate the effect of some variables involved in annealing procedure which are not adequately covered in Sections III–V.

The paper concludes with a brief summary and some practical recommendations for the successful working of deoxidized bismuth-bearing coppers.

II.—PREVIOUS WORK.

Following earlier work by Blazey[2, 3, 4] and by Archbutt and Prytherch,[5] it was shown by Voce and Hallowes[1] that coppers nominally free from oxygen but containing about 0·002% or more of bismuth were brittle in the temperature range between 400° and 700° C. and at room temperature after annealing in this range. The severity of the brittleness and the range of temperature over which it extended increased with the bismuth content. Slow cooling from annealing temperatures above 700° C. developed brittleness which did not occur if the material was rapidly cooled, and, finally, the annealing temperature above 700° C. at which the brittleness disappeared rose with increase of bismuth content. It was concluded that the solid solubility of bismuth in deoxidized coppers increased with temperature and that serious embrittlement did not occur in either hot or cold working if the procedure were such that most of the bismuth remained in solid solution.

The practical implications of this work are that the permissible bismuth content of deoxidized copper is dependent on: (*a*) the hot-working temperature or, in cold working, the temperature of prior annealing and the rate of cooling after heat-treatment, (*b*) the severity of the working operation to which the material is to be subjected, (*c*) the grain-size of the copper, and (*d*) the presence of minor constituents which may affect the amount of free bismuth available for embrittlement.

In the works trials on deoxidized fire-refined coppers containing bismuth, selenium, and tellurium, already described,[6] it was not possible to assess the individual influence of each element. Attempts to correlate hot-working behaviour with high-temperature tensile, notched-bar, and bend tests were inconclusive, but cold-working behaviour could be correlated with the results of room-temperature tests.

Cook and Parker [7] studied the effects of bismuth, selenium, and tellurium, added separately and together to cathode copper, and found that bismuth contents up to 0·0035 and 0·0065% (the maximum contents used) in phosphorus-deoxidized non-arsenical and arsenical coppers respectively, had no adverse effects on their hot- and cold-working properties during tube manufacture. Failures occurred in the laboratory when specimens cut from the tubes containing approximately 0·003% bismuth or more were bent at 600° C., and marked reductions occurred at room temperature in the tensile strength and elongation of similar specimens from the arsenical tubes with bismuth contents of 0·005% or more.

III.—LABORATORY ROLLING TRIALS.

15-lb. charges of O.R.C. cathode copper were melted under charcoal, deoxidized with phosphor-copper to leave a residual phosphorus content of about 0·04%, and cast into strip ingots, 9 × 4·5 × 1 in. Bismuth metal, in amounts up to 0·1%, was added to the melt before pouring. The bismuth and phosphorus contents of the coppers are shown in Tables I and II.

Each casting was cut into four pieces, two for cold and hot rolling respectively in the as-cast condition, and two for cold rolling after soaking for 1 hr. at 900° C. in an atmosphere of nitrogen, followed by quenching of one and slow cooling of the other. The rolling schedules are also given in Tables I and II, together with the results obtained. The ingots were rolled in one direction only, with no intermediate annealing.

The cold-rolling schedule was completed on all the coppers containing up to about 0·03% bismuth, in spite of some cracking of as-cast material, and heat-treatment prior to rolling had little effect. Edge cracking occurred in some cases with 0·015% bismuth and over, but even the material of highest bismuth content (0·10%) was cold rolled both in the "as-cast" and "quenched from 900° C." conditions, though the strip obtained was badly frayed at the edges.

Hot rolling, commencing at 900° C. and with reheating to temperature between successive passes, gave satisfactory results down to 56% reduction with all bismuth contents up to 0·03%, but the coppers containing 0·05, 0·07, and 0·10% bismuth cracked. Further rolling at lower temperatures indicated brittleness in the region of 450°–550° C.

TABLE I.—*Cold-Rolling Trials in the Laboratory.*

Rolling Schedule : The following passes were used without any intermediate annealing, but with occasional cooling off when specimens became hot. All the specimens were rolled to strip in one direction only.

Although cracking occurred in a number of cases, the rolling schedule was completed except where otherwise stated.

Pass No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Thickness, mm.	22	19·4	17·0	14·6	12·8	11·3	9·6	8·1	6·8	5·4	4·3	3·1	2·3	1·6	1·2	0·8
Reduction, %	0	7	23	34	42	49	56	63	67	76	81	86	90	93	95	97

Mark.	Bi, %.	P, %.	Cold Rolling as Cast.	Cold Rolling After 1 hr. at 900° C. and Quenching in Water.	Cold Rolling After 1 hr. at 900° C. and Slowly Cooling in the Furnace.
JXH1 *	0·00002	0·038	Satisfactory.	Satisfactory.	Satisfactory.
JXH2	0·0023	0·040	„	„	„
JXH9	0·0036	0·037	„	„	„
JXH3	0·0054	0·040	„	„	„
JXH4	0·015	0·039	Slight cracking at 5th pass.	„	„
JXH5	0·031	0·040	Cracking commenced at 2nd pass.	„	Satisfactory. Very slight cracking at 3rd pass.
JXH7	0·057	0·039	Slight edge cracking.	Cracks developed at 1st pass.	Satisfactory. Very slight cracking at 1st and 2nd passes.
JXH8	0·073	0·043	Slight edge cracking.	Serious cracking at 1st pass. Rolling discontinued.†	Slight cracks at 1st pass.
JXH6	0·10	0·040	Cracked at 1st pass.	Cracked at 1st pass. Very poor strip.	Cracked badly at 3rd pass. Rolling discontinued after 4th pass.

* No bismuth addition.

† Cracking comparable with that in the 0·10%-bismuth alloy.

TABLE II.—*Hot-Rolling Trials in the Laboratory.*

Rolling Schedule: Specimens reheated to the stated temperatures in an atmosphere of nitrogen between each pass and rolled in one direction only. Thus, each strip was rolled to 56% reduction at 900° C., and for each subsequent pass the temperature was lowered progressively.

Pass No.			0	1	2	3	4	5	6	7	8	9	10	11	12
Thickness, mm.			22	19·4	17·0	14·6	12·8	11·3	9·6	8·1	6·8	5·4	4·3	3·1	2·3
Reduction, %			0	7	23	34	42	49	56	63	67	76	81	86	90
Mark.	Bi, %.	P, %.	900° C.							680° C.	650° C.	550° C.	500° C.	Not Reheated (below 500° C.).	
JXH1*	0·00002	0·038	Satisfactory.							Sat'f'y.	Sat'f'y.	Sat'f'y.	Sat'f'y.	Sat'f'y.	Sat'f'y.
JXH2	0·0023	0·040	,,							,,	,,	,,	,,	,,	,,
JXH9	0·0036	0·037	,,							...	...	...	...	...	...
JXH3	0·0054	0·040	,,							Sat'f'y.	Sat'f'y.	Sat'f'y.	Sat'f'y.	Split.	...
JXH4	0·015	0·039	,,							,,	,,	,,	Split.	...	...
JXH5	0·031	0·040	,,							,,	,,	Split.	...	...	...
JXH7	0·057	0·039	Cracked at 1st pass and eliminated at 2nd pass.							...	...	...	...	...	...
JXH8	0·073	0·043	,, ,, ,, ,,							...	...	...	...	...	...
JXH6	0·10	0·040	Cracked badly at 1st pass, eliminated.							...	...	...	...	...	...

* No bismuth addition.

in the coppers containing between 0·005 and 0·03% bismuth, as shown in Table II.

IV.—MANUFACTURING-SCALE TRIALS.

1. *Preparation of Materials.*

300-lb. charges of O.R.C. copper electro-ingots were melted under charcoal in salamander pots in a coke-fired, forced-draught Morgan tilting furnace and deoxidized with phosphor-copper before addition of the bismuth. In the arsenical series, arsenic was introduced as the element before the bismuth.

A billet, 5 ft. long × 3 in. dia., and a vertically cast cake, 28 × 7·5 × 3 in., were poured from each charge, using salamander tundishes, and moulds dressed with a fluid mixture of vaseline and china clay. Approximately 12 in. was cropped from each end of the billet and 6 in. from the head of the cake.

Twelve melts were prepared with bismuth contents from nil to 0·01% in each of the arsenical and non-arsenical series. The residual phosphorus content, with occasional exceptions in the non-arsenical series, was between 0·03 and 0·05%, and arsenic, when present, lay between 0·3 and 0·4%. Analyses of the remelted electro-ingots, made without bismuth additions, are given in Table III, and the analyses of the billets are included in Table IV; the billet analysis is in each case

TABLE III.—*Spectrographic Analyses of Castings Without Added Bismuth.*

Element, %.	*Non-Arsenical.* Marks: KAV70 (billet) and KAV71 (strip).	*Arsenical.* Marks: KAV120 (billet) and KAV121 (strip).
Antimony	0·0002	0·001
Arsenic	0·002	0·36 *
Bismuth	0·00005 *	0·0001 *
Cobalt	n.d. (<0·0001)	n.d. (<0·0001)
Iron	0·01	0·001
Lead	0·001	0·0004
Phosphorus	0·046 *	0·040 *
Silicon	n.d. (<0·008)	n.d. (<0·008)
Manganese	0·005	0·001
Nickel	0·0006	0·0006
Silver	0·004	0·004
Tin	0·0005	0·0005
Zinc	n.d. (<0·001)	n.d. (<0·001)
Tellurium	n.d. (<0·004)	n.d. (<0·004)

* Chemical determination.
n.d. = not detected; the limit of detection is indicated in brackets.

TABLE IV.—*Drawing Behaviour of Phosphorus-Deoxidized Copper Tubes Containing Bismuth.*

The Table records significant cracking and failures.

Mark.	Composition, %.			Intermediately Annealed at 650° C. During Manufacture.	Intermediately Annealed at 750° C. During Manufacture.
	Bi	P	As		
				Non-Arsenical.	
KAV 70*	0·00005	0·046	...	Satisfactory at all stages.	Satisfactory at all stages.
KAV 94	0·0005	0·040	...		
KAV 74	0·0011	0·048	...		
KAV 76	0·0015	0·046	...		
KAV 78	0·0020	0·038	...		
KAV108	0·0026	0·032	...		
KAV 82	0·0030	0·045	...		
KAV106	0·0035	0·042	...		
KAV 88	0·0040	0·026	...		
KAV 90	0·0051	0·039	...		
KAV 92	0·0060	0·040	...	Both tubes cracked on 2nd shoulder and broke up in following draw. Discarded.	
KAV104	0·0075	0·043	...		
KAV102	0·010	0·035	...		One of 2 tubes cracked on 2nd tag, but drawn satisfactorily.
				Arsenical.	
KAV120	0·0001	0·040	0·36	Satisfactory at all stages.	Satisfactory at all stages.
KAV118	0·0006	0·049	0·36		
KAV116	0·0011	0·047	0·31		
KAV114	0·0016	0·048	0·35		
KAV112	0·0022	0·040	0·35		
KAV122	0·0027	0·043	0·36		
KAV124	0·0031	0·049	0·34	1 of 2 tubes cracked on 1st tag, but drawn satisfactorily.	
KAV126	0·0035	0·043	0·33	Both tubes cracked on 1st tag and 1 on 2nd tag, but drawn satisfactorily.	
KAV128	0·0040	0·045	0·36	1 of 2 tubes cracked on 2nd tag, but drawn satisfactorily.	
KAV130	0·0051	0·044	0·37		
KAV132	0·0062	0·043	0·39	Both tubes cracked on 1st and 2nd tags, but drawn satisfactorily.	
KAV134	0·0075	0·044	0·38		
KAV136	0·0092	0·043	0·41		Both tubes cracked on 1st tag and 1 on 2nd tag, but drawn satisfactorily.

Sequence of Operations.—The sequence of operations was: shell 3–3·2 in. O.D., 0·375 in. wall; cold shouldered; mandrel drawn to 2·44 in. O.D., 0·25 in. wall; annealed and quenched, one half at 650° C. and the other at 750° C.; cold shouldered; mandrel drawn to 1·91 in. O.D., 0·14 in. wall; annealed and quenched as before; cold shouldered; mandrel drawn to 1·44 in. O.D., 0·094 in. wall; cold tagged; plug drawn to 1·25 in. O.D., 0·0625 in. wall; cold tagged; plug drawn to 1·125 in. O.D., 0·0625 in. wall.

Annealing.—Annealing was for 10 min. at temperature; tubes were quenched approximately 2½ min. after removal from muffle; quenching temperature visually estimated at 550°–600° C. and 600°–650° C. respectively for 650° and 750° C. anneals; tubes pickled 5 min. in 10% sulphuric acid after annealing.

* No bismuth addition.

the same as that of the cake poured from the same charge. Analyses of all the castings showed the amounts of each impurity to be similar to those reported in Table III.*

---

* With the following exceptions: Sb and Mn occasionally 0·005% in the arsenical coppers. Fe regularly between 0·0005 and 0·003% in the non-arsenical coppers. Pb usually 0·0004% in both series.

2. *Working Operations.*

(a) *Tube Manufacture.*

(i) *Hot Piercing of Billets.*—After heating to 900° C. for 1 hr., the billets were pierced on a rotary piercer of the Mannesman type. The shells were 7–8 ft. long × 3–3·2 in. external dia. (tapered) × 0·375 in. wall thickness. A slight temperature drop occurred during piercing, which occupied about 30 sec., and the shells cooled some 100°–200° C. while being restamped before quenching from about 750° C.

Every billet provided a sound tube shell on piercing, with the single exception of the arsenical copper with the highest bismuth content (0·0092%), in which fine cracking occurred; this did not prevent subsequent drawing.

(ii) *Tube Drawing.*—The shells were drawn to tubes 1·125 in. external dia. × 0·0625 in. wall thickness in five reductions with two intermediate anneals, the first three reductions being by mandrel and the last two by plug drawing. The tubes were halved after the first reduction and each half given the same reductions during drawing, but one half was intermediately annealed at 650° C. (the usual temperature at the mill in question) and the other at 750° C. throughout the operations; each anneal was followed by quenching. Prior to the mandrel draws, the tubes were " cold shouldered " or compressed at the end to fit the mandrel, and cold shouldering was replaced by " tagging ", a more severe form of end compression, before plug drawing.

The behaviour of the tubes during drawing is summarized in Table IV. Higher bismuth contents were tolerable in both the arsenical and non-arsenical coppers when the intermediate annealing temperature was raised to 750° C., although it will be seen from the footnote to Table IV that the actual quenching temperatures were considerably lower than the annealing temperatures. Of the tubes annealed at 750° C. only those of highest bismuth content (0·01%) cracked, and this near the end of the schedule. Of those annealed at 650° C. the tubes of both varieties of copper with bismuth contents exceeding 0·005% cracked badly, and the arsenical coppers cracked less seriously and somewhat inconsistently with bismuth contents as low as 0·003%.

Lengths of the tubes containing up to 0·003% bismuth in both the arsenical and non-arsenical series intermediately annealed at 650° C. were re-annealed at and quenched from temperatures of 550° and 600° C. and then redrawn in three passes, without further annealing, to 0·625 in. external dia. and 0·0313 in. wall thickness. The first reduction was by mandrel and the others by plug drawing. Cold shouldering and tagging operations again preceded the mandrel and plug draws respectively. All the tubes were drawn successfully with the exception of the highest bismuth content (0·003%) in each series, which cracked on tagging.

(b) *Rolling of Cakes.*

Half of each cake was soaked for 45 min. at 850°–950° C. and hot rolled from 3 in. to 0·75 in. thickness in 3 passes at an initial temperature which did not fall below 820° C. The strips were air cooled from about 750° C. and then reduced cold to a final thickness of 0·4 in. in 2 passes, 0·75 to 0·6 in., and 0·6 to 0·4 in. Halves of two of the non-arsenical cakes—one containing 0·0035%, the other 0·0074% bismuth—were quenched from 850° C. and cold rolled to 0·4 in. in three 50% reductions, with intermediate annealing at 900° C. followed by quenching between each.

During hot rolling, only slight edge cracking, unrelated to bismuth content, occurred on a few materials, and no cracking was observed during the cold reductions which followed. The two cakes reduced by cold rolling only, following high-temperature quenching, were uncracked.

3. *Grain-Size of Tubes and Strips.*

The importance of grain-size was not fully appreciated when these manufacturing trials were carried out, but in view of later evidence [1] the grain-sizes of a representative selection of the finished tubes and strips were measured in the annealed condition. Corresponding tubes and strips from the same charge were chosen for the determinations, and the materials were annealed for ½ hr. at 550°, 600°, 650°, and 750° C. in accordance with the annealing schedules used prior to the laboratory tests described in Section V. Tests showed that 10-min. anneals as used during drawing gave grain-sizes similar to those obtained after ½ hr.

The results indicated that there was little difference between the grain-sizes of the arsenical and non-arsenical coppers after similar working and annealing treatment, and no significant variation with bismuth content. The grain-sizes of tubes and strips were similar for a given final annealing treatment and appeared to be a function of the final annealing temperature, there being no apparent effect attributable to earlier thermal history. Since the laboratory and manufacturing anneals were both preceded by severe cold work, it may be inferred that the grain-sizes of the coppers after annealing in manufacture were defined by the annealing temperature, and that the relationship between annealing temperature and grain-size was approximately as follows :

Annealing Temperature, ° C.	Grain-Size, $\sqrt{\text{Area}}$ of Average Grain, mm.
550°	0·02
650°	0·04
750°	0·07

V.—LABORATORY TESTS ON THE TUBES AND STRIPS.

1. *Flattening and Doubling-Over Tests on Tubes.*

Specimens of the tubes were flattened to contact by hammering for a length of about 2 in. at one end, and this end of the tube was then doubled back through 180°, again hammering to contact.

(a) *Tubes Annealed at* 650° *or* 750° *C. During Manufacture.*

The results of tests on the as-drawn tubes and on sample lengths annealed in the laboratory for ½ hr. at, and quenched from, 550°, 650°, and 750° C. are given in Table V.

(i) *As Drawn.*—Cracking occurred indiscriminately (including one of the bismuth-free arsenical tubes) and was probably influenced more by the degree of hardening during drawing than by the bismuth content or the annealing treatment in manufacture.

(ii) *Annealed and Quenched.*—Tubes re-annealed and quenched from the annealing temperatures used in manufacture showed no embrittlement, but re-annealing at lower temperatures caused embrittlement in some cases. The arsenical coppers were not re-embrittled when a manufacturing anneal of 750° C. had been used, but both varieties of copper showed the effect when this anneal was at 650° C.; the non-arsenical coppers were also re-embrittled despite annealing at 750° C. during drawing.

On the whole, therefore, the non-arsenical coppers appeared more sensitive to bismuth embrittlement than the arsenical, though this was somewhat at variance with the behaviour of the coppers in tube drawing.

In neither the arsenical nor the non-arsenical series was there a single instance of cracking of annealed tubing containing 0·0026% bismuth or less; the same amount of bismuth was permissible for any of the severe cold-working operations in manufacture.

TABLE V.—*Flattening and Doubling-Over Tests on Phosphorus-Deoxidized Copper Tubes Containing Bismuth.*

The Table records significant cracking.

Mark.	Composition, %.			As Drawn.		Manufacturing Anneals at 650° C.	Manufacturing Anneals at 750° C.
				Manufacturing Anneals at :		Annealed at 550° C.* in Laboratory.	Annealed at 550° C.* in Laboratory.
	Bi	P	As	650° C.	750° C.		
				Non-Arsenical Coppers.			
KAV 70†	0·00005	0·046	...	...	...	...	...
KAV 94	0·0005	0·040	...	*CD* (1)	...	...	...
KAV 74	0·0011	0·048	...	*CF*	*CF*	...	...
KAV 76	0·0015	0·046	...	...	...	...	...
KAV 78	0·0020	0·038	...	...	*CF* (1)	...	...
KAV108	0·0026	0·032	...	...	...	...	...
KAV 82	0·0030	0·045	...	...	...	*CF*/*CD*	*CD* (1)
KAV106	0·0035	0·042	...	...	*CD* (1)	...	...
KAV 88	0·0040	0·026	...	...	...	...	...
KAV 90	0·0051	0·039	...	...	...	...	*CD* (1)
KAV 92	0·0060	0·040	...	...	...	*TD*	*CF*/*CD*
KAV104	0·0075	0·043	...	...	...	*TD*	*CF*
KAV102	0·010	0·035	...	...	...	*TD*	*CF*
				Arsenical Coppers.			
KAV120†	0·0001	0·040	0·36	*CD* (1)	...	...	...
KAV118	0·0006	0·049	0·36	*CD* (1)	...	...	...
KAV116	0·0011	0·047	0·31	...	*CF* (1)	...	...
KAV114	0·0016	0·048	0·35	...	*CF*	...	...
KAV112	0·0022	0·040	0·35	...	...	...	...
KAV122	0·0027	0·043	0·36	...	...	...	...
KAV124	0·0031	0·049	0·34	*CF* (1)	...	...	...
KAV126	0·0035	0·043	0·33	*CF* (1)	...	*CF*/*CD*	...
KAV128	0·0040	0·045	0·36	*CD* (1)	*CF* (1)	...	...
KAV130	0·0051	0·044	0·37	*SF*	*CF* (1)	*CF* (1)	...
KAV132	0·0062	0·043	0·39	*CF*	...	...	...
KAV134	0·0075	0·044	0·38	*CF*	*CF*	...	...
KAV136	0·0092	0·043	0·41	*CF*	*CF*	*CF* (1)	...

* All tubes annealed at 650° or 750° C. in the laboratory were flattened and doubled-over successfully except those of non-arsenical copper containing 0·006% or more bismuth which had received manufacturing anneals at 750° C.; these tubes cracked on flattening.

† No bismuth addition.

Code.

CF = cracked on flattening.
CD = cracked on doubling-over.
SF = split open on flattening.
TD = tubes discarded at early stage of drawing.
(1) = one of two tubes cracked; in all other cases of failure, both tubes cracked.

(b) *Tubes Containing up to* 0·003% *Bismuth, Annealed at* 550° *or* 600° *C. Prior to Further Drawing.*

Duplicate specimens from tubes annealed at 600° C. before further drawing (see p. 8) were annealed for 30 min. at (*a*) 550° C. and (*b*) 600° C. and quenched. Single specimens from tubes annealed at 550° C. prior to redrawing were re-annealed for 30 min. at 550° C. and quenched.

Every sample passed the flattening and doubling test without cracking.

2. *Bend Tests on Tubes.*

Tubes with up to 0·003% bismuth were tested in the "quarter-hard" condition, in which temper tubing is normally supplied for such purposes as domestic water services. Tubes annealed at 550° C. during manufacture were re-annealed at the same temperature, quenched, and hollow sunk 0·031 in. on the diameter. 30-in. lengths of these "quarter-hard" tubes were bent through 90° over a 1·75-in. radius in a standard tube-bending machine. All the tubes were successfully bent without cracking.

Hot bend tests were also made at 550° C. 12-in. samples from each "quarter-hard" tube were filled with sand and annealed for 1 hr. at 550° C.; each was rapidly removed from the furnace and bent through 90° on a heated former of 1·5-in. radius. The tubes of highest bismuth content (0·003%) in both the arsenical and non-arsenical series cracked during these tests. Tubes containing 0·0025% bismuth passed the test.

VI.—THE INFLUENCE OF SOME OTHER VARIABLES IN THE HEAT-TREATMENT OF DEOXIDIZED COPPERS CONTAINING BISMUTH.

The preceding Sections have been concerned primarily with hot-working and annealing temperatures, but other features of annealing practice which have been shown [1] in small-scale laboratory tests to influence the degree of embrittlement of deoxidized bismuth-bearing coppers are the annealing atmosphere, the rate of cooling from the annealing temperature, and transfer of bismuth from copper of higher bismuth content to copper of lower bismuth content during annealing.

Experiments were made, using the coppers produced in the works trials, to examine the influence of these variables.

It has already been shown [1] that thin strips (0·03 in.) of non-arsenical copper are less brittle after annealing in air (in the brittle range) than after bright annealing, but that the effect is not perceptible with thicker-section specimens (0·4 in.). In the present work, both arsenical and non-arsenical coppers were tested and were found to behave similarly, the oxidizing atmosphere having some beneficial effect on the thin strips, but no effect which could be attributed to the annealing atmosphere was observed for the thicker sections.

1. *Rate of Cooling from the Annealing Temperature.*

Notched-bar specimens were annealed in air at 750° C. for 30 min. and cooled (*a*) by quenching in water, (*b*) by withdrawal from the furnace into the air, and (*c*) by cooling slowly in the furnace. The air-cooled specimens were wired together into two bundles with about 12 specimens in each, so that their rate of cooling would more nearly approach that of a larger object; the specimens cooled in the furnace were in the brittle range between 700° and 400° C. for 2½ hr. and were cooled from 400° C. to room temperature in a further 10 hr.

The effect of cooling the coppers at these different rates through the embrittling temperature range is shown in Table VI. Quenching from 750° C. produced ductile material throughout the whole range of bismuth contents used (with the exception of the highest in the arsenical series, 0·0092%), but slow furnace cooling induced embrittlement when the bismuth content exceeded about 0·0025% in both the arsenical and non-arsenical series. Although the notched-bar values were still high, particularly in the arsenical coppers, all values under about 95 ft.lb. provided specimens broken on impact. Air cooling of these relatively small masses gave lowered test values when the bismuth contents were greater than about 0·006%, non-arsenical, and 0·0035%, arsenical.

It is concluded that deoxidized coppers containing not more than about 0·0025% bismuth are ductile after annealing at 750° C. irrespective of the rate of cooling. Coppers with bismuth contents in excess of this should preferably be quenched.

2. *Transfer of Bismuth.*

In the earlier work,[1] bismuth-free copper was embrittled by transfer of bismuth from coppers containing 0·075 and 0·1% bismuth, and the present tests were designed to show whether this effect occurred on annealing in proximity to coppers of lower bismuth content. Strips of deoxidized bismuth-free copper, 0·03 in. thick, were annealed in a 95 : 5 nitrogen–hydrogen atmosphere, separated from, but in close proximity to, similar deoxidized copper strips containing 0·01% bismuth. The reverse-bend-test results in Table VII show that bismuth transfer and embrittlement occurred in both arsenical and non-arsenical coppers and confirm that this effect can have practical significance in bright annealing thin sections near others having bismuth contents of the order discussed in this paper.

TABLE VI.—*The Effect on Notched-Bar Value of Rate of Cooling Through the Embrittling Temperature Range.*

Non-Arsenical.						Arsenical.						
Mark.	Composition, %.		Notched-Bar Value (ft.lb.). Annealed at 750° C. in Air for 30 min.			Mark.	Composition, %.			Notched-Bar Value (ft.lb.). Annealed at 750° C. in Air for 30 min.		
	Bi	P	Quenched.	Air Cooled.	Furnace Cooled.		Bi	P	As	Quenched.	Air Cooled.	Furnace Cooled.
KAV 67*	0·00007	0·044	103	119	119	KAV121*	0·0001	0·040	0·36	112	119	111
KAV 95	0·0005	0·040	106	119	115	KAV119	0·0006	0·049	0·36	112	119	112
KAV 75	0·0011	0·048	112	119	119	...	...	...	...	...	...	...
KAV 77	0·0015	0·046	114	119	119	KAV115	0·0016	0·048	0·35	115	118	119
KAV 79	0·0020	0·038	107	119	106	KAV113	0·0022	0·040	0·35	113	119	112
KAV 81	0·0025	0·050	107	118	114	KAV123	0·0027	0·043	0·36	113	119	94
KAV 83	0·0030	0·045	109	119	42	KAV125	0·0031	0·049	0·34	116	119	116
KAV107	0·0035	0·042	106	115	46	KAV127	0·0035	0·043	0·33	108	101	72
KAV 89	0·0040	0·026	107	119	116	KAV129	0·0040	0·045	0·36	114	82	63
KAV 91	0·0051	0·039	109	119	37	KAV131	0·0051	0·044	0·37	112	106	73
KAV 93	0·0060	0·040	108	118	24	KAV133	0·0062	0·043	0·39	109	64	67
KAV101	0·0074	0·042	114	32	21	KAV135	0·0075	0·044	0·38	107	87	107
KAV103	0·010	0·035	105	110	18	KAV137	0·0092	0·043	0·41	41	61	78

Values above and below about 95 ft.lb. were respectively partially broken and broken.
* No bismuth addition.

Table VII.—*Bismuth Transfer in Thin Copper Under Bright-Annealing Conditions. (Recipient Separated from Donors by a 2-mm. Gap. Each Recipient with its Two Donors Wrapped Separately in Copper Foil.) Annealing Treatment:* 1 *hr. at* 600° *C., Followed by Quenching.*

Donor.					Recipient.					
Mark.	Original Composition, %.			Bi after test, %.	Mark.	Original Composition, %.			Bi after test, %.	Drop in Reverse-Bend Value.
	As	P	Bi			As	P	Bi		
KAV 103	...	0·035	0·010	0·0088	KAV 71	...	0·046	0·00005	0·0014	From 44 to 24.
					KAV 121	0·36	0·040	0·0001	0·0009	From 38 to 28.
KAV 137	0·41	0·043	0·0092	0·0090	KAV 71	...	0·046	0·00005	0·0015	From 43 to 21.
					KAV 121	0·36	0·040	0·0001	0·0013	From 39 to 23.

Relatively thick pieces of copper of different bismuth content annealed in air showed no transfer effects. Arsenical and non-arsenical notched-bar specimens of deoxidized coppers containing 0·005% bismuth showed no change in their test values after annealing while stacked between, and completely surrounded by, similar specimens containing 0·01% bismuth.

VII.—Summary and Conclusions.

The practical aspects of bismuth embrittlement of deoxidized coppers have been studied by laboratory rolling trials and by the manufacture on an industrial scale of tubes and strips. In the main, the behaviour of the coppers was consistently related to their bismuth contents. Arsenical and non-arsenical coppers behaved somewhat differently, both in working operations and in laboratory tests, but the differences were minor and were not altogether consistent; in some cases the non-arsenical materials were slightly less affected by the presence of bismuth while in others the reverse was true. For practical purposes it is concluded that arsenical and non-arsenical deoxidized coppers are similarly affected by a given bismuth content, and hereafter no distinction is drawn between these two materials. Where tolerance limits for bismuth are quoted in the following conclusions, the lower figure has been taken when the two coppers behaved differently.

The grain-size of the materials has been shown [1] to affect markedly the degree of bismuth embrittlement, so that values for grain-size are an essential part of their description. The following conclusions refer to the materials used in the present investigation, with grain-sizes in the range 0·02–0·07 mm. $\sqrt{\text{area}}$; the approximate values varied with the temperature of heat-treatment, i.e. 550° C., 0·02 mm.; 650° C., 0·04 mm.; 750° C., 0·07 mm.

The principal conclusion drawn from this work is that modification of annealing practice on the lines indicated by present knowledge of the mechanism of bismuth embrittlement raises the limiting bismuth contents beyond those at which failures may occur using normal methods of fabrication. Notably, a relatively high intermediate annealing temperature, followed by quenching, permits successful cold working of materials which would otherwise fail.

Detailed conclusions are as follows:

1. *Hot Working.*

(*a*) Hot rolling at 820° C. or higher is practicable with up to and including 0·03% bismuth; higher bismuth contents cause cracking. At lower rolling temperatures, severe cracking occurs with lower bismuth contents, e.g. 0·015% at 550° C. and 0·005% at 500° C.

(*b*) Hot piercing is satisfactory at 900° C. with bismuth contents up to and including 0·0075%, and only slight (tolerable) cracking occurs with 0·01% bismuth.

(*c*) Hot bending at 550° C. is satisfactory with bismuth contents up to and including 0·0025%. From analogy with the cold-working behaviour of annealed and quenched material, it is likely that higher bismuth contents would be tolerable in bending at higher temperatures, e.g. 0·005% at 700° C. and 0·007% at 750° C.

2. *Cold Working.*

(*a*) Cold rolling of chill-cast materials is satisfactory with up to and including 0·01% bismuth; higher bismuth contents cause slight edge cracking, but annealing and quenching from 900° C. raises the permissible limit to approximately 0·03%. The cold-rolling properties are thus relatively insensitive to bismuth content, and it is likely that bismuth limits for practical purposes will be determined by considerations other than rolling behaviour.

(*b*) Tube drawing and the associated severe tagging operations are satisfactory with bismuth contents up to and including 0·0075%, provided that the materials are annealed at and quenched from 750° C., both before working and at intermediate stages. Materials annealed at and quenched from 650° C. behave satisfactorily with up to and including 0·0025% bismuth, and the same limit applies for materials annealed at 550° and 600° C.

(*c*) Judging by the behaviour in flattening and doubling-over tests, material annealed at and quenched from high temperatures during manufacture will be re-embrittled if after further cold work it is subsequently annealed at and quenched from lower temperatures.

(*d*) Cold bending of " quarter-hard " tubes, annealed at 550° C. during processing, presents no difficulty with bismuth contents up to and including 0·003%, and it is likely that considerations of tube-drawing behaviour rather than of cold-bending behaviour will fix the tolerance limits for materials destined for tubes.

3. *Annealing Procedure.*

(*a*) Oxidizing annealing atmospheres reduce bismuth embrittlement to some extent in relatively thin-section materials, e.g. 0·03 in. thick, but the effect is not large and is unlikely to be of practical use in view of the obvious objection to such treatment of thin material.

(*b*) Rapid cooling after annealing is essential if the benefit of high-temperature annealing is to be fully realized, and quenching is necessary unless the material is of sufficiently thin gauge to cool rapidly in air.

(*c*) Bismuth transfer can occur to coppers of thin section (e.g. 0·03 in. thickness) from closely adjacent copper of higher bismuth content when annealing is carried out in bright-annealing atmospheres. This possibility should be borne in mind, although there is no evidence that it is of practical significance under industrial conditions and with the bismuth contents normally encountered.

VIII.—PRACTICAL RECOMMENDATIONS.

1. *Hot Working.*

Severe hot work should not be performed in the temperature range 400°–700° C. with bismuth contents of 0·002% or more. Relatively mild work is practicable in this temperature range with contents up to and including 0·003%. Temperatures appreciably above this range, e.g. 750°–900° C., are recommended for materials of higher bismuth content, or where the working operation is severe.

2. *Cold Working.*

Cold work should be preceded by annealing at relatively high temperatures and quenching, the annealing temperature required varying with the bismuth content of the copper and the severity of the working operation. For example, severe cold work should be preceded by annealing at and quenching from :

650° C. for material containing up to 0·0025% bismuth.
750° C. „ „ „ from 0·0025 to 0·007% bismuth.

Temperatures about 50° C. lower are permissible if only mild cold working is to follow.

ACKNOWLEDGEMENTS.

The author's thanks are due to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper, and the co-operation of Dr. Maurice Cook of Imperial Chemical Industries, Ltd., Metals Division, in arranging for the casting and working operations to be carried out, is gratefully acknowledged.

The work represents part of a general investigation of the effects of bismuth, selenium, and tellurium in copper.

REFERENCES.

1. E. Voce and A. P. C. Hallowes, *J. Inst. Metals*, 1947, **73**, 323.
2. C. Blazey, *J. Inst. Metals*, 1927, **37**, 51.
3. C. Blazey, *J. Inst. Metals*, 1929, **41**, 321.
4. C. Blazey, *J. Inst. Metals*, 1931, **46**, 353.
5. S. L. Archbutt and W. E. Prytherch, " The Effect of Impurities in Copper ". London : **1937** (British Non-Ferrous Metals Research Association). (See Chapter 5, p. 46.)
6. G. L. Bailey and A. P. C. Hallowes, *J. Inst. Metals*, 1942, **68**, 347.
7. M. Cook and G. Parker, *J. Inst. Metals*, 1942, **68**, 369.

THE PROMOTION AND ACCELERATION OF METALLIC CORROSION BY MICRO-ORGANISMS.*

By T. HOWARD ROGERS,† D.I.C., A.I.M.

(Communication from the British Non-Ferrous Metals Research Association.)

Synopsis.

During recent years many corrosion investigators have had good reason to suspect that micro-organisms can play a part in the corrosion of metals.

In 1936 the British Non-Ferrous Metals Research Association began research on the influence of bacteria and other living organisms, in the corrosion of condenser-tube alloys.

This paper gives details of some of the more important of these researches, and describes experiments devised to show that bacteria are able to initiate and accelerate corrosion. This can occur both by direct attack, during the life of a bacterial colony closely associated with a metal surface, and by indirect attack due to the accelerative corrosive action of some products of bacterial metabolism. In the latter case, acceleration of a corrosion cell may be effected at some distance from the site of the bacterial activity, and can occur under sterile conditions if certain products, produced during the bacterial breakdown of protein, are still present.

I.—Introduction.

Of recent years, many of those who have investigated the problem of metallic corrosion have had reason to suspect that bacteria, moulds, and other living organisms can play a part in such action.[5, 14, 20, 21, 29, 45]

The suggestion that bacteria might have an influence in the corrosion of metals was made by Garrett as early as 1891.[18] In discussing the increase in the corrosive action of water on lead, caused by compounds of nitrogen, Garrett suggested that under some conditions the ammonia content of a water might be increased through the bacterial breakdown of organic matter, and that bacteria might also be responsible for the oxidation of the ammonia to nitrite or nitrate, thereby making the water more aggressive. More modern investigation along the same lines has been reported by Hill [27] and Caldwell and Ackerman [11] in 1946. In 1921, Grant, Bate, and Myers [19] brought forward evidence to show that the rate of pitting of condenser tubes in

---

* Manuscript received 28 April 1948. The work described in this paper was made available to members of the B.N.F.M.R.A. in confidential research reports between 1939 and 1944.

† Senior Investigator, British Non-Ferrous Metals Research Association, London.

a power station using cooling water from Sydney Harbour was seriously increased by ammonia produced in the shut-down condensers by bacterial action on the organic matter in the stagnant cooling water contaminated with sewage. Bengough and May[3] also found that some condenser-tube failures were associated with the products of micro-biological action. In 1923 von Wolzogen Kühr and van der Vlugt[46, 47] called attention to the effect of the sulphate-reducing bacteria on the corrosion of iron pipe-lines, a subject which has received considerable further study at the hands of Baars,[1] Bunker,[6–10] Hadley,[22, 23] Starkey,[41] and many others,[17, 42, 44, 48, 51] while Rogers[37, 38] has studied these bacteria in relation to other metals.

Although modern corrosion literature contains references to the effect of bacteria in causing corrosion of metals, very little experimental laboratory work, other than with sulphate-reducers, seems to have been undertaken. In 1936 the British Non-Ferrous Metals Research Association initiated research on the influence of micro-organisms in the corrosion of condenser-tube alloys, and since then many cases have been noted of their influence in the corrosion of metals. The sulphate-reducing organisms have been found to be responsible for accelerated attack on non-ferrous materials as well as iron. In some cases, organisms other than bacteria have been found to influence corrosion, e.g. moulds developing during corrosion tests can have very disturbing effects, and acid exudates from lichens have been found to increase corrosion of outdoor metallic structures.

Corrosion by bacterial action can be brought about in various ways : (*a*) by direct action, e.g. by the production of corrosive substances such as carbon dioxide,[39] hydrogen sulphide, ammonia,[27] organic or inorganic acids[2, 27, 50] ; (*b*) by the metabolism of the bacteria, producing organic products which can act as depolarizers or catalysts of corrosion reactions ; and (*c*) in cases similar to the anærobic corrosion of iron, by the activities of the sulphate-reducing organisms, where under some conditions the corrosion reaction is an integral part of the metabolic cycle of the bacteria. These divisions are arbitrary, and overlapping must be expected to occur, but they are used here for convenience in presenting the work.

Colonies of bacteria producing substances under (*a*) may be in close contact with the metal surface, growing in almost stationary slimy deposits, and in this case the necessary concentration of corroding agent is often maintained only in the locality of the colony, and may be undetectable in the surrounding water or soil. Bacteria causing corrosion in this way, need only produce very small quantities of a corrosive product for localized attack to become very severe. More-over, the colony, although not producing any markedly corrosive substance, may act as a deposit, so setting up a differential oxygen cell or causing an unequal distribution of electrical potential, giving rise to local anodes and cathodes.

In other conditions the corroding medium may be generally infected with the offending organisms, and if they produce substances which are able to catalyse corrosion reactions, it is possible for the medium to remain abnormally corrosive even after the bacteria have died, become dormant, or been removed.

This paper describes many experiments, using pure and mixed cultures of bacteria isolated from contaminated waters, both fresh and marine, which show that under some conditions colonies of certain bacteria can considerably increase the corrosive attack on metals. It also shows that substances known to be produced by bacterial metabolism can cause accelerated corrosion.

II.—LOCAL CORROSION CAUSED BY BACTERIA.

1. *Experimental Methods.*

Several waters were examined bacteriologically, and cultures of bacteria obtained therefrom; these included samples of sea waters which had caused abnormal pitting of condenser-tube alloys in laboratory impingement tests,* water from an inland power station using sewage effluent for cooling, and estuarine water from a coastal power station. These bacteria, in both mixed and pure cultures, were used in corrosion tests.

A suitable test for the corrosive action of bacteria must comply with both corrosion and bacteriological requirements, and a technique had to be developed for maintaining active colonies for long periods in stationary slimy deposits on the surfaces of metal tubes or specimens. The method used by Grant, Bate, and Myers [19] did not prove satisfactory for long-period tests, and a new technique was developed which (*a*) enabled the bacterial colony to be fed and maintained in close contact with the metal, and (*b*) prevented desiccation of the colonies even over long periods. A flat circle of agar 1 in. in diameter by $\frac{1}{4}$ in. deep was cut into two semi-circular halves and the two halves set in a petri dish about $\frac{1}{4}$ in. apart. The tops of these half circles were inoculated with selected bacteria and used as a base for the colonies. A small specimen of the metal to be tested was placed on top of these semi-circles of agar after the colonies had been allowed to develop for 24 to 48 hr., and the

---

* The assessment of condenser-tube alloys for service is usually carried out in the jet impingement apparatus developed by R. May.[31]

petri dish filled with sufficient liquid* to cover the agar and the test-piece. By this means contact between the metal and the colony was effected; the division between the half circles giving free access to water and air, toxic salts could diffuse out, and the fluid could be pipetted off and replaced under sterile conditions as required.

2. *Copper Tolerance.*

Early work showed that colonies of some bacteria and also moulds growing in contact with 70 : 30 brass were able to accelerate corrosion and cause deep pits underneath the colonies. Results were variable, and many colonies quickly died out, which was not surprising as copper salts, the normal corrosion products of brass, are usually toxic to bacterial growth. That some bacteria could tolerate a high concentration of copper salts was obvious, as organic matter was present within many of the pits.

This factor is especially important in stagnant conditions, but may not be so significant where the corrosion products are being washed away by flowing water. It was found that many of the cultures isolated from an estuarine water showing abnormal corrosion properties could withstand concentrations of copper salts much higher than that usually stated in the literature to be lethal to micro-organisms. Several of the non-sporing types isolated could withstand concentrations of copper higher than 100 p.p.m. One of these was a non-sporing, Gram negative rod, forming a reddish-brown colony, and appeared to be a similar organism to that isolated from sea water by Waksman *et al.*[48] The suggestion of these workers that copper was necessary for normal development of this bacterium was not tested as the organism was isolated from copper-containing water and then cultured into copper-containing sea-water medium. Another culture, a spore-forming organism, taken from a metal specimen corroding in infected sea water, resisted 2000 p.p.m. of copper. All the cultures taken from the jet impingement apparatus have been found capable of withstanding a higher copper concentration than that normally accumulating in waters during tests with this apparatus.

3. *Increase of Corrosion Due to Bacterial Activity.*

The series of cultures isolated from estuarine water known to be corrosive, and also a culture obtained from the pitted area of a piece of metal corroding in sea water in the jet impingement apparatus, were tested by the technique mentioned above. The fluid used for

---

* Sterile water with and without added nutrients.

flooding the petri dishes was sterile sea water and the test metal 70 : 30 brass. It was found that in many cases appreciable corrosion took place underneath the colonies in as short a time as 28 days. The type of corrosion obtained was more rapid than that associated with normal deposit attack and was often intercrystalline. The controls showed no more attack than is normally found with 70 : 30 brass in sea water.

Efforts were made to increase the rate of attack due to the bacteria by adding to the sea water substances which would act as foodstuffs for them and so increase their activity. Earlier work had suggested that organic acids produced as a result of the breakdown of sugars have an influence on corrosion in sea water, and in one series of experiments mannitol together with asparagine, as a source of nitrogen, were added to the sea water. The specimens showed severe attack, the measured depth of the pits being from two to ten times as great as that obtained in the previous tests. Some of the specimens showed a protective film, but it had often been broken down, and in these cases attack had continued underneath the film, which flaked off when touched with a needle, revealing a deep pit. The fact that the addition of mannitol to sea water made such a great difference to the magnitude of the attack is of interest because mannitol is a constituent of many seaweeds,[28, 34, 43] and although its presence in the open sea is doubtful, it is highly probable that estuarine waters will at times contain this substance and also that inshore water will contain organic acids or their salts derived from its breakdown.

In another series, in which peptone was added to the sea water, it was found that the peptone favoured film formation on the metal. Some bacteria were able to break down these films, while others were unable to do so. It was found that some colonies which were unable to break down the protective film and pit the metal did so if the surface film was broken by scratching.

Further work was undertaken using the same technique with pure (single strain) and impure (mixed strain) cultures, and it was found that impure cultures always produced the more severe attack.

In practice the influence of bacteria on corrosion usually occurs in conditions of flowing water, and it was thought that changing the liquid during the tests would accelerate attack, by removing from the solution some of the copper salts which, even if not toxic, interfere with film formation on the metal. Tests were therefore made in which the liquid was changed during the course of the experiment. The first change was made three days after inoculation and the second after a further seven days; the test was then left until the full 28 days had elapsed before examination was made. The results taken as a whole showed quite clearly that changing the liquid increased the corrosion.

Samples of water have been taken from the jet impingement apparatus and estimates made of the bacterial numbers. These counts have shown that the sea-water samples received into the laboratory vary greatly in bacterial population and in the type of bacteria present; nor does the bacterial population remain constant during storage.[24] It has also been shown that the bacterial population of the jet impingement apparatus will vary during a run. The work suggested that a high bacterial count does not necessarily imply that the water will be exceptionally corrosive, but that the presence in the water of bacteria forming viscid or slimy colonies will usually be associated with anomalous results in corrosion tests.

It was shown that many of the bacteria found in the sea waters used in jet tests could be inhibited by the use of the dye Gentian Violet. Addition of this dye to sea waters used for jet-test runs controlled most forms of bacterial attack, but occasionally abnormal results were obtained which were attributed to a resistant strain of bacteria developing preferentially in the presence of this dye.

These experiments showed that bacteria are capable of having an effect in corrosion by sea water. How the bacteria accelerate corrosion was not immediately obvious, but the work has made certain suggestions possible. The present author's theory is that the acceleration of corrosion by bacteria, under these conditions, is mainly due to the presence of hydrogen acceptors and oxidation–reduction systems set up during bacterial metabolism. It is suggested that the presence of mannitol accelerates corrosion because, during its fermentation by the bacteria, hydrogen acceptors capable of causing depolarization are produced. That the bacteria used in these experiments did contain enzymes capable of both activating hydrogen and catalysing dehydrogenation reactions was proved by experiment, using the Thunberg tube technique.[12]

4. *Effect of Moulds.*

A few investigations were made on the corrosive action of moulds. When the moulds were grown on gelatine on the surface of brass plates, deep pits were rapidly and regularly produced by the common moulds of the atmosphere. In this case the attack was most probably caused by the diffusion to the metal of the organic acids known to be produced during the growth of many moulds.

Many bacteriological examinations have been carried out concurrently with runs of the jet impingement apparatus. Several times it has been shown that severe corrosion is associated with infections of bacteria and moulds of a type which will cause attack when tested experimentally under stagnant conditions.

III.—CORROSION CAUSED BY GENERAL BACTERIAL INFECTION.

1. *Pigments.*

Work on condenser-tube corrosion at the British Non-Ferrous Metals Research Association has often revealed cases in which failure due to abnormally rapid pitting appeared to be connected with some variable property of sea water not revealed by ordinary chemical analyses, and of more or less seasonal incidence. It was noticed that this rapid pitting tended to occur when the surface of the metal was coated with a brown film, which examination suggested was of biological origin. This view received some confirmation from the work on corrosion by colonies of bacteria, where it was noticed that some which produced black or brown pigments were among those causing the most severe corrosion.

One pigment was found to be melanin, an organic substance produced by the action of the enzyme tyrosinase on tyrosine, and it was shown that bacteria producing tyrosinase could accelerate corrosion in direct relation to the amount of tyrosine present. Acceleration of corrosion may be brought about in this case by the formation of quinones during the fermentation reaction, which may possibly play a part in cathodic depolarization.

2. *Sulphur Compounds.*

Samples of sea water known to give rapid pitting were also found to contain an organic sulphur compound, capable of being repeatedly reduced to a mercaptan and oxidized back to a disulphide. As these changes could be brought about readily, it appeared possible that the compound, when present on the metal surface, might act as an oxygen carrier, speeding up the depolarization of the cathodic areas around the pits, thereby increasing the rate of pitting. It was also noticed that sometimes a sample of sea water which gave no pitting did so if it became " infected " with a very small quantity of a water which had these properties. This again suggested that bacteria might be responsible, and as some of the bacteria isolated in the static tests gave positive nitroprusside * reactions for sulphydryl groups, considerable attention was paid to these substances.

---

* To determine the presence of –SS– and –SH groups, extensive use was made of the nitroprusside test. This test was devised by Mörner [33] and depends on the fact that sodium nitroprusside, in alkaline solution, produces a deep purple coloration in the presence of soluble sulphides and –SH groups. –SS– groups give the colour after reduction with *sulphide-free* KCN.

The principal sulphur compounds entering into protein structure are the disulphide, cystine * (CSSC), and its corresponding mercaptan form, cysteine * (CSH), also a similar substance, glutathione * (a stable complex of the three amino-acids, cystine, glycine, and glutamic, which, like cystine, exists in disulphide * and mercaptan forms), and methionine.*

Sulphydryl compounds are capable, under certain conditions, of reversible oxidation–reduction reactions. Thus cysteine in alkaline solution, in the presence of oxygen and traces of various catalytic metals, is oxidized to cystine. Copper is one of these metals, and it is effective in extremely small concentrations.[30, 40] After oxidation the cystine can be reduced again by reducing agents such as active hydrogen or sulphites.

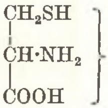
Glutathione is also capable of similar behaviour in the presence of a metal catalyst, but methionine, since it contains no –SH group, does not give rise to any oxidation–reduction system.

The source of these compounds is plant and animal tissue. Glutathione is present in all tissues, cystine in many, and both can be released by bacterial action. Many seaweeds contain cystine, and in the *Laminariae*[32] there may be as much as 3·4%. Cystine may possibly diffuse from the living plant, but when the weed decays through bacterial action, it is certainly liberated into the surrounding water, and this was confirmed by experiment. Some *Laminaria* was allowed to decompose in the laboratory, and cystine was detectable both in the water and in the bacterial slime on the decomposing weed.

As cystine, glutathione, and methionine are all of protein origin, and as bacteria are the active agents in protein decomposition, it may be safely argued that the presence of these compounds in sea water is

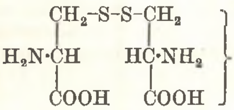
---

* Cysteine (CSH) : β-thio-α-aminopropionic acid.
Cystine (CSSC) : di-β-thio-α-aminopropionic acid.
Reduced glutathione (GSH) : glutamyl-cysteinyl-glycine.
Oxidized glutathione (GSSG) : di-glutamyl-cysteinyl-glycine.
Methionine : γ-methylthiol-α-aminobutyric acid.
Formulæ :



$$\left.\begin{array}{l} CH_2SH \\ | \\ CH\cdot NH_2 \\ | \\ COOH \end{array}\right\}$$

Cysteine.



$$\left.\begin{array}{ccc} & CH_2\text{–}S\text{–}S\text{–}CH_2 & \\ & | \qquad\qquad | & \\ H_2N\cdot CH & & HC\cdot NH_2 \\ | & & | \\ COOH & & COOH \end{array}\right\}$$

Cystine.

due to the action of micro-organisms in releasing them from decomposing organic matter.

Harvey[25] has shown that compounds such as cystine and glutathione are found in both off-shore and in-shore waters, and that there are definite seasonal variations in the amounts present. Also these substances are present in greater quantity where organic matter is being broken down, such as in estuaries, harbours, &c.

It is well known that the corrosion of metals is governed mainly by the type of film which forms on the surface of the material and the presence or absence at the seat of corrosion of substances which can behave as anodic or cathodic depolarizers. One of the main characteristics of cystine from the corrosion viewpoint is its affinity for certain metals and its ability to form metallic complexes on their surfaces. As has already been stated, cystine and its reduced form cysteine are capable of forming a reversible oxidation–reduction system of the type[26]:

$$\underset{\text{(disulphide)}}{\overset{\text{Cystine}}{\text{Cys-SS-Cys}}} + 2\text{H} + 2e \rightleftharpoons \underset{\text{(mercaptan)}}{\overset{\text{Cysteine}}{2\ \text{Cys-SH}}}$$

This suggests that the system might well cause depolarization at a corrosion centre. Thus cystine would appear to have two characteristics which under suitable conditions could have considerable influence on corrosion, namely the property of forming films and a depolarizing action.

The effect of these substances in the acceleration of corrosion, and the importance of organic sulphur compounds of the mercaptan–disulphide type in accelerating the corrosion of copper and copper-base alloys, are shown in Section IV.

IV.—CYSTINE AS AN ACCELERATOR OF CORROSION IN SEA WATER.

1. *Acceleration of Impingement Attack.*

To prove that a mercaptan–disulphide system was an effective corrosion accelerator, experiments were carried out under sterile conditions on 70 : 30 brass and other standard condenser-tube materials, in sea water with and without additions of cystine and glutathione.

As the jet impingement apparatus,[31] in which several specimens undergoing impingement are tested together in one large container, does not lend itself to sterile conditions, the Brownsdon and Bannister impingement corrosion apparatus,[4] which uses a separate unit for each test, was modified for the purpose. To find the normal rate of attack for each jet in the absence of organic sulphur, 12 control 70 : 30 non-arsenical brass specimens were first tested in a run of 500 hr. under sterile conditions, in a sea water that gave a negative reaction to the nitroprusside test and to Feigl's mercury-bead test,[15] and showed no abnormal pitting action. Sterile air was fed to the jets, and frequent checks showed that the apparatus remained sterile under working conditions.

Several runs were then made using the same jets in sea water from the same batch, sterilized and with the addition of varying amounts of the sulphur compounds, the breakdown of which was prevented by the sterility of the apparatus. In case sterilization of the sea water by heat in an autoclave had affected its corrosion properties, a few tests were made using the sea water which had not been autoclaved. A test was also made in the presence of cystine in water which had been infected with a culture of bacteria isolated from a sample of sea water producing abnormal attack.

All the specimens which had been tested in waters containing sulphur compounds were found at the end of the runs to have developed brown films to a varying extent. These films closely resembled the film often found in cases of abnormally rapid pitting in practice. Also, the presence of the sulphur compounds vastly increased the amount of pitting as compared with controls run in water free from these substances as shown by the tests quoted above.

A selection of the results obtained is given in Table I. Some of the tests were repeated several times, and to ensure that the pitting was not due to the peculiarity of a particular jet, similar experiments were made using different jets. The results were substantially the same.

The work established that when these substances were present, corrosion was accelerated even under sterile conditions. There is evidence, however, that if certain bacteria are in the water the rate of corrosion may be increased still further (Table I, jet No. 2*a*).

2. *Effect on Impingement Attack of the Decontamination of Sea Water.*

Before the effect of cystine as a corrosion accelerator could be correctly assessed, however, it was necessary to obtain a decontaminated water either free from, or containing only a very small quantity of, cystine and related compounds. Thus, sea waters to which sufficient cystine had been added (about 50 mg./l.) to give a bright nitroprusside reaction, were treated with the following substances: activated and granulated charcoal, metallic copper, cupric oxide, cuprous chloride, chlorine, bromine, and hydrogen peroxide.

TABLE I.—*The Effect of Organic Sulphur Compounds as Corrosion Accelerators on Non-Arsenical* 70 : 30 *Brass.*

Jet. No.	Sulphur Compound Added (parts per 100,000).*		Depth of Pit, mm.		Remarks.
			Control.†	Test.	
3*a*	3·3	Cystine (sterile)	0·07	0·43	Severe impingement attack, concentrated over an area which had progressively decreased in size by the encroachment of a thin brown cathodic film. Thick brown film also present on the anodic area.
5*a*	3·3	Cystine (non-sterile)	0·06	0·41	Severe impingement attack, gradually increasing in area. Brown film was less pure than in 3*a* and was being gradually removed as attack spread. Some brown film over anodic area.
1*a*	2·5	Cystine (sterile)	0·02	0·36	Closely resembling 3*a*.
2*b*	1·0	Cystine (sterile)	0·06	0·30	Same, but cathodic film thinner; anodic film thin and apparently continuous over centre of attacked area.
4*c*	0·1	Cystine (sterile)	0·05	0·39	Anodic film absent over attacked area. Cathodic film thin but strong and apparently very active, causing impingement attack to be more concentrated.
5*c*	0·01	Cystine (sterile)	0·06	0·23	No anodic brown film. Cathodic film weaker, and had not been able to prevent spreading of the attack.
6*c*	0·001	Cystine (sterile)	0·07	0·11	No anodic film and only a trace of cathodic film; attacked area had spread almost as much as controls.
3*b*	3·3	Reduced glutathione (sterile)	0·07	0·31	Severe impingement attack, gradually increasing in area by the undermining of a cathodic film. The undermining was associated with the development of pits close to the edge of the main area of attack.
6*b*	3·3	Reduced glutathione (non-sterile)	0·07	0·35	Resembled 3*b*, but the pitting and undermining of cathodic scale was less marked.
4*b*	0·1	Reduced glutathione (sterile)	0·05	0·39	Impingement attack localized by the cathodic film, which was being undermined by severe pitting under blisters around the main anodic area.
2*a*	3·3	Cystine (unsterile + culture *P/G*) ‡	0·06	0·55	General corrosion similar to 3*a* except that attack was deeper and larger. Film very thick.

* i.e. Weight in grammes per 100,000 c.c. of water.

† Sterile run without cystine additions.

‡ Culture *P/G* was isolated from an actively pitting brass specimen which had been in natural sea water.

The oxidants chlorine, bromine, and hydrogen peroxide decomposed the cystine and it was impossible to estimate the exact amount required. Charcoal was only partially successful in removing the cystine. It was troublesome to use, tended to colour the water, and possibly affected the carbonate equilibrium as well as removing scale-forming substances. Use of these reagents was not continued.

The copper compounds were quite successful; they precipitated the cystine, but in the absence of exact knowledge of the reaction between them and cystine, an excess had to be added, again an undesirable condition in corrosion experiments. The most suitable method appeared to be to pass the sea water over metallic copper; this is easy to carry out and does not contaminate the water with any undesirable amount of salt or reagent. A small amount of copper salt was, of course, introduced into the water, but this was found to be insignificant. Several jet impingement apparatus runs have been made using this method, and it has been found that a sea water so treated has reduced corrosive properties and does not deposit on the surface of the specimen the dark film which is often associated with abnormal corrosion behaviour.

It is well known that cystine has a great affinity for copper and copper salts, and the use of copper oxide for the extraction of cystine from protein hydrolysates is familiar, the organic sulphur compound being precipitated as a copper mercaptide complex.[36]

Several experiments have been made, both in the Brownsdon and Bannister impingement apparatus and in the May jet impingement apparatus, to compare the corrosion behaviour of alloys in contaminated and decontaminated waters. In general, it has been found that decontamination considerably lessens the severity of the corrosion, the amount of which increases again on the addition of cystine. It has also been shown that large amounts of cystine form films which stifle attack at the jet, but generally cause an increase in attack at areas shielded from oxygen, e.g. at blisters which tend to form in the film.

The important part which contamination can play in corrosion in sea waters is illustrated in Tables II and III. Removal, by activated charcoal, of most of the contamination of a natural water considerably reduced attack at the jet and at "shielded areas". The addition of extra cystine over and above the contamination already present in the natural sea water, stifled attack at the jet owing to the formation of heavy films, but attack at the "shielded areas" became increasingly severe. In 3% sodium chloride no attack occurred at the jet or at "shielded areas", but the addition of 10 mg./l. cystine to this solution caused attack of the type observed in natural sea waters (Fig. 1, Plate I).

TABLE II.—*Copper–Nickel–Iron Alloy Containing* 5% *Nickel and* 5% *Iron Tested in the Quenched and Cold-Rolled Condition in the Brownsdon and Bannister Apparatus Under Varying Conditions of Contamination* (*see Fig*. 1, *Plate* I).

Specimen.	Water.	Depth of Attack at the Jet, mm.	Remarks.
A/1	Natural, dirty.	0·35	Deep attack at the jet, some attack at "shielded areas".
A/2	Natural, dirty.	0·89	Deep attack at the jet, some attack at "shielded areas".
A/3	Natural, as above, cleaned activated charcoal.	0·12	Attack at the jet, no attack at "shielded areas".
A/4	Natural, as above, cleaned activated charcoal.	0·11	Attack at the jet, no attack at "shielded areas".
A/5	Natural, as above, plus 35 mg./l. cystine.	Nil	Heavy film, attack at the jet stifled. Very severe attack at "shielded areas" and some blistering.
A/6	3% NaCl in distilled water.	Nil	No attack at "shielded areas" or at the jet.
A/7	As above, plus 10 mg./l. cystine.	0·16	Attack at the jet and at "shielded areas".

TABLE III.—*Copper–Nickel–Iron Alloy Containing* 5% *Nickel and* 5% *Iron Tested in the Aged* 600° C. *Condition in the Brownsdon and Bannister Apparatus, Using Contaminated and Uncontaminated Sea Waters* (*see Fig*. 2, *Plate* I).

Specimen.	Water.	Cystine Additions.	Depth of Attack at Jet, mm.
A	Clean natural sea water	None	0·01
B		Plus 0·5 mg./l. cystine	0·20
C		Plus 2·0 mg./l. cystine	0·38
D	Partially decontaminated dirty sea water	None	0·23
E		Plus 0·5 mg./l. cystine	0·52
F		Plus 2·0 mg./l. cystine	0·54

Two different waters, one a clean sea water, and the other a sea water partially decontaminated by passage over copper, were used with and without added cystine (Table III). In each case the addition of cystine increased the corrosion (see Fig. 2, Plate I).

3. *The Effect of Cystine on the Corrosion of Copper.*

The effect of cystine on the corrosion of copper was studied by immersing sheets of high-conductivity copper, 1 dm.^{2} in area, in beakers containing 600 ml. of sea water, with and without added cystine. The liquid was stirred by a jet of air which was not allowed to impinge upon the metal, and the water changed every 48 hr. The corrosion of the copper was in each case measured by chemical estimation of the total copper salts in the beakers. Fig. 4 (Plate II) shows the results of these experiments in clean sea water and in sea waters containing respectively 3, 25, and 50 mg./l. cystine. The curves were obtained over a period of three weeks. All points on the graphs are the average of not less than four experiments, with the exception of the last three points of the 50 mg./l. experiments, which were obtained respectively from three, two, and one experiments.

It will be noticed that curve *A*, no added cystine, departs from a straight line only by showing a slight alteration in slope at about 10 days. This increase in rate at about this period was found to occur in all the experiments and seemed to be associated with the development on the copper specimens of a patchy light-brown film. Whether this was caused by the cumulative film formation due to small quantities of cystine present in the natural sea water is not known.

In all cases the corrosion of copper is initially increased by the presence of cystine. In the case of sea water to which 3 mg./l. cystine has been added (curve *B*), the accelerated rate compared with that in sea water containing no added cystine (curve *A*) continues until the tenth day, while in waters with higher concentrations of added cystine (curves *C* and *D*), the accelerated rate persists for only two days and then begins to fall off.

In each of the three series of experiments made in sea water containing added cystine, it was found that, after varying periods of time depending on the concentration of cystine, the corrosion rate slowed down until it was less than in water containing no added cystine, but none of the cystine concentrations used produced a film which was completely protective.

Copper corroding in the presence of cystine becomes brown, owing to the formation of a film of cystine–copper complex, which gives a positive nitroprusside reaction. The film becomes darker as the amount of this complex increases.

Some of the experiments with cystine suggested that it was possible

PLATE I

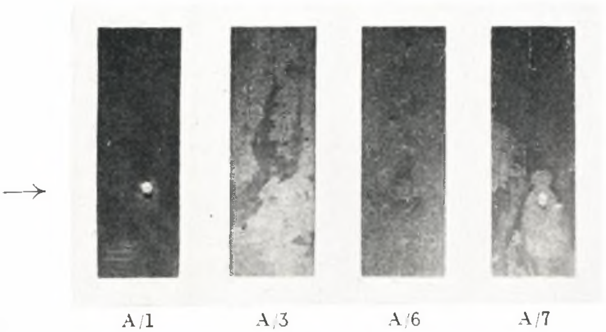


FIG. 1.—Specimens as Described in Table II, Showing Attack at the Jet Area in the Brownsdon and Bannister Apparatus. × 1.

A/1 Natural dirty sea water.
A/3 Natural dirty sea water cleaned through activated charcoal.
A/6 3% NaCl in distilled water.
A/7 3% NaCl in distilled water plus 10 mg./l. cystine.

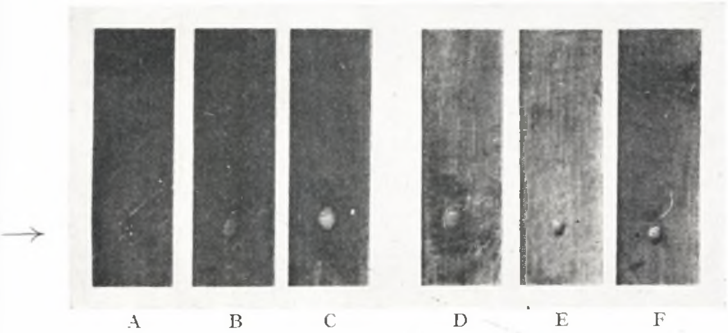


FIG. 2.—Specimens as Described in Table III, Showing Attack at the Jet Area in the Brownsdon and Bannister Apparatus. × 1.

A. No cystine, clean natural sea water.
B. As A, plus 0·5 mg./l. cystine.
C. As A, plus 2·0 mg./l. cystine.
D. Partially decontaminated dirty sea water.
E. As D, plus 0·5 mg./l. cystine.
F. As D, plus 2·0 mg./l. cystine.

PLATE II.

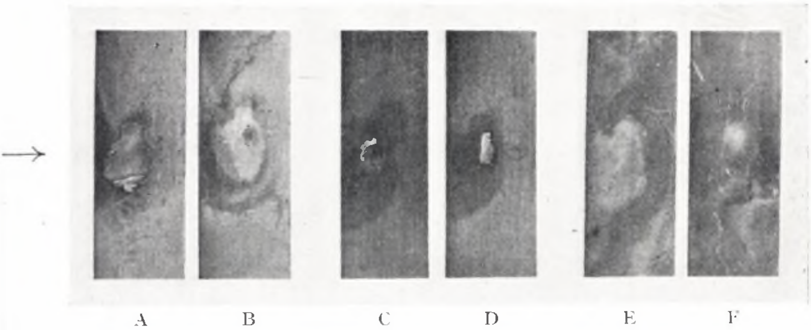


FIG. 3.—Specimens as Described in Table IV, Showing Attack at the Jet Area in the Brownsdon and Bannister Apparatus. × 1.

A and B. 48 hr. exposure to cystine-containing sea water before test.
C and D. 240 hr. exposure to cystine-containing sea water before test.
E and F. No exposure.

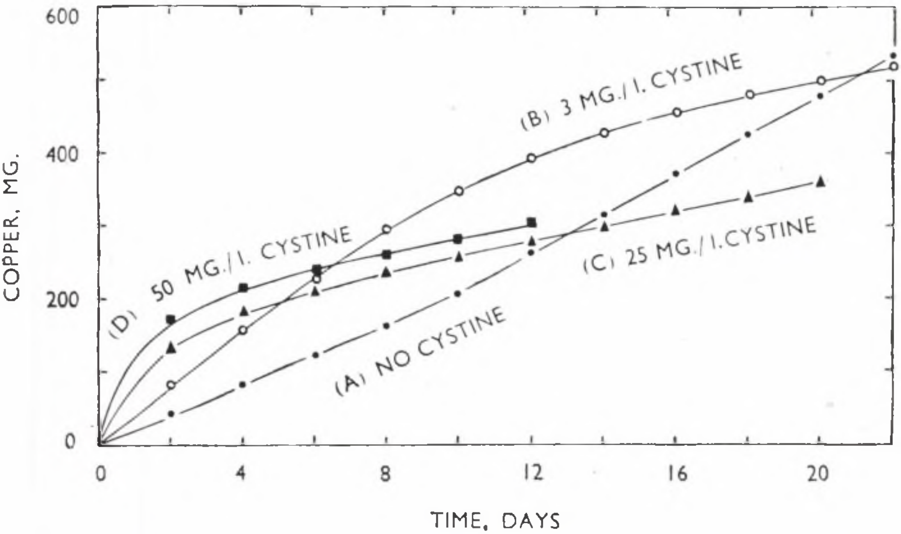


FIG. 4.—Curves of Total Copper *versus* Time. 1 dm.^{2} H.C. copper in aerated sea water containing varying amounts of cystine. Water changed every 48 hr.

to obtain two forms of cystine film: incomplete films which may accelerate general corrosion, and more nearly complete films which tend to be protective but which can also accelerate pitting action.

If a copper sample is exposed to sea water containing a low concentration of cystine, filming of the surface is incomplete, and stimulation of attack is maintained even after all the cystine has been removed from the water. This is due to the fact that cystine first comes down preferentially on local anodes or cathodes (depending on the *p*H of the solution), and complete filming does not occur until all local preferences are satisfied. Further, if such a partially filmed specimen is transferred to a water free from cystine, acceleration of attack continues.

The effect of impingement on cystine films was studied by placing two copper specimens in sea water containing 25 mg./l. cystine for 48 hr. and two specimens for 240 hr., the sea water containing cystine being aerated and changed every 48 hr. These specimens, together with two unfilmed copper controls, were then tested in sea water containing no added cystine in the Brownsdon and Bannister apparatus for 500 hr. The results are shown in Table IV. The depth of attack at the jet, the size of the unfilmed areas, and the amount of copper salts in the flasks at the end of each separate run were measured.

TABLE IV.—*Impingement Experiments in Clean Sea Water on H.C. Copper Previously Exposed to Sea Water Containing* 25 *mg./l. Cystine* (*see Fig.* 3, *Plate* II).

Specimen.	Prior Exposure in Cystine-Containing Sea Water, hr.	Depth of Attack at Jet, mm.	Size of Unfilmed Area at Jet, cm.^{2}	Copper in Water at End of Experiment, mg./l.
A	48	0·18	0·50	78
B	48	0·15	0·55	79
C	240	0·30	0·10	53
D	240	0·27	0·08	51
E	None	0·05	No film	52
F	None	0·05	No film	72

Note.—In Specimens *A* and *B* the films at the jet broke down within a few hours, and by 100 hr. the whole jet area was bright. At the end of the run the original film was only present under the holder, the remainder having partially disappeared. There were distinct signs of localized attack all over the specimen where the film had become incomplete.

In *C* and *D* after 24 hr. both specimens had a bright area at the jet which attained its maximum area in a few days. At the end of the run both specimens were still well filmed except for the small area at the jet, to which corrosion appeared to be entirely confined.

In *E* and *F* there was general attack all over the specimens.

In the experiment above, no filmed specimen had resisted attack at the jet for more than 24 hr., and the highly cathodic film on specimens *C* and *D* had concentrated the attack at the jet. The amount of copper in the water was considerably less in *C* and *D* than in *A* and *B*, suggesting that the thicker film, while concentrating attack at the jet, had had a definite protective effect over the rest of the specimen. These experiments show good examples of the two types of film which can be produced by cystine. Specimens *A* and *B* had a generally accelerative film all over their surfaces, while specimens *C* and *D* had thick films which were highly cathodic. The concentrated attack at the jet found on specimens *C* and *D* was an example of the acceleration usually found where mechanical breakdown occurs in a highly cathodic film (see Fig. 3, Plate II).

The reason for the discrepancy in the concentration of copper in solution for the checks is not understood, but corrosion was not confined to the jet, there being general attack all over the specimens.

Since the completion of these experiments on the effects of cystine as a corrosion accelerator of copper-base alloys, a routine examination has been made for the presence of organic sulphur compounds in all service failures sent to the British Non-Ferrous Metals Research Association for examination and report. In many failed tubes from marine condensers organic sulphur has been isolated from the areas o failure. In one case of repeated failure of condenser tubes at a foreign power station using estuarine cooling water contaminated with sewage, the black corrosion product on the tube walls was found to contain a copper–organic disulphide complex, and a violent form of pitting action had been caused by the presence of the organic sulphur.

V.—OTHER INSTANCES OF MICRO-ORGANISMS CAUSING ACCELERATION OF CORROSION.

1. *Sulphate-Reducing Organisms.*

The action of these organisms in the anærobic corrosion of iron is well known and now has an extensive literature. With regard to non-ferrous metals, many cases of acceleration of corrosion owing to the presence of these organisms have been encountered, both in sea water and in fresh water. In the case of non-ferrous metals and alloys, corrosion does not necessarily take place during the activity of the sulphate-reducing organisms, the fact that hydrogen sulphide has been evolved being sufficient to bring about a violently corrosive environment, especially in sea water.

This property of hydrogen sulphide of rendering a sea water abnormally corrosive once it has been evolved by bacterial action, is not entirely understood. It has been found both in laboratory tests and practical failures that sea water containing sulphate-reducing bacteria which have evolved hydrogen sulphide when the water has been stagnant, can remain extremely corrosive although conditions change to considerable aeration and no hydrogen sulphide is chemically detectable in the aerated sea water. The present author has investigated the inhibition of these sulphate-reducing organisms,[37, 38] and the use of dyestuffs of the diaminoacridine (flavine) types has been found very successful.[55]

2. *Slimes and Micro-Biological Deposits.*

The effect of bacteria and various micro-biological activities in causing fouling of ships' hulls received considerable attention during the war, and work reported in recent publications [52, 53, 54] has done much to clear up some doubtful points, such as the toxicity of copper and mercury salts to bio-fouling in general and the problems of leaching rate and succession of organisms. In condensers, both land and marine, the problem of bio-fouling can be extremely important, and much work has been done on the control of such growths.[13, 16, 35] As long as these slimes are alive their main effect is to reduce heat transfer, but when they die and decomposition sets in, corrosion troubles are likely to occur. Several well authenticated cases are known of condenser-tube failures in fighting ships being due to pitting, originally initiated by a mussel causing partial tube stoppage, aggravated by the decomposition of the mussel proteins, with the release of sulphur compounds.

3. *The Decomposition of Paraffin Wax.*

Many corrosion experiments are made using paraffin wax as a sealing agent or as a barrier between liquid and glass, but the present author has shown that bacteria can break it down to carbon dioxide and water, with consequent alteration in the *p*H of the corroding medium, thereby affecting corrosion experiments.[39]

VI.—METHODS OF CONTROL.

Evidence that bacteria can play a part in the corrosion of metals has naturally led to investigation into methods of control. The most obvious method is to destroy the bacteria and so prevent their action. The problem of inhibiting the growth of bacteria under such conditions is difficult because many disinfectants have corrosive properties; also many disinfectants employed against pathogenic organisms, which outside the human body have comparatively little resistance, are of no use against the true water forms unless used in much greater concentration than would be economic or desirable. When a survey is made of the substances which might fulfil the special requirements of this problem, non-corrosive dyestuffs should not be forgotten; in some cases of corrosion by bacteria it may be possible to find specific inhibiting dyes whose small effective concentration would be economic. It has been shown experimentally that a dye such as Gentian Violet can inhibit many types of the bacteria found in sea water which can interfere in corrosion experiments. Inhibition of the sulphate-reducing organisms in closed systems can be successfully carried out by the use of dyes of the diaminoacridine type, a method now being extensively used by some commercial undertakings where the activities of the sulphate-reducing bacteria are detrimental to their products.[38]

These methods are satisfactory when the amount of water is not too great and the system is closed, but in cases where the water is in circulation or where the amount to be treated exceeds the economic limit, the best way of combating bacterial corrosion is by the production of resistant alloys. It must also be pointed out that in many cases the bacterial production of corrosion accelerators occurs in natural waters long before they can be treated in any way, and this again calls for more resistant alloys rather than bactericides.

The use of chlorine in various dosages with and without ammonia is becoming increasingly popular in power-plant operation, and it must be borne in mind that chlorine, while excellent as a slime preventer, is not always a deterrent of indigenous water organisms, which are the ones most likely to cause a corrosive environment, and it may not destroy corrosion accelerators which have been released into a water by bacterial action before the water reached the chlorinating plant.

VII.—Conclusions.

Experiments have been described which show that bacteria, living in waters or other media in contact with metallic structures, can initiate or accelerate corrosion. Local attack can be increased if bacteria are present which produce substances, such as acids or alkalis, which, although insufficient to render a mass of liquid corrosive, can build up local concentrations of corrosive materials in the vicinity of a colony.

It has also been shown that products of bacterial metabolism, such as some organic sulphur compounds, can act as accelerators of pitting action; these substances are often very active in small concentrations and when once released by bacterial action can cause a water to remain abnormally corrosive long after bacterial activity has ceased. It is thought that in some cases bacteria increase corrosion because in the course of their natural metabolism they produce or activate substances which can act as hydrogen acceptors or oxygen carriers, which in their turn affect reactions at the anodes and cathodes of corrosion cells.

Whatever may be the means by which micro-organisms affect corrosion, sufficient experimental work has been completed to show that the corrosive conditions of any environment cannot be assessed by physical and chemical methods alone. The biological aspect must also be taken into account.

ACKNOWLEDGEMENTS.

The author thanks the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish the paper, and his colleagues in the Corrosion Department of the B.N.F.M.R.A for much helpful advice. Some of the work was done in the Bacteriological Department of the Imperial College, and the author records his appreciation of the help and facilities so freely given by Dr. S. E. Jacobs and his staff.

REFERENCES.

1. J. K. Baars, *Dissertation, Delft*, **1930**, 164 pp.
2. T. D. Beckwith, *Gas*, 1945, **21**, (12), 47.
3. G. D. Bengough and R. May, *J. Inst. Metals*, 1924, **32**, 81.
4. H. W. Brownsdon and L. C. Bannister, *J. Inst. Metals*, 1932, **49**, 123.
5. C. L. Bulow, *J. New England Water Works Assoc.*, 1945, **59**, 163.
6. J. H. Bunker, " A Review of the Physiology and Biochemistry of the Sulphur Bacteria ". London : **1936** (H.M.S.O.).
7. J. H. Bunker, *Proc. Brit. Assoc. Refrig.*, 1936–37, **33**, (1), 151.
8. J. H. Bunker, *J. Soc. Chem. Ind.*, 1939, **58**, 93.
9. J. H. Bunker, *Chem. and Ind.*, 1940, **59**, 412.
10. J. H. Bunker, *Proc. Soc. Agr. Bact.*, 1942, **13**, 8.
11. D. H. Caldwell and J. B. Ackerman, *J. Amer. Water Works Assoc.*, 1946, **38**, 61.
12. S. W. Cole, " Practical Physiological Chemistry ". Cambridge : **1933** (Heffer and Sons, Ltd.).
13. J. G. Dobson, *Trans. Amer. Soc. Mech. Eng.*, 1946, **68**, 247.
14. J. M. Drabelle, *Power Plant Eng.*, 1944, **48**, 122.
15. Fritz Feigl, *Chem. and Ind.*, 1938, **57**, 1161.
16. C. W. Fritz, *Pulp Paper Mag. Canada*, 1938, **39**, 739.
17. P. Ganser, *Gas J.*, 1940, **231**, 371.
18. J. H. Garrett, " The Action of Water on Lead ". London : **1891** (H. K. Lewis, Ltd.).
19. R. Grant, E. Bate, and W. H. Myers, *Inst. Eng. Australia, Sydney Div.*, **1921**, Paper No. 8.
20. W. L. Haase, *Korrosion u. Metallschutz*, 1940, **16**, 155.
21. W. L. Haase, *Wasser*, 1941–42, **15**, 258.
22. R. F. Hadley, *Oil Gas J.*, 1939, **38**, (19), 92.
23. R. F. Hadley, *Bull. Tech. Sect. Amer. Gas Assoc.*, **1940**, 23 pp.

24. H. W. Harvey, " Recent Advances in the Chemistry and Biology of Sea Water ". Cambridge : **1945** (Cambridge University Press).
25. H. W. Harvey, *J. Marine Biol. Assoc.*, 1939, **23**, 499.
26. L. F. Hewitt, " Oxidation–Reduction Potentials in Biochemistry and Bacteriology ". London : **1936** (London County Council).
27. J. C. Hill, *J. Amer. Water Works Assoc.*, 1946, **38**, (8), 980.
28. H. Kylin, *Z. physiol. Chem.*, 1915, **49**, 371.
29. T. E. Larson, *J. Amer. Water Works Assoc.*, 1939, **31**, (7), 1186.
30. C. C. Lucas and J. M. R. Beveridge, *Biochem. J.*, 1940, **34**, 1356.
31. R. May, *J. Inst. Metals*, 1928, **40**, 141.
32. A. Mazur and H. I. Clarke, *J. Biol. Chem.*, 1938, **123**, 729.
33. K. A. H. Mörner, *Z. physiol. Chem.*, 1901, **34**, 207.
34. V. K. Nizovkin and N. Skroznikova, *Trans. VI Mendeleev Congr.*, 1932, **2**, (1), 782 (1935).
35. W. J. O'Connell, Jr., *Refiner Natural Gasoline Manuf.*, 1941, **20**, 223.
36. N. W. Pirie, *Biochem. J.*, 1931, **25**, 614.
37. T. H. Rogers, *J. Soc. Chem. Ind.*, 1940, **59**, 34.
38. T. H. Rogers, *J. Soc. Chem. Ind.*, 1945, **64**, 292.
39. T. H. Rogers, *Nature*, 1943, **152**, 105.
40. S. M. Rosenthal and Carl Voegtlin, *U.S. Public Health Rep.*, 1933, **48**, (14), 347.
41. R. L. Starkey, *J. Amer. Water Works Assoc.*, 1945, **37**, (10), 963.
42. R. L. Starkey and K. M. Wight, *Amer. Gas. Assoc.* (*Final Rep. Iron Corrosion Research Fellowship*), **1945**, 108 pp.
43. J. Stenhouse, *Chem. Soc. Memoirs*, (II), **1843–45**, 136.
44. A. C. Thaysen, *J. Inst. Petroleum*, 1939, **25**, 411.
45. A. H. Thomas, *Water Works and Sewerage*, 1942, **89**, (a), 367.
46. C. A. H. von Wolzogen Kühr, *Water en Gas*, 1923, **7**, 277.
47. C. A. H. von Wolzogen Kühr and L. S. van der Vlugt, *Water* (*Netherlands*), 1934, **16**, 147.
48. S. A. Waksman, D. B. Johnstone, and C. L. Carey, *J. Marine Research*, 1943, **5**, 136.
49. H. E. Watts, " Explosion in Petroleum Spirit Tank at Saltend, Hull, Yorkshire ". London : **1936** (H.M.S.O.).
50. Carl Wilson, *J. Amer. Water Works Assoc.*, 1945, **37**, 52.
51. O. B. Wilson, *Water and Water Eng.*, 1945, **48**, 594.
52. First Report of the Marine Corrosion Sub-Committee, *J. Iron Steel Inst.*, 1943, **147**, 339.
53. " Fouling of Ships' Bottoms " : Marine Corrosion Sub-Committee, *J. Iron Steel Inst.*, 1944, **150**, 143.
54. Report on Anti-Fouling Research 1942–44, *J. Iron Steel Inst.*, 1946, **154**, 197 P.
55. Sydney G. Paine and T. Howard Rogers, " Improved Method for Preventing Corrosion and Contamination by the Action of Sulphate-Reducing Bacteria " : British Non-Ferrous Metals Research Association, *Brit. Patent Specification* No. 497,829 (Dec. **1938**).

1141

THE CONSTITUTION OF ALUMINIUM-MAGNESIUM-ZINC-CHROMIUM ALLOYS AT 460° C.*

By (Miss) K. LITTLE,† M.A., B.Sc., Student Member, H. J. AXON,‡ D.Phil., B.Met., Student Member, and W. HUME-ROTHERY,§ M.A., D.Sc., F.R.S., Member.

Synopsis.

The constitution of the aluminium-rich alloys of the system Al–Mg–Zn–Cr at 460° C. has been investigated, the maximum amounts of added materials being 20% of magnesium and 10% each of zinc and chromium. In the ternary system Al–Cr–Zn the $CrAl_7$ phase of the binary system Al–Cr can take up zinc into solid solution, and the resulting phase is a stable phase in most alloys containing more than small percentages of chromium. In the cast state many of these alloys contain crystals of the Cr_2Al_{11} phase surrounded by sheaths of $CrAl_7$, and annealing periods of the order of 2 months are required for the removal of the Cr_2Al_{11}. In the ternary system Al–Cr–Mg the stable phases in the alloys examined are $CrAl_7$ and a ternary phase of variable composition denoted E, and the same phases are found in quaternary alloys containing 2% and 8% zinc.

I.—Introduction.

Previous papers[1, 2, 3, 4, 5] have described the constitution of Al–Mg–Mn–Zn alloys at different temperatures, while the effect of 1% silicon on these alloys has also been studied.[6, 7] In order to understand the effect of chromium on this class of alloy, it is necessary first to determine the constitutional diagrams of the various quaternary systems which are involved, and the present paper describes an investigation of the constitution of Al–Mg–Zn–Cr alloys at 460° C., as determined by the microscopic examination of alloys after annealing at this temperature, the maximum amounts of added materials being 20% of magnesium and 10% each of zinc and chromium. Some confirmatory X-ray diffraction results are also included. With aluminium-rich alloys it has been possible to obtain conditions of true equilibrium by annealing treatments of the order of 2–3 weeks, but with some of the other alloys it has been found that when chromium is present, equilibrium cannot be obtained even after annealing treatments of many weeks.

---

* Manuscript received 3 March 1948.

† British Nylon Spinners, Ltd., Coventry; formerly Inorganic Chemistry Laboratory, Oxford.

‡ Metallurgy Section, A.E.I. Laboratory, Aldermaston, near Reading; formerly Inorganic Chemistry Laboratory, Oxford.

§ Royal Society Warren Research Fellow, Oxford.

II.—EXPERIMENTAL DETAILS.

1. *Materials Used.*

The aluminium used in the present work was super-purity metal kindly presented by the British Aluminium Company, Ltd. The zinc was from special zinc given by the National Smelting Corporation, to whom the authors must express their thanks. Spectrographic analysis showed that the metal contained the following impurities: lead 0·001, cadmium 0·001, copper 0·0016, iron 0·001, and zinc (by difference) 99·995%. The magnesium, of Canadian origin, was of 99·96% purity, and was supplied by the Light Metals Control Board. The chromium was introduced into the alloys in the form of master alloys, one of which was given by the National Physical Laboratory and the other by the British Aluminium Company, Ltd. The analyses of these two alloys are given below:

Source of Alloy.	Chromium, %.	Silicon, %.	Iron, %.	Copper, %.
N.P.L.	8·6	0·002	0·003	...
British Aluminium Company .	9·5	0·004	0·0025	0·001

2. *Preparation and Annealing of Alloys.*

The alloys were melted in crucibles lined with an alumina–fluorspar mixture, the general policy being to melt the aluminium and aluminium–chromium master alloy first, and then to add the zinc and magnesium. The whole was thoroughly stirred with an alumina stirrer, and was cast as soon as possible into a heavy copper mould to give an ingot of $\frac{3}{8}$ or $\frac{5}{16}$ in. dia. The alloys were sealed in evacuated hard glass tubes and were then annealed in tubular electric resistance furnaces controlled by Foster temperature regulators. The details of preparation and annealing technique have been described in previous papers.[1, 3, 5]

3. *Microscopic Examination of Alloys.*

The alloys were sectioned with a fine-toothed hacksaw and were then ground by hand and polished, the general methods being similar to those described in earlier papers.[1, 3, 5] The micro-constituents encountered in the ternary Al–Cr–Zn alloys were the α solid solution in aluminium and the two compounds $CrAl_7$ and Cr_2Al_{11}, of which the latter disappeared after long periods of annealing and was thus not an equilibrium constituent of the alloys concerned.

The compounds $CrAl_7$ and Cr_2Al_{11} are both hard and unreactive and appear as grey particles, often in considerable relief in the unetched section. The particles of $CrAl_7$ are stained only by comparatively violent etching reagents. Of these the most suitable were found to be a hot 1% aqueous solution of caustic soda or a hot alkaline permanganate solution. The latter consisted of 1 part of $2N$-sodium hydroxide and 10 parts of $N/10$-potassium permanganate, and was used at 60°–70° C. This solution deteriorates rapidly and must be prepared fresh for each alloy. When the two compounds are present in the same alloy, the general tendency is for the $CrAl_7$ to be attacked and stained more readily than the Cr_2Al_{11}, but the distinction is not always reproducible, and repeated etching and polishing is desirable before a conclusion is reached. Both the above-mentioned reagents are suitable for this purpose, and the alkaline permanganate solution is on the whole more reliable. Fig. 1 (Plate III) shows the microstructure of an alloy containing 7·65% chromium and 10·22% zinc after annealing for 26 days at 460° C. The micro-section shows one crystal of Cr_2Al_{11} surrounded by a sheath of $CrAl_7$, together with numerous crystals of the latter compound. This specimen was heavily etched with alkaline permanganate with the result that the α solid solution has been stained.

In the ternary system Al–Cr–Mg the phases encountered were the α solid solution, $CrAl_7$, a ternary phase denoted E, and chilled liquid. The ternary phase E is softer than $CrAl_7$, and in unetched sections it appears whiter in colour and in less relief than $CrAl_7$. E is not attacked by nitric or sulphuric acids, but is outlined by a 1-min. swab etch with 1% aqueous hydrofluoric acid. It may be distinguished from $CrAl_7$ by the alkaline permanganate reagent referred to above. With this reagent, $CrAl_7$ gives a brown tarnish and is more heavily attacked than the E phase, which shows at first a whitish blue-grey colour and turns brown only on prolonged etching. The chilled liquid in these alloys is revealed as a characteristic duplex structure by etching in concentrated nitric acid or by swabbing for 30 sec. in 1% aqueous hydrofluoric acid. Fig. 2 (Plate III) shows the microstructure of an alloy containing approximately zinc 2, magnesium 3, and chromium 6% after annealing for 33 days at 460° C. The section is polished but unetched and shows the α solid solution together with crystals of $CrAl_7$ surrounded by E.

III.—DESCRIPTION AND DISCUSSION OF RESULTS.

In order to appreciate the results it is necessary to consider first the equilibrium diagrams of the binary systems Al–Mg and Al–Cr, and these are reproduced in Figs. 3 and 4. In the system Al–Mg at 460° C. the phases met with in the range of composition with which the present paper is concerned are the α solid solution of magnesium in aluminium, and the liquid phase. The solidus point of the α solid solution at

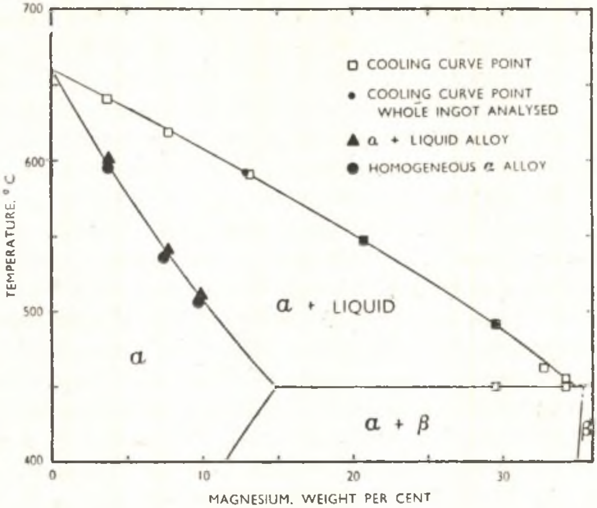


FIG. 3.—The Equilibrium Diagram of the System Aluminium–Magnesium.

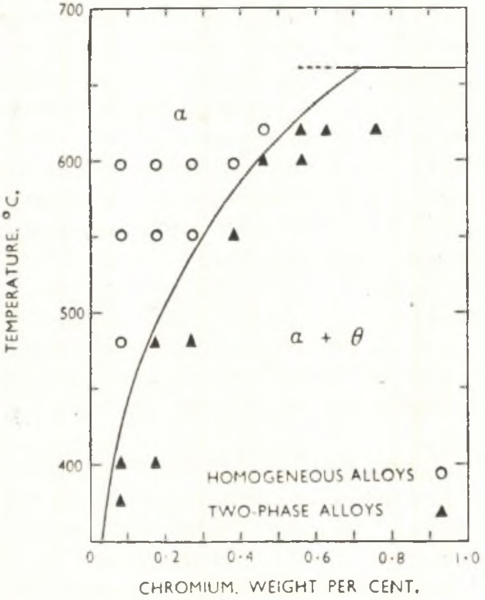


FIG. 4.—The Equilibrium Diagram of the System Aluminium–Chromium. (After Raynor and Little.)

FIG. 1.—Microstructure of an Alloy Containing 7·65% Chromium and 10·22% Zinc After Annealing for 26 Days at 460° C. × 1000.

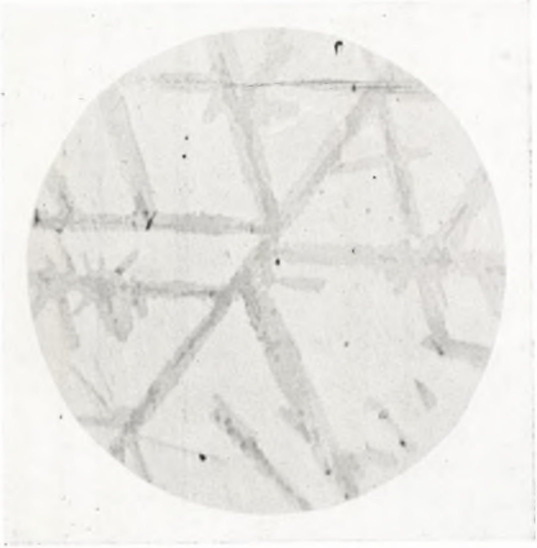


FIG. 2.—Microstructure of an Alloy Containing Approximately Zinc 2, Magnesium 3, and Chromium 6% After Annealing for 33 Days at 460° C. × 1000.

460° C. lies at approximately 14% magnesium.[8] In the system Al–Zn the alloys concerned are all within the α solid-solution range at 460° C. The system Al–Cr has been studied by Raynor and Little,[9] according to whom the solid solubility of chromium in aluminium decreases from 0·72% chromium at 660° C. to 0·13% chromium at 460° C.

1. *The System Aluminium–Chromium–Zinc.*

No previous detailed examination of this system appears to have been made, and the alloys whose compositions are represented by squares in Fig. 5 were therefore prepared and annealed for 26 days at 460° C. After this treatment the alloys represented by the symbols ⧅ and ⧄ were found to consist of the α solution together with $CrAl_7$ and traces of Cr_2Al_{11}. It seemed very improbable that this could represent a true equilibrium condition, and the four alloys marked ⧄ were therefore given a further annealing treatment of 31 days, making a total of 57 days at 460° C. After this further treatment, the Cr_2Al_{11} phase had disappeared, and the alloys were of the ($\alpha + CrAl_7$) type. It is thus clear that the traces of the Cr_2Al_{11} found in the alloys after the 26-day anneal were due to lack of equilibrium, and this was confirmed by the fact that inconsistent results were obtained when attempts were made to determine the tie lines by measurements of the lattice spacings of the α phase in the alloys annealed for periods of the order of 4 weeks. The results for the four alloys marked ⧄ suggest that in the true equilibrium state the alloys shown in Fig. 5 will all be of the ($\alpha + CrAl_7$) type. Examination

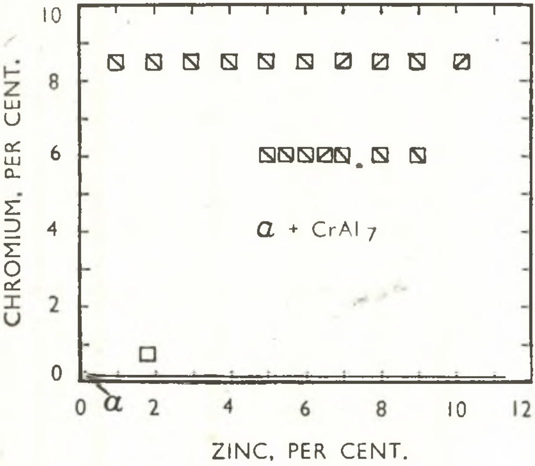


Fig. 5.—Alloys Examined in the System Aluminium–Chromium–Zinc.

showed that in the alloys containing 8·5 and 6% of chromium the Cr_2Al_{11} phase was present in the original castings, and that in many cases the particles of Cr_2Al_{11} were surrounded by a sheath of $CrAl_7$; it seems probable that this is one of the reasons for the sluggishness of the reaction $\alpha + Cr_2Al_{11} = CrAl_7$.

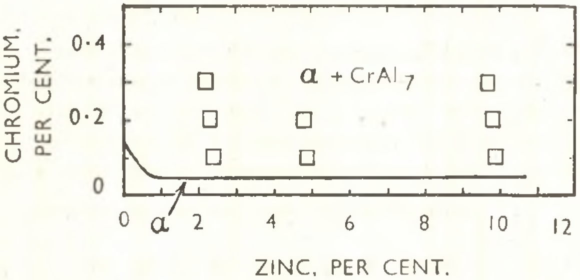


FIG. 6.—The System Aluminium–Chromium–Zinc. Equilibrium diagram of aluminium-rich alloys at 460° C.

In Fig. 5, the one alloy marked □, together with others of low chromium content, contained no particles of Cr_2Al_{11} in the original casting, and these alloys appeared to reach equilibrium very much more rapidly. In Fig. 5 there is a very narrow area at the bottom of the diagram, representing the homogeneous α solid solution, but this is too restricted to be shown on the scale of the diagram. Fig. 6 shows the results obtained in this region of composition for the structures of alloys annealed at 460°C,

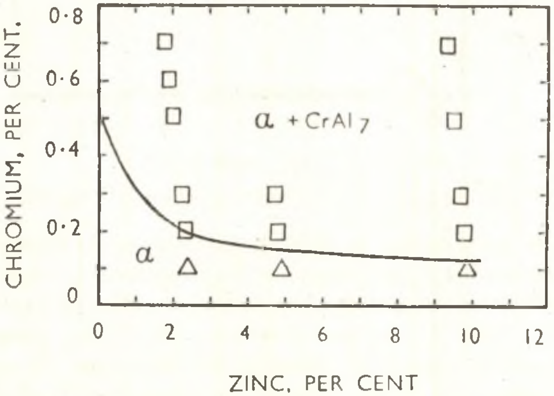


FIG. 7.—The System Aluminium–Chromium–Zinc. Equilibrium diagram of aluminium-rich alloys at 620° C.

for 21 days, while Fig. 7 shows the solubility curve * at 620° C. as determined by annealing treatments of 12 days. It will be seen that at each temperature the solubility of chromium is diminished by the addition of zinc. These alloys were not analysed because other experiments had shown that with small percentages of chromium, the intended compositions were attained to a high degree of precision.

The microscopic work thus showed that under conditions of true equilibrium the stable phases in the alloys examined were α and $CrAl_7$, although in the alloys of higher chromium content Cr_2Al_{11} is present in the cast ingots and is removed only by very prolonged annealing. The absence of any other phases was confirmed by the fact that Debye–Scherrer films of several poly-phase alloys contained only the lines characteristic of the α, $CrAl_7$, and Cr_2Al_{11} phases. In view of the difficulties of obtaining true equilibrium in these alloys, attempts to determine tie lines from lattice-spacing measurements were discarded, but as some work in this connection suggested a variation in the composition of the $CrAl_7$ phase, it was thought of interest to examine the composition of crystals of this compound extracted electrolytically from slowly cooled alloys, using the method of Raynor and Hume-Rothery.[2] The results of this work are given in Table I, from which it will be seen that the "$CrAl_7$" phase is able to take up zinc into solid solution, the percentage increasing with the zinc content of the melt.

TABLE I.

Composition of Melt.		Percentages of Chromium and Zinc in Extracted Crystals of "$CrAl_7$".	
Cr, %.	Zn, %.	Cr, %.	Zn, %.
3·0	2·0	22·94	0·18
1·6	3·0	21·05	1·40
1·0	4·0	22·0	1·91
1·0	10·0	24·23	2·81

2. *The System Aluminium–Chromium–Magnesium.*

The equilibrium diagram of this system has been investigated by Erdmann-Jesnitzer,[10] whose results are in substantial agreement with those of the present work as far as the general form of the diagram is concerned. The present results are shown in Fig. 8, which covers the range 0–20% magnesium and 0–10% chromium. Most of the alloys

---

* For the experiments at 620° C. the alloys were enclosed in alumina collars inside sealed glass tubes in order to prevent contact between the alloy and the glass.

shown in this diagram were annealed for periods of 16–25 days, but the critical alloys which were near to the boundary of a phase field were annealed for one month at 460° C. The alloys whose compositions are indicated by full squares or triangles are those which were analysed after the annealing treatment. The analytical results showed that the intended composition was attained satisfactorily provided that the chromium and magnesium contents were each less than about 5%. With higher percentages of these elements there was a tendency for magnesium to be lost in melting, particularly when the chromium content was high. These alloys are therefore represented in the diagram by open squares and triangles with arrows pointing in the direction of lower magnesium content. It must be emphasized that such points do not indicate the actual composition of the alloys concerned, but the points are included in the diagram as evidence that the whole region of composition was explored thoroughly in order to ensure that no additional phases were present.

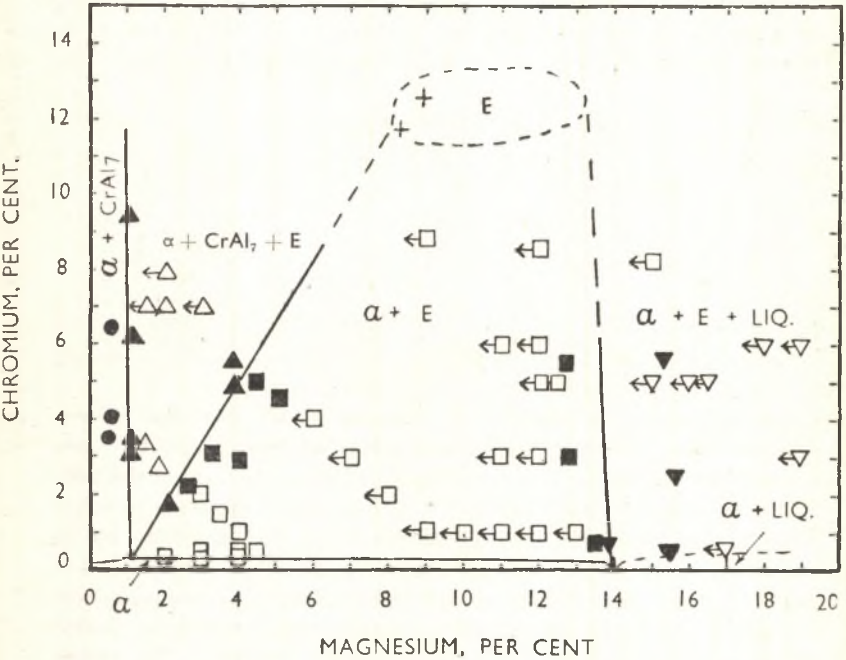


FIG. 8.—The System Aluminium–Chromium–Magnesium. Equilibrium diagram of aluminium-rich alloys at 460° C.

From Fig. 8 it will be seen that the solid phases met with in the range of composition concerned are (1) the α solid solution, (2) the $CrAl_7$ phase of the binary system Al–Cr, (3) a ternary phase denoted *E* which is of variable composition, and (4) the liquid phase. The phase fields lie in regular order as shown, and the results for aluminium-rich alloys are shown on a larger scale in Fig. 9, which includes points for some alloys whose compositions are too close together to be shown in Fig. 8. The apex of the 3-phase (α + $CrAl_7$ + *E*) triangle meets the α solid-solubility curve at the point corresponding with 1·1% magnesium and 0·3% chromium. A measurement was made of the lattice spacing of the α phase in an annealed 3-phase (α + $CrAl_7$ + *E*) alloy, and this confirmed the composition of the α corner of the 3-phase triangle.*

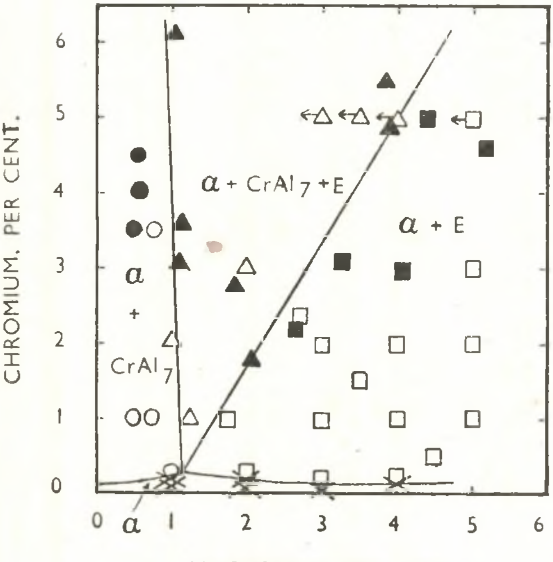


Fig. 9.—The System Aluminium–Chromium–Magnesium. Equilibrium diagram of aluminium-rich alloys at 460° C.

As shown in Fig. 8, the *E* phase is of variable composition. The two points marked + represent the compositions of crystals of *E* extracted electrolytically by the method of Raynor and Hume-Rothery [2] from slowly cooled melts of ternary alloys. The details of the extraction are given in Table II, and it will be seen that the compositions of the two extracts lie almost exactly on the (α + $CrAl_7$ + *E*/α + *E*) side of the

---

* As shown by Axon and Hume-Rothery,[12] the lattice spacing/composition curve in the system aluminium–magnesium is not linear in the region 0–2% magnesium.

3-phase triangle as deduced by microscopic work. The direction of the ($\alpha + E/\alpha + E +$ liq.) phase-field boundary suggests that the E phase is of variable composition, and this was confirmed by the fact that the lattice spacings of E were not constant. The crystal structure of E is cubic, with lattice spacing $a = 14{\cdot}65$ kX., and the unit cell probably contains 16 molecules of $CrMg_2Al_{12}$. Details of a goniometric and X-ray study of crystals of the E phase are being described elsewhere.[11]

TABLE II.

Composition of Melt from which Crystals of E were Extracted Electrolytically.		Composition of Extracted Crystals.	
Cr, %.	Mg, %.	Cr, %.	Mg, %.
3·0	15·0	12·6	8·8
3·0	25·0	11·8	8·2

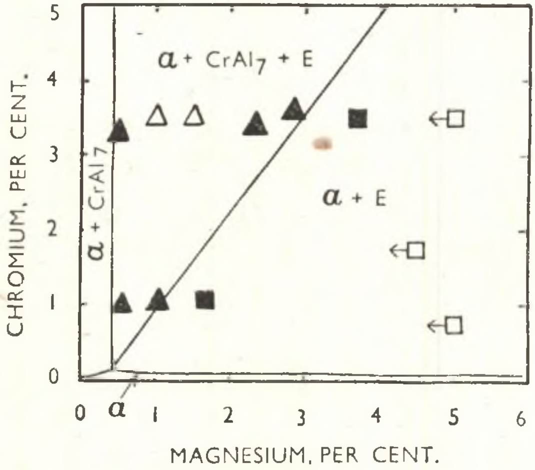


FIG. 10.—The System Aluminium–Chromium–Zinc–Magnesium. Equilibrium diagram of aluminium-rich alloys containing 8% zinc at 460° C.

3. *The Quaternary System Aluminium–Magnesium–Zinc–Chromium.*

In studying the quaternary system it was found convenient to prepare alloys with constant percentages of zinc, and to anneal them for one month at 460° C. In this way, if we regard the ternary system Al–Cr–Mg of Fig. 9 as lying in the basal plane of a quaternary model, we obtain the structures on horizontal sections across the model at constant percentages of zinc. Fig. 10 shows the structures of aluminium-rich alloys containing

8% zinc; the symbols in this diagram have the same meaning as those in Fig. 9. Within the range of composition covered by this diagram, no new phases are introduced, and the phase fields lie in the regular sequence ($\alpha + CrAl_7$), ($\alpha + CrAl_7 + E$), ($\alpha + E$), and α; the boundary between the ($\alpha + E$) and ($\alpha + E +$ liq.) fields was not investigated. The general form of the diagram in Fig. 10 is similar to that of Fig. 9, but the ($\alpha + CrAl_7$) field is slightly narrowed. In the ternary system Al–Mg–Zn, alloys containing 8% zinc can dissolve up to 4·8% magnesium before the α solid-solubility curve is exceeded, and with higher percentages of magnesium the alloys are of the ($\alpha + T$) type, where T denotes the ternary phase which is usually called $Al_2Mg_3Zn_3$, although it is actually of widely variable composition. It follows therefore that in Fig. 10 the ($\alpha/\alpha + T$) boundary will lie at 4·8% magnesium on the base of the Figure and that with higher contents of magnesium there will be an ($\alpha + T + E$) triangular field. In the present investigation the alloys examined did not contain sufficient magnesium for the T phase to have been encountered.

A series of 26 quaternary Al–Mg–Zn–Cr alloys containing 2% zinc was also prepared and annealed for 1 month at 460° C. Using the synthetic compositions, the observed microstructures were plotted in a diagram analogous to Fig. 10, and in this diagram the boundaries between the phase fields were identical with those of Fig. 9. In view of the very small displacement of the boundaries produced by 8% zinc, we may expect the effect of 2% zinc to be extremely small, and as this was confirmed by the diagram based on synthetic compositions, the alloys containing 2% zinc were not analysed. In general, therefore, the structures of the quaternary alloys containing up to 8% zinc are simple and can be readily understood, and interpolation may be used between Fig. 9 (0% zinc) and Fig. 10 (8% zinc).

As a matter of interest, crystals of the E phase were extracted electrolytically from a slowly cooled quaternary alloy containing chromium 3, magnesium 15, and zinc 1·5%. The analysis of these crystals indicated that they contained chromium 13·2, magnesium 12·2, and zinc 0·7%. Comparison of these figures with those obtained from the ternary Al–Cr–Mg alloys (see p. 50) shows that the magnesium content of the E phase can vary considerably, and that some zinc can be taken into solid solution.

ACKNOWLEDGEMENTS.

The authors must express their gratitude to Professor Sir Cyril Hinshelwood, F.R.S., for laboratory accommodation and many other facilities which have greatly encouraged the present research.

REFERENCES.

1. E. Butchers, G. V. Raynor, and W. Hume-Rothery, *J. Inst. Metals*, 1943, **69**, 209.
2. G. V. Raynor and W. Hume-Rothery, *J. Inst. Metals*, 1943, **69**, 415.
3. A. T. Little, G. V. Raynor, and W. Hume-Rothery, *J. Inst. Metals*, 1943, **69**, 423.
4. A. T. Little, G. V. Raynor, and W. Hume-Rothery, *J. Inst. Metals*, 1943, **69**, 467.
5. A. T. Little, W. Hume-Rothery, and G. V. Raynor, *J. Inst. Metals*, 1944, **70**, 491.
6. H. J. Axon and W. Hume-Rothery, *J. Inst. Metals*, 1948, **74**, 315.
7. H. J. Axon, E. Butchers, and W. Hume-Rothery, *J. Inst. Metals*, 1948, **74**, 330.
8. E. Butchers and W. Hume-Rothery, *J. Inst. Metals*, 1945, **71**, 291.
9. G. V. Raynor and K. Little, *J. Inst. Metals*, 1945, **71**, 481.
10. F. Erdmann-Jesnitzer, *Aluminium-Archiv*, 1940, (**29**).
11. K. Little (to be published).
12. H. J. Axon and W. Hume-Rothery, *Proc. Roy. Soc.*, 1948, [A], **193**, 1.

METALLURGICAL ABSTRACTS

AUTHOR INDEX TO ABSTRACTS

Author Index to Abstracts

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 16 SEPTEMBER 1948 Part 1

I.—PROPERTIES OF METALS

***Stressed Aluminium.** E. A. Owen, Y. H. Liu, and D. P. Morris (*Nature*, 1948, **161**, (4096), 681–682).—Note reporting variations of lattice parameter of pure aluminium after release of compression. The parameter suddenly increased and then decreased exponentially to a metastable value independent of the amount of compression, but still in excess of the normal value (only regained on subsequent annealing). X-ray examination showed that the effect was connected with recrystallization and residual stresses in the material.—M. B. W.

Beryllium and Beryllium Bronze (Beryllium Copper). (Gadeau). See p. 7.

***On the Transformation of Cerium at High Temperature.** Jean Loriers (*Compt. rend.*, 1948, **226**, (12), 1018–1019).—L. considers that the divergencies of previous workers on the transformation of cerium are due to the relative impurity of the specimens used. He has investigated by differential thermal analysis from 20° C. to the m.p. of cerium (815° C.), three specimens containing: (1) cerium 99·6, iron 0·0005, silicon 0·4%; (2) cerium 99·6, iron 0·03, silicon 0·35%; (3) cerium 99·55, iron 0·22%, + small amounts of other metals (not silicon). He found three endothermic effects, the first (at increasing temp.) at between 540° and 640° C. according to the specimen used; the second at 710°; and the third at about 740° C. This result confirms the dilatometric observations of F. Trombe and M. Foëx on iron-free cerium, but is in contradiction to those of Jaeger and others. L. considers that it is thus established that, in the absence of iron, there is a transformation of cerium at about 640° C., and that it is probable that there are many transformations in the pure metal between 600° C. and its m.p.—J. H. W.

***Thermal Conductivity of Copper and German Silver at Liquid Helium Temperatures.** J. F. Allen and E. Mendoza (*Proc. Camb. Phil. Soc.*, 1948, **44**, (2), 280–288).—Thermal conductivities increase with temp. in the range 0°–4° K., being below the max. value predicted from formulæ derived by Makinson and others. For copper, the results agree with the predicted form L_0T/ρ_0 (L_0 = Lorenz number, ρ_0 = residual electrical conductivity) and lie on a straight line, though the slope is 1·4 times too large. Extrapolation indicates that copper will have a conductivity at 0·01° K. comparable with the room-temp. conductivity of German silver, and that it has sufficient for magnetic cooling experiments involving heat transfer through metals, even in strong magnetic fields. For German silver, the conductivity depends on T^3, indicating that lattice conductivity is mainly responsible. A. and M. found poor conductivity between the metal surface and the bulk of the liquid.
—M. B. W.

Properties of the Rarer Metals: Germanium. —— (*Canad. Metals*, 1947, **10**, (1), 37).—A brief survey.—R. L. B.

Properties of the Rarer Metals: Indium. —— (*Canad. Metals*, 1947, **10**, (1), 37–38).—A brief review.—R. L. B.

Properties of the Rarer Metals: Iridium. —— (*Canad. Metals*, 1947, **10**, (5), 42).—A brief account.—R. L. B.

---

* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

***Influence of Various Factors on the Creep of Lead.** J. Neill Greenwood and J. H. Cole (*Metallurgia*, 1948, **37**, (222), 285–289).—Cf. *Met. Abs.*, 1948, **15**, 138. The tests described were designed to investigate the influence of steady stress at ordinary temp. and at 50° C., and of steady stress and previous heat-treatment at ordinary temp. with a superposed fluctuating tensile stress, on the creep of lead. With a simple tensile stress, creep curves plotted over periods up to about nine years showed a marked increase in strain rate over a critical stress—the " creep yield stress "—which was 300 lb./in.^{2} at 15°–20° C., and 250 lb./in.^{2} at 50° C. The effect of superposing a gentle 50-cycle alternating stress was markedly to increase the rate of stretch, but the vibration also accelerated the recrystallization of the lead, accompanied by a greatly increased grain-size. Annealing at 120° C. for 24 hr. led to a marked stabilization of the crystal structure, which was reflected in the rates of stretch observed. A comparison of these results, which were obtained on lead containing 0·009% total impurities, with the work of other observers indicates that less-pure leads crept at a slower rate.—M. A. V.

Manufacture of Lead Shot. Merritt A. Williamson (*Metal Progress*, 1947, **52**, (3), 393).—W. directs attention to a paper by Tammann and Dreyer (*Z. Metallkunde*, 1933, **25**, 64; *J. Inst. Metals*, 1933, **53**, 299) in which it is stated that addition of arsenic improves the roundness of lead shot by forming lead arsenite with the layer of lead oxide which would otherwise prevent the shot from becoming round.—N. B. V.

***Metastable States of Nickel Characterized by a High Initial Permeability.** J. L. Snoek and J. F. Fast (*Nature*, 1948, **161**, (4101), 887).—With pure annealed nickel, the initial permeability for a sample which has been taken through a temp. cycle has an abnormally high value that is reduced by mechanical shock or vibration or by demagnetizing treatments.—M. B. W.

***Catalytic Poisons and Magnetic Susceptibility [of Palladium].** M. H. Dilke, D. D. Eley, and E. B. Maxted (*Nature*, 1948, **161**, (4099), 804).—Preliminary measurements on the change in magnetic susceptibility of palladium due to dimethyl sulphide. About one electron enters the *d*-band of the metal.—M. B. W.

The Metals of the Platinum Group. C. A. H. Jahn (*Metallurgia*, 1948, **37**, (222), 307–310).—A general account is given of the manufacture, properties, and uses of platinum, iridium, osmium, ruthenium, rhodium, and palladium. —M. A. V.

Strontium. —— (*Canad. Metals*, 1947, **10**, (8), 19, 34).—A brief account of properties and uses.—R. L. B.

The Use of Zirmet for Gas Absorption. W. M. Raynor (*Foote Prints*, 1947, **18**, (2), 22–24).—R. discusses the gas-absorbing properties of zirconium. —A. I. V.

Tensile Strength of Metals. —— (*Chem. Age*, 1947, **57**, (1460), 17).—An extract from the Williams Lecture to the Institute of British Foundrymen by Sir Edward Appleton (see *Met. Abs.*, 1948, **15**, 132).—S. R.

†Mechanical Properties of Metals at Low Temperatures: A Survey. L. Seigle and R. M. Brick (*Trans. Amer. Soc. Metals*, 1948, **40**, 813–861; discussion, 861–869).—See *Met. Abs.*, 1948, **15**, 226.—R. W. R.

The Rheological Properties of Matter Under High Pressure. P. W. Bridgman (*J. Colloid Sci.*, 1947, **2**, (1), 7–16).—A study of rheological properties of matter, whereby are understood those properties which play a role when a body receives permanent alteration of geometrical configuration without fracture. Such permanent alterations of shape follow the application of shearing stresses. In the case of solids, permanent deformation does not occur until the shearing stress rises above some threshold value, the relevant property of the solid being designated generically as plasticity. The study of hydrostatic pressure effects is of considerable significance as to the underlying mechanisms.—A. I. V.

Summarized Proceedings of Conference on the Rheology of Solids—Birmingham 1947. —— (*J. Sci. Instruments*, 1947, **24**, (12), 309–312).—A report of a conference on experimental rheology with particular reference to rigidity and hardness. *E. Orowan* spoke on transformations in solids, and described the physical basis of nucleation and growth phenomena, and that of transformation by shear, as in martensite. In the latter, surface energy plays only a minor role in producing supersaturation, because the two phases lie on each other along planes of nearly identical structure. Since the elastic energy which represents the energy barrier in strain transformations is proportional to the transformed volume, there is no stable size for nuclei and no nuclei in the usual sense of the word. Other characteristics of the martensite type of transformation were discussed. *H. O'Neill* reviewed methods and instruments for measuring hardness, discussing accuracy and degree of reproducibility. The dependence of the work-hardening in the region of the indentation on the type of indenter was discussed, and research methods adopted to minimize work-hardening effects were reviewed. *W. A. Gurney* discussed hardness testing of rubber, and *R. Hill*, *S. J. Tupper*, *E. H. Lee*, and *D. Tabor* described experiments on wedge indentation and theories of static and dynamic hardness. Each contribution was followed by discussions, which are briefly noted.—G. V. R.

***Internal Stresses in Metals.** W. A. Wood and N. Dewsnap (*Nature*, 1948, **161**, (4096), 682–683).—Note discussing a suggestion by Greenough (*Nature*, 1947, **160**, 258; *Met. Abs.*, 1948, **15**, 340) that Wood's X-ray measurements on metal subjected to plastic deformation could be explained by intergranular stresses. W. and D. reject the suggestion by an argument assuming that the stress experienced by a grain depends mainly on its neighbours. Experiments showed that the internal stresses were irregular in magnitude and independent of the direction of the previously applied stress. Also, measurements of the mean diameter of broadened diffraction rings showed no appreciable change.—M. B. W.

Internal Stresses in Metals. G. B. Greenough (*Nature*, 1948, **161**, (4096), 683).—Cf. preceding abstract. Further note, in which G. assumes that the intergranular stress depends equally upon the yield tension in the grain and that of its neighbours. G. considers that experimental observations support his hypothesis and that successful numerical interpretation has been obtained (*Inst. Metals Monograph and Rep. Series* No. **5**, p. 377). Reference is made to the application of the hypothesis to Wood and Rachinger's work on line broadening with iron filings (*Nature*, 1948, **161**, 93; *Met. Abs.*, 1948, **15**, 575).
—M. B. W.

***Influence of Plastic Extension and Compression on the Fracture Stress of Metals.** D. J. McAdam, Jr., G. W. Geil, and W. D. Jenkins (*Amer. Soc. Test. Mat. Preprint* No. **30**, 1947, 19 pp.; and (abridged) *Mech. World*, 1947, **122**, (3169), 373–374).—Results of longitudinal and transverse tests on cold-extended metal, and of tensile tests on previously compressed cylindrical bars showed that the general effect of plastic deformation on the fracture stress is a work-hardening effect similar to the effect on the flow stress. The authors found no boundary between brittle fracture and fibrous fracture. During the investigation, thousands of fractures with widely varying ductility were examined, and a detailed study of the propagation of the cracking preceding fracture was made. The difference between the longitudinal and transverse yield points illustrates the anisotropic effect of plastic deformation on elastic limit and flow stress. Fracture stress should be defined as the load at beginning of fracture divided by the sectional area at that instant. By comparing results obtained at room temp. and at −188° C., longitudinal and transverse tensile tests on hot-rolled or cold-extended plate showed that plastic extension increases the fracture stress both in longitudinal and transverse directions; the shift of yield-stress range in the direction of plastic deformation is discussed. A *bibliography* of 24 references is appended. —R. L. B.

***An Experimental Study of the Propagation of Plastic Deformation Under Conditions of Longitudinal Impact.** P. E. Duwez and D. S. Clark (*Amer. Soc. Test. Mat. Preprint* No. **31,** 1947, 21 pp.).—The mathematics of longitudinal impact at the end of a hypothetical bar of infinite length and another of finite length are reviewed. The authors describe the operation of the two impact-testing machines built for experimental verification of the theory of the propagation of plastic strain, the "sling shot" machine (employing a 3-lb. hammer and as many as 8 large elastic bands), and the rotary machine (converted 750-h.p. hydraulic impulse turbine generator with a 44-in.-dia. wheel). Details are given of the testing machines used to determine the static stress–strain curves. The distribution of plastic strain, at const. and at varying impact velocities, was investigated in tension on annealed 0·071-in.-dia. copper wire and in compression on cold-rolled mild steel. The influence of release of loading and the reflection of plastic waves were studied. The concept of critical velocity in tensile impact is discussed.—R. L. B.

Impact Loading of Structures. D. Lauqharne Thornton (*Engineering,* 1948, **165,** (4292), 409–412).—A mathematical discussion of the transmission of strain due to rapid loading through metals, with special reference to steel, but of general interest.—R. Gr.

Intercrystalline Cohesion and the Stress-Rupture Test. H. H. Bleakney (*Amer. Soc. Test. Mat. Preprint* No. **34,** 1947, 15 pp.).—A discussion of the causes of intercrystalline failure of metals when stressed at elevated temp. The existing knowledge on intercrystalline cracking and rupture is examined, and the salient features needing further investigation are listed. A selected *bibliography* of 33 references is given.—R. L. B.

Mechanism of Fractures of Brittle Solids. Nelson W. Taylor (*J. Colloid Sci.*, 1947, **2,** (1), 185).—A theory is proposed which connects the stress f required to break a brittle material in simple tension with its duration of application t. The theory shows why a solid object does not have a single characteristic breaking strength and how it adjusts its fracture mechanism to whatever stress is applied. Applicability of the theory to certain aspects of the fatigue of metals under stress-corrosion conditions is indicated. —A. I. V.

***Dry Friction of Metals as Affected by Surface Finish and Surface Coatings.** (Ludwig). See p. 28.

***Welding or Sticking of Electrical Contacts.** Erle I. Shobert II (*Amer. Soc. Test. Mat. Preprint* No. **96,** 1947, 15 pp.).—A machine developed to test the properties of contact materials was used by six firms to measure the welding or sticking characteristics of contacts. Data from standardized tests for welding and sticking of nickel, silver, and tungsten contacts were remarkably consistent between the various laboratories. A theory developed to fit the experimental facts is mathematically expounded. S. compares the calculated and measured values of limiting current for silver, nickel, tungsten, palladium, platinum, molybdenum, silver–cadmium, and silver–zinc.—R. L. B.

***Concept of the Hydrogen Potential in Steam–Metal Reactions.** Carl A. Zapffe (*Trans. Amer. Soc. Metals*, 1948, **40,** 315–352; discussion, 352–354).—See *Met. Abs.*, 1948, **15,** 327.—R. W. R.

***The Vapour Pressure of Metals.** Rudolph Speiser (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19,** (5), 12–20).—An account is given of vapour-pressure measurements carried out in the cryogenic laboratory of Ohio State University.—A. I. V.

***Variation of the Thermo-Electric Power of Metals by Solution of Elements.** Charles Crussard and Francis Aubertin (*Compt. rend.*, 1948, **226**, (12), 1003–1005).—C. and A. investigated the modification of the thermo-electric power of aluminium by small amounts of foreign atoms, according to whether they were in the dissolved or precipitated state. The metal may be considered as synthetic impure aluminium containing traces of one of the following metals: Sn, Si, Ti, Cr, Mn, Fe, Ni, Cu, or Mg. The aluminium was studied: (1) as quenched after long annealing at 600° C., in which case the impurity metal was entirely in solution (except nickel and iron), and (2) after slowly cooling for 48 hr., so that all the metal not soluble at the surrounding temp. was precipitated. The thermo-electric power in the slowly cooled metal was never higher than that of the annealed metal and was often considerably lower. In the dissolved state, the impurities increase the thermo-electric power of aluminium if they precede this metal in the Periodic Table and lower it if they follow the metal; if they are in the same vertical column, the action is very feeble. There are some exceptions to this law: titanium in solution in aluminium; aluminium, silicon, and manganese dissolved in iron and nickel; copper, silver, or gold dissolved in nickel, palladium, or platinum.—J. H. W.

***The Total Emissivity of Various Materials at 100°–500° C.** B. T. Barnes, W. E. Forsythe, and E. Q. Adams (*J. Opt. Soc. Amer.*, 1947, **37**, (10), 804–807).—The emissivities of 15 metals, some with various surface finishes, at 100° C., are listed. Figures for carbon and glass are given for higher temp. as well, and the methods of making such measurements, and their significance, are explained. In general, emissivity varies inversely as the reflection factor of a surface, but the observation that polished tungsten gives a lower emissivity than polished aluminium is somewhat anomalous.—E. van S.

***Theory of the Anomalous Skin Effect in Metals.** G. E. H. Reuter and E. H. Sondheimer (*Nature*, 1948, **161**, (4089), 394–395).—A note. R. and S. have re-formulated equations derived by Pippard (*Proc. Roy. Soc.*, 1947, [A], **191**, 385; *Met. Abs.*, 1948, **15**, 391) in a study of the skin effect at high frequencies and low temp. A short account is given of the mathematical derivation of the variation of the components of the surface impedance with frequency and temp.—M. B. W.

***Surface Resistance of Metal Films at a Frequency of 24,000 Mc./s.** L. Speirs (*Nature*, 1948, **161**, (4094), 601).—A fresh investigation of the theory. Measurements have given excellent qualitative agreement.—M. B. W.

II.—PROPERTIES OF ALLOYS

Aluminium and Its Alloys. Hugh P. Vowles (*Canad. Metals*, 1947, **10**, (9), 26–27).—A brief survey of history, production, properties, and uses.—R. L. B.

***Resistance to Buckling of Light-Alloy Plates.** W. Muckle (*Trans. N.E. Coast Inst. Eng. Ship.*, 1947–48, **64**, (6), 223–272).—Describes results obtained from buckling tests carried out on plates of three aluminium alloys, namely A.W.5 (3% magnesium), A.W.6 (5% magnesium), and A.W.15 (clad Duralumin). Two sizes of plate were investigated; these had spans of 15 and 30 in., respectively. Plate thicknesses in the range $\frac{3}{16}$–$\frac{7}{16}$ in. (15 in. span plate) and $\frac{3}{8}$–$\frac{7}{8}$ in. (30 in. span plate) were used. The effect of variation of plate width was also examined. The results obtained are given in tabular form and, in addition, as buckling stress–span/thickness curves. It was found that the results obtained could be represented by the empirical equation:

$$P = \frac{A}{1 + B\left(\frac{s}{t}\right)^2}$$

where P = buckling stress (tons/in.^{2}), s = span (in.), and t = thickness (in.). For half-hard A.W.6 and A.W.15 the values of the constants A and B were 39 and 1/370, respectively. The buckling strengths of plates in soft A.W.6 and soft and half-hard A.W.5 alloys were rather lower than those given by the half-hard A.W.6 alloy. Tests carried out on lapped plates revealed that lapping increased the buckling stress. The results obtained with the aluminium plates are compared in a series of graphs with those obtained for steel by Montgomerie. A number of theoretical aspects of the buckling of plates are treated mathematically.—R. W. R.

Some Recent Advances in the Light-Alloy Field. H. Sutton (*Proc. S. Wales Inst. Eng.*, 1947, **62**, (3), 80–105; discussion, 106–110).—The heat-treatment of high-strength wrought aluminium alloys is considered: (1) Duralumin alloys aged at normal temp., (2) Duralumin alloys aged at raised temp. (Super-Duralumin), and (3) aluminium–zinc–magnesium alloys. Clad light alloys overcome intercrystalline corrosion and stress-corrosion. Medium-strength wrought aluminium-rich and magnesium-rich alloys are surveyed. The properties of light casting alloys are tabulated, and graphs are given comparing their fatigue properties with those of mild steel. Tables are presented which compare British, American, German, and Japanese specifications for Duralumin and similar alloys. The mechanical properties of American, German, and Japanese high-strength wrought aluminium–zinc–magnesium alloys are reviewed.—R. L. B.

***The Heat-Treatment and Properties of Some Beryllium–Nickel Alloys.** W. Lee Williams (*Trans. Amer. Soc. Metals*, 1948, **40**, 163–175; discussion, 175–179).—See *Met. Abs.*, 1948, **15**, 229. In the discussion, *E. N. Skinner* presents some figures showing the age-hardening response of an alloy containing 2·07% beryllium, given various prior cold-working treatments. Max. hardnesses found were generally higher than those reported by W.—R. W. R.

***Cast Heat-Resistant Alloys of the 26%-Chromium–20%-Nickel Type.—I.** Howard S. Avery and Charles R. Wilks (*Trans. Amer. Soc. Metals*, 1948, **40**, 529–577; discussion, 577–584).—See *Met. Abs.*, 1948, **15**, 230. In discussing the metallography of the alloys, *D. N. Frey* presents some additional photomicrographs.—R. W. R.

***The Cobalt–Chromium "J" Alloy at 1350° to 1800° F.** Nicholas J. Grant (*Trans. Amer. Soc. Metals*, 1948, **40**, 585–610; discussion, 610–616).—See *Met. Abs.*, 1948, **15**, 230. In the discussion, *F. S. Badger* presents some preliminary results of an investigation being carried out on the stress–rupture properties of Vitallium.—R. W. R.

***Cobalt-Base and Nickel-Base Alloys for Ultra-High Temperatures.** F. S. Badger, Jr., and F. C. Kroft, Jr. (*Metal Progress*, 1947, **52**, (3), 394–402).—A paper read before the Western Metals Congress, March 1947, in which are discussed alloys developed for use at 1400°–1800° F. (760°–982° C.) in highly stressed turbine blading and sheet for combustion chambers and exhaust systems of jet-propelled aircraft. The alloys concerned are basically cobalt–chromium alloys containing 5–6% tungsten or molybdenum and varying amounts of nickel up to 35%. Their microstructures as cast or forged and after ageing for various periods at 1475° F. (801° C.) are illustrated and discussed, and the results of short-time tensile tests on small precision-cast specimens from room temp. to 1800° F. (982° C.), both as-cast and after ageing at 1350° F. (732° C.), are reported. Both yield and ultimate stress at 1000°–1200° F. (538°–649° C.) are much improved by ageing, though ductility decreases markedly; at higher temp. the improvement is not so great. Stress-rupture curves at various temp. for periods up to 1000 hr. are given. At 1800° F. the alloy containing chromium 25–28%, tungsten 7·5%, nickel 10–12%, cobalt balance, is much superior to the others. Finally, there is a note on the carburization of the alloys.—N. B. V.

High-Temperature Alloys [Co–Cr–Mo, Fe–Cr–Co–Ni]. —— (*Mech. Eng.*, 1947, **69**, (1), 37–38).—Vitallium (Co 65, Cr 29, Mo 6%) has good corrosion-resistance at high temp., coupled with high load-carrying capacity, and is used for buckets in aircraft turbo-superchargers. An alloy containing Ni 20, Cr 21, Co 21%, Fe balance, with smaller amounts of a number of other elements, endures a stress of 15,000 lb./in.^{2} at 1500° F. (815° C.) without excessive creep. Cobalt-base alloys are stronger for short-time performance, while alloys containing equal amounts of nickel, chromium, cobalt, and iron are better for times greater than 10,000 hr.—H. Pl.

Beryllium and Beryllium Bronze (Beryllium Copper). Robert Gadeau (*Microtecnic*, 1947, **1**, (2), 43–46; (3), 69–71; (4), 85–89; (5), 111–114).—Full particulars are presented of the preparation of beryllium and its alloys by reduction from either the double fluoride or beryllia. Beryllium, sometimes containing 0·2% titanium, is used for internal radiation windows and external exit windows for X-ray tubes. Besides copper–beryllium alloys, it forms alloys of commercial importance with iron, nickel, and silver. Some details are given of the iron–beryllium, nickel–beryllium, and silver–beryllium equilibrium diagrams, together with a few particulars of the mechanical properties attainable with different forms of heat-treatment. Gold–beryllium alloys are produced chiefly for dental appliances. By far the greatest use of the metal is in the manufacture of the copper–beryllium alloys and beryllium bronze. Copper, when containing about 2% beryllium, is capable of being hardened by heat-treatment from 100 to 350 Brinell. The addition of 0·4% nickel has a grain-refining influence. A complete copper–beryllium equilibrium diagram is presented, and the effects of quenching, annealing, and coalescence and over-annealing are explained. The physical properties of beryllium bronze are reviewed. G. describes in detail the founding, hot and cold working, turning, welding, and heat-treatment of beryllium-bronze alloys.—R. L. B.

***The Damping Capacity of Copper–Manganese Alloys.** R. S. Dean, E. V. Potter, R. W. Huber, and H. C. Lukens (*Trans. Amer. Soc. Metals*, 1948, **40**, 355–380).—Continuing previous work (*Trans. Amer. Soc. Metals*, 1941, **29**, 402; 1945, **34**, 465; *Met. Abs.*, 1941, **8**, 225; 1946, **13**, 117), in which the unusually high damping capacity of copper–manganese alloys was reported, the authors measured the damping capacities of a wide range of compositions in various heat-treated states. Damping capacities at low stresses were measured by the "resonance curve" method, and high stress capacities were determined by the free torsional vibration method. Values for the elastic moduli and Poisson's ratio were also calculated from the results of the experiments. Alloys containing over 36% manganese show wide variations in damping capacity depending on the heat-treatment accorded them; this is due to sluggishness of the transformations in the alloy which enables transitional states to be preserved by quenching. Alloys with up to 74% manganese, quenched from the γ field, have comparatively low damping capacities; above 74% manganese the damping capacity increases from 0·2% to 1·4% at 95% manganese (low stresses). This increase in damping capacity is associated with tetragonal structures in the alloys, increasing with deviation from the cubic lattice. At high stresses, plastic deformation increases the damping capacity; the 82% alloy has a damping capacity of 80% at 10,000 lb./in.^{2} Alloys with between 74 and 90% manganese are very plastic because they are in a transitional state connected with the transformation of the γ structure from cubic to tetragonal, which occurs in the range 79–82% manganese. The transformation resembles a polymorphic transformation (in a pure metal), the variable being composition rather than temp. Slowly cooled alloys have very high damping capacities above 36% manganese and especially below 87%; the 60% alloy has a damping capacity of about 250% at 10,000

lb./in.^{2}. The high damping capacities of the slowly cooled or quenched cold-worked and reheated alloys is due to partial re-arrangement of the atoms in the γ phase, preparatory to the formation of definite decomposition phases. In general, high damping capacity is associated with low elastic moduli.
—R. W. R.

***The Electrical Resistivity and Temperature Coefficient of Resistance of Copper–Manganese Alloys.** R. S. Dean, E. V. Potter, and R. W. Huber (*Trans. Amer. Soc. Metals*, 1948, **40**, 381–400).—The room-temp. resistivities of alloys containing 0–100% manganese were measured by comparing the voltage drop across a $\frac{1}{4}$ in. bar specimen of the alloy with that across a standard resistor. The coeff. of resistance were determined from the room-temp. readings and from another set of measurements made at about 125° C. Some measurements were also made on wire specimens in the temp. range 400°–850° C. At room temp., the resistivities of alloys quenched from the single-phase γ field vary from 2×10^{-6} ohm-cm. for pure copper to a maximum of 188×10^{-6} ohm-cm. at 65% manganese, then decline to 45×10^{-6} ohm-cm. for γ manganese. The temp. coeff. has a small negative value up to 60% manganese, is zero between 60 and 70%, and thereafter increases rapidly up to 40×10^{-4} for pure γ manganese; this increase is associated with the change in structure from cubic to tetragonal. The resistivities of two-phase (quenched and reheated) alloys vary linearly with composition. Extrapolation to 100% manganese indicates a value of $145–164 \times 10^{-6}$ ohm-cm. for α manganese; the temp. coeff. of β and α manganese are 11×10^{-4} and $3–4{\cdot}2 \times 10^{-4}$ respectively. Slowly cooled alloys in the range 40–90% manganese have abnormally low resistivities and high temp. coeff., minimum and max. values respectively occurring near 80% manganese. X-ray studies showed that this is due to the occurrence of a transitional phase, ε, during the γ to $\gamma \rightarrow \alpha$ change. This phase is most prevalent near 80% manganese and has a resistivity of 94×10^{-6} ohm-cm. and a temp. coeff. of 19×10^{-4}. The relation between damping capacity and resistivity is discussed; max. damping capacity occurs in the early stages of the transition and before the ε phase is formed.—R. W. R.

Copper Alloys Containing Phosphorus, Lead, and Nickel. V. A. Grodsky (*Rev. Nickel*, 1947, **13**, (1), 12).—See *Met. Abs.*, 1947, **14**, 68.—R. W. R.

***Effects of Nickel, Zinc, and Lead Additions to 5%-Tin Bronze.** Ralph L. Fox, Jr. (*Foundry*, 1948, **76**, (6), 102–103, 258, 260, 262).—F. investigated the following compositions: 88/5/2/5, 88/5/3/4, and 88/5/5/2 copper–tin–nickel–zinc; additions of up to 2% lead were made to each alloy. Melting was done in an induction furnace under a charcoal cover, and about 0·025% phosphorus added before pouring. Shaped test bars, fluidity spirals, and hollow cylinders for pressure test were poured from each melt. Various pouring temp. in the range 1310°–1110° C. were employed. All castings were made in green sand containing 6% moisture. Tensile figures obtained were: 88/5/5/2, U.T.S. 19·2–21·9 tons/in.^{2}, elongation *ca.* 40%; 88/5/3/4, U.T.S. 18·7–20·5 tons/in.^{2}, elongation *ca.* 45%; 88/5/2/5, U.T.S. 17·9–19·6 tons/in.^{2}, elongation *ca.* 45%. The elongation of 88/5/5/2 is reduced to *ca.* 25% on addition of 1·9% lead; the other alloys are little affected by lead contamination. All the alloys examined were much superior to gun-metal (88/8/4) as regards pressure tightness.—R. W. R.

Solidification Mechanism of Tin Bronzes. Clyde L. Frear (*Foundry*, 1948, **76**, (4), 68–71, 124, 126; (5), 130–132, 348, 350–351).—After a brief discussion of the influence of alloying additions on the properties of bronzes, F. considers the symptoms, appearance, and causes of microporosity in these alloys. It is suggested that the freezing range of an alloy is only a minor factor affecting the tendency towards microporosity. Solidification by dendrite growth is discussed in some detail. The formation of micro-cavities is ascribed to an unusual form of dendritic growth which hinders feeding, thus causing voids to form between the dendrite arms. The defect can be minimized by ensuring that the liquid metal in the feeder is exposed to atmospheric pressure until after the casting itself has solidified completely; methods for the attainment of this are discussed. Low pouring temp. are also beneficial. —R. W. R.

***The Disordering of β Brass by Cold Work.** R. W. K. Honeycombe and W. Boas (*Nature*, 1948, **161**, (4094), 612–613).—An αβ brass was used to give much heavier deformation of the β phase than is possible by drawing down the pure phase. The state of order was found by electrical-conductivity methods. By comparing curves for the αβ type of varying reductions in area with similar curves for the α brass containing 35·1% zinc, the behaviour of the β was deduced. Disordering commences at 85% reduction and is completed by 95%. There is recovery which is complete after 27 days, so that a certain degree of re-ordering appears at room temp. The resistivity of the α solid solution was increased by cold work, but not that of pure copper. This suggests that a degree of order exists in α brass.—M. B. W.

***Thermal Conductivity of Copper and German Silver at Liquid Helium Temperatures.** (Allen and Mendoza). See p. 1.

***Plastic Flow of a Magnesium Alloy [AZ61] Under Biaxial Stresses.** D. M. Cunningham, E. G. Thomsen, and J. E. Dorn (*Amer. Soc. Test. Mat. Preprint* No. **33**, 1947, 8 pp.).—An experimental evaluation of the plastic flow in a magnesium alloy AZ61 tubular extrusion under varying ratios of biaxial stressing. Longitudinal, circumferential, and radial strains were calculated from measurements taken with axial and diametral gauges. The simple idealized theory for plastic flow, effective plastic strain, and work-hardening is discussed. Stresses and strains were evaluated by means of an internally-loaded thin-walled tubular specimen. Experimental data are plotted graphically, and the effect of variable stress ratios is illustrated. The agreement between theory and experiment is imperfect. A *bibliography* of 21 references is appended.—R. L. B.

[I.—] Recent Developments in Magnesium. [II.—] New Metallurgical Techniques and New Alloys of Magnesium. J. C. McDonald (*Metal Progress*, 1947, **52**, (1), 83–87; (2), 243–248).—A paper read before the Western Metals Congress at Oakland, Calif., in March 1947. (I.—) McD. describes briefly a number of developments, including improvements in casting technique, fatigue properties, notch effect, and simplification of the design of structures in which magnesium is used. (II.—) Reference is made to the paper by George (*Trans. Amer. Soc. Metals*, 1947, **38**, 686; *Met. Abs.*, 1948, **15**, 103) on special metallographic techniques for magnesium, and an account is given of the cerium- and zirconium-containing alloys, which have outstanding mechanical properties. The magnesium–cerium alloys are notable for their strength at moderately elevated temp. and for their creep resistance. Finally, new applications of magnesium are mentioned.—N. B. V.

A Recent Development in Metallurgical Technique as Applied to Magnesium Alloys. F. A. Fox (*Brit. Sci. News*, 1948, **1**, (7), 13–15).—A brief account of recent work on the grain refinement of magnesium–aluminium alloys. —R. W. R.

***Effect of Lattice Distortions on the Mean Rate of Propagation of Large Barkhausen Discontinuities [in Nickel–Iron Alloys].** L. J. Dijkstra and J. L. Snoek (*Nature*, 1948, **161**, (4101), 886–887).—Experiments showed that, for 60 : 40 nickel–iron alloys, the coeff. relating the rate of propagation to the external field is sensitive to lattice defects. Also, the ratio of this coeff. to the electrical resistance was found to be independent of temp.—M. B. W.

Mumetal—A High-Permeability Alloy. N. G. Neuweiler (*Microtecnic*, 1947, **1**, (1), 15–17).—The mechanical properties and workability of this alloy, basically consisting of iron and nickel, are discussed. The uses and the magnetic and electrical characteristics of Mumetal are described. —R. L. B.

The Alloy Ni-Span. W. A. Mudge and A. M. Talbot (*Rev. Nickel*, 1947, **13**, (1), 10–11).—See *Met. Abs.*, 1948, **15**, 5.—R. W. R.

A Zinc–Manganese–Copper Die-Casting Alloy [Z 100]. —— (*Mech. World*, 1948, **123**, (3200), 554).—Briefly describes the properties of a new alloy (Z 100) made by the Lukens Aluminum Corpn., U.S.A. The alloy contains zinc 60, manganese 25, copper 15, and aluminium 0·15%, and gives a U.T.S. of 40–45 tons/in.^{2} The alloy should not be confused with Zamak Z 100. —R. W. R.

Influence of Structure and Composition on the Elastic Properties of Metallic Alloys. L. Guillet (*Génie Civil*, 1947, **124**, (3), 45–50; *Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (9), 429–432).—See *Met. Abs.*, 1947, **14**, 8.—R. L. B.

***Influence of Homogeneous Work on the Internal Friction of a Solid Solution.** Christian Boulanger (*Compt. rend.*, 1948, **226**, (15), 1170–1171).—All cold working of a metal entails a notable increase of internal friction, part temporary and part permanent, but results in the deformation of the metal by both elongation and lateral compression. B. studied the effects of pure tension on paramagnetic solid solutions low in inclusions and annealed to a state of very small internal friction. The alloy selected was 80 : 20 nickel–copper. There is no relation between the internal friction and the elastic limit or the hardness of the solid solution.—J. H. W.

Creep and Some Creep-Resisting Alloys. G. Burns (*Eng. Inspection*, 1947, **11**, (4), 20–22).—See *Met. Abs.*, 1948, **15**, 7.—R. L. B.

Alloys for Severe High-Temperature Service. W. C. Leslie and D. J. McPherson (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19**, (5), 42–47).—A survey of recent developments.—A. I. V.

Alloys for High Temperatures. L. B. Pfeil (*Rev. Nickel*, 1948, **14**, (1), 1–8).—A summary of a lecture delivered in Paris before the Centre d'Études Supérieures de Métallurgie. P. describes and compares British and American nickel-bearing, heat-resistant alloys. The uses of these materials in gas-turbines are discussed.—R. W. R.

High-Temperature Alloys. —— (*Mech. Eng.*, 1947, **69**, (5), 404).—Intermetallic compounds have high m.p. and good corrosion-resistance at elevated temp. Chromium borides cemented with nickel or cobalt exhibit these qualities to a marked degree. Sweat-cooling techniques, which involve the use of porous materials, for turbine blades, are being investigated and are showing promise.—H. Pl.

Precipitation-Hardening. —II, —III, —IV. L. Sanderson (*Chem. Age*, 1947, **56**, (1447), 412–414; (1456), 741–743; 1947, **57**, (1460), 13).—Cf. *Met. Abs.*, 1948, **15**, 302. (II.—) Modifications in the properties of alloys due to precipitation are described, using the results of microscopic, X-ray diffraction, electrical-conductivity, and magnetic studies. (III.—) A discussion on precipitation-hardening in aluminium alloys. (IV.—) A general account of precipitation-hardening in aluminium, copper, and magnesium alloys.—S. R.

***Tempering Effects and the Mechanical Equation of State.** J. C. Fisher and C. W. MacGregor (*Trans. Amer. Soc. Metals*, 1948, **40**, 302–312; discussion, 312–314).—See *Met. Abs.*, 1948, **15**, 226.—R. W. R.

The Determination of Equilibrium Diagrams. G. V. Raynor (*J. B'ham. Met. Soc.*, 1948, **28**, (1), 3–23; discussion, 24–36).—Besides yielding much information of practical importance, constitutional diagrams, accurately determined under equilibrium conditions, are of great interest in connection with the electronic theory of alloy formation. R. reviews the different methods available for the determination of such diagrams. Thermal analysis is still the best method for liquidus curves; accurate control of the cooling rate (1°–1½° C./min.), protection of the melt from oxidation, const. stirring, and accurate analysis of the sample are precautions necessary with this method. In instances where the primary arrest is too slight to be accurately detected by thermal analysis, the solubility method is used; in this method a melt is held at a pre-determined temp. between the liquidus and solidus and a sample of liquid then removed and analysed. Peritectic reactions are readily located by a logarithmic plot of the experimental points. Solidus curves are usually determined by the quenching method or from heating curves; the former tends to place the solidus slightly too high, while the latter is liable to errors due to segregation in the specimen and is therefore mainly useful with gently sloping curves. Curves of solid solubility are determined by micrographic or by X-ray methods; these two methods are complementary and the most accurate results are obtained by their joint use. X-ray methods are used in two ways in determining equilibrium diagrams: (*a*) as a precision tool for determining a line in an equilibrium diagram from lattice-spacing changes, and (*b*) for determining the structures of intermediate phases. The use of the method in the latter application may often be extended by extracting the constituent electrolytically. R. describes each of the methods in some detail.—R. W. R.

***Welding or Sticking of Electrical Contacts.** (Shobert). See p. 4.

III.—STRUCTURE

(Metallography ; Macrography ; Crystal Structure.)

[For all abstracts on the constitution of alloy systems, including X-ray studies, see II.—Properties of Alloys.]

***Effect of Sixteen Alloying Elements Upon the Grain-Size of Cast 4·5%-Copper–Aluminium Alloy.** Harold G. Bowen, Jr., and Harold Bernstein (*Trans. Amer. Soc. Metals*, 1948, **40**, 209–222).—In each test the aluminium was melted in a small crucible, the alloying additions added as hardener alloys, the melt held at temp. for ½ hr., and then stirred. After holding for a further ½ hr., the crucible was withdrawn from the furnace and cooled in air. The grain-sizes of the ingots thus obtained were found by sectioning and microscopical examination. Commercial-purity materials were used throughout. Two holding temp. (730° and 955° C.) were employed. The additions tried may be grouped as follows in order of effectiveness: (*a*) refiners: titanium, boron, niobium, zirconium (>0·18%); (*b*) coarseners: chromium, antimony, zirconium (<0·16%), manganese, beryllium, iron, molybdenum; (*c*) ineffective elements: vanadium, tungsten, cerium, cobalt, tin, magnesium. Melts held at the higher temp. had coarser structures than those held at the lower. Experiments in which two refining additions were made to the same melt did not reveal a cumulative effect. The crystallization characteristics of the alloy were greatly affected by the addition of refiners.
—R. W. R.

***Influence of the Orientation of Grain Boundaries of High-Purity Aluminium on Their Attack by Hydrochloric Acid.** (Yannaquis and Lacombe). See p. 14.

***Hexagonal Slip in Beryllium Crystal.** Lester Tarnopol (*Metal Progress*, 1947, **52**, (3), 391).—T. publishes a photograph which shows slip planes forming a perfect hexagon round a Brinell impression in a single crystal of 99·5+% beryllium.—N. B. V.

***Metallographic Identification of Sigma Phase in 25–20 [Chromium–Nickel] Austenitic Alloy.** G. N. Emmanuel (*Metal Progress*, 1947, **52**, (1), 78–79).—A series of photomicrographs show the effect of various etching reagents and techniques on the appearance of the σ phase.—N. B. V.

***Orientation of Thin Films of Cuprous Oxide Formed on Copper.** Henri Frisby (*Compt. rend.*, 1948, **226**, (7), 572–573).—The investigation of surfaces of electropolished copper (*ibid.*, 1947, **224**, 1003; *Met. Abs.*, 1947, **14**, 373) was continued with a study of the films of cuprous oxide that are formed on the surface of copper heated to 100° C. in boiling water. Under the experimental conditions adopted, the oxide orientates itself both to an axis of symmetry of the subjacent metal and to the plane of the free surface of the specimen. But the free surface is plane only on a macroscopic scale. To obtain a characteristic diagram it is necessary to use lightly polished surfaces whose irregularities must be considered on an atomic scale.—J. H. W.

***The Crystal Structure of Element 43 [Technetium].** Rose C. L. Mooney (*Phys. Rev.*, 1947, [ii], **72**, (12), 1269).—Cf. *Met. Abs.*, 1948, **15**, 461. Element 43 (technetium) is isomorphous with rhenium, ruthenium, and osmium, and crystallizes in the close-packed hexagonal arrangement. The cell contains 2 atoms of technetium, and has the following dimensions:

$$a = 2{\cdot}735 \pm 0{\cdot}001 \text{ Å}, \; c = 4{\cdot}391 \pm 0{\cdot}001 \text{ Å}, \; c/a = 1{\cdot}604$$

The calculated density, based on an atomic weight of 99, is 11·487 g./cm.^{3} Each atom has six neighbours at 2·735 Å and six more at the somewhat smaller distance of 2·704 Å.—G. V. R.

***Mechanical Behaviour of Crystal Boundaries in Metals [Tin].** R. King, R. W. Cahn, and B. Chalmers (*Nature*, 1948, **161**, (4096), 682).—Note reporting grain-boundary slip between tin bi-crystals at temp. a few degrees below the m.p. with shear stress on the boundary, the rate of movement diminishing with time. An initial rate of 7×10^{-4} cm./hr. under a stress of 590 g./cm.^{2} at 222° C. is recorded.—M. B. W.

***Metallography of Hot-Dipped Galvanized Coatings.** D. H. Rowland (*Trans. Amer. Soc. Metals*, 1948, **40**, 983–1005; discussion, 1005–1011).—See *Met. Abs.*, 1948, **15**, 337. Some further examples of structures found are given in the discussion.—R. W. R.

Polishing Metallographic Specimens with Diamond Dust. Gordon C. Woodside and Harold H. Blackett (*Metal Progress*, 1947, **51**, (6), 945–947; and (summary) *Indust. Diamond Rev.*, 1948, [N.S.], **8**, (88), 92–93).—Diamond dust paste has been successfully used for polishing micro-specimens of such hard materials as molybdenum carbide.—N. B. V.

Mount-Identification Tool. O. L. Neftsinger (*Metal Progress*, 1947, **52**, (1), 250).—N. describes an electromagnetic device for dropping a small steel identification tag into the plastic mount of micro-specimens.—N. B. V.

Sources of Polishing Scratches. David J. Mack (*Metal Progress*, 1947, **52**, (1), 105–106).—Eight possible causes of scratches in micro-specimens are listed, with advice for eliminating them.—N. B. V.

Metals Through the Microscope. Peter R. Lewis (*Sci. Amer.*, 1947, **177**, (1), 24–25).—A popular account.—H. Pl.

***Plastic Replicas for Surface-Finish Measurement [—II].** J. Pearson and M. R. Hopkins (*J. Iron Steel Inst.*, 1948, **159**, (1), 67–70).—A more detailed account of a method described earlier (*J. Iron Steel Inst.*, 1948, **158**, (1), 138; *Met. Abs.*, 1948, **15**, 432). A number of additional uses for the methyl methacrylate replicas are suggested; these include microscopic examination, projection transparencies, multiple-beam interferometry, and electron microscopy.—R. W. R.

Fractography: The Study of Fractures at High Magnification. C. A. Zapffe, F. K. Landgraf, Jr., and C. O. Worden, Jr. (*Iron Age*, 1948, **161**, (14), 76–82).—In fractography, which is the microscopic study of fracture facets at high magnification, it is found that a considerable amount of information can be deduced from the appearance of these facets and that there is a marked sensitiveness of the cleavage pattern to constitutional effects. The authors summarize the principal features of fractography and indicate its application to the study of various ferrous and non-ferrous metals, including zinc, bismuth, ferro-silicon and ferro-chromium alloys, and molybdenum. It was found that certain features, visible in fractographs, are associated with the physical properties of the metals concerned.—J. H. W.

***Photo-Elastic Investigation of Internal Stresses in Silver Chloride Caused by Plastic Deformation.** J. F. Nye (*Nature*, 1948, **161**, (4088), 367–368).—Experiments were made with annealed rolled sheets, 0·3–1·0 mm. thick, of polycrystalline silver chloride. This substance was used since it has a cubic crystal structure, optically isotropic when unstressed, and it is expected that the results will apply to metals. N. discusses the type of stress patterns obtained in relation to : (1) the process of plastic deformation, (2) the influence of grain boundaries, (3) re-arrangements of dislocations and atoms during annealing, and (4) relative crystal orientation.—M. B. W.

***The Fourier Method of Crystal-Structure Analysis.** W. Cochran (*Nature*, 1948, **161**, (4098), 765).—A note reporting results of an investigation of the Fourier synthesis. The Fourier and least-square methods are found to be closely related. Justification is found for a method suggested by Booth (*Proc. Roy. Soc.*, 1946, [A], **188**, 77).—M. B. W.

***A New Fourier Refinement Technique.** Andrew D. Booth (*Nature*, 1948, **161**, (4098), 765–766).—A note giving results of fresh mathematical treatment.—M. B. W.

Method of Steepest Descents: Improved Formula for X-Ray Analysis. V. Vand (*Nature*, 1948, **161**, (4094), 600).—A method of lessening calculation in the application of the method proposed by Booth.—M. B. W.

***Geiger-Counter Measurements of Bragg and Diffuse Scattering of X-Rays by Single Crystals.** Kathleen Lonsdale (*Acta Crystallographica*, 1948, **1**, (1), 12–20).—A discussion of the suitability of Geiger equipment for the measurement of scattering intensities from small single crystals, based on restricted experiments with commercial American equipment and organic crystals. —M. B. W.

Phase-Angle Determination in X-Ray Crystallography. Alexander R. Stokes (*Nature*, 1948, **161**, (4096), 679–680).—Short note on the connection between diffuse reflections and phase angles of Bragg reflections.—M. B. W.

IV.—DENTAL METALLURGY

Investing Gold Inlay Patterns Under a Partial Vacuum. R. W. Lovel (*Brit. Dental J.*, 1947, **83**, (4), 81).—Surface bubbles on castings can be eliminated by investing the patterns under a partial vacuum. The fresh investment is made to boil under the reduced pressure. A description is given of Hollenback's apparatus and method for investing using a dental lathe. Large castings are more suitably prepared by the painting-brush method.—R. L. B.

V.—POWDER METALLURGY

Low *versus* High Pressure in Making Cemented-Carbide Tools. Anton Niedzwiedski (*Metal Progress*, 1947, **52**, (1), 104).—N. describes pre-war practice at a works in Poland. The use of high pressure proved superior to low pressure, as it resulted in less shrinkage and internal stress with consequently less scrap and fewer failures in service.—N. B. V.

Carbide Cutting Tools. H. Eckersley (*Brit. Eng. Export J.*, 1947, **30**, (26), 698–703).—See *Met. Abs.*, 1948, **15**, 504.—R. L. B.

The Manufacture of Copper–Lead Bearings from Metal Powder. E. R. Darby (*Canad. Metals*, 1947, **10**, (9), 21–22).—R. L. B.

Tungsten Carbides. E. M. Trent (*Brit. Eng. Export J.*, 1947, **30**, (25), 553–557).—See *Met. Abs.*, 1948, **15**, 504.—R. L. B.

The Development of a Heat and Fire-Resistant Material of Low Specific Gravity. J. Bingel (*Arch. Metallkunde*, 1947, **1**, (7/8), 309–310).—High-temp. heat-resisting materials of low specific gravity are of great importance in the development of the gas turbine, and the substitution of silicon carbide (of low specific gravity) for austenitic steels (of high specific gravity) would lead to greater efficiency. The production by powder-metallurgy processes and the properties of silicon carbide, with additions of small amounts of lower-m.p. metals to inhibit grain growth at high temp., are discussed, and the following compositions are proposed: (1) silicon carbide 84, titanium carbide 5, cobalt 6, chromium 3, and tungsten 2% for gas-turbine blades working at temp. up to 1000° C., and (2) silicon carbide 88, titanium carbide 2, and iron 10% for the jets of jet engines.—E. N.

Friction in Powder Metallurgy. H. W. Greenwood (*Metallurgia*, 1948, **37**, (222), 283–284).—Friction affects the compression of powder compacts in two ways, firstly as friction between the walls of the die and the powder, and secondly as inter-particle friction. Friction at the walls is entirely deleterious, and smooth walls, possibly lubricated, are necessary. Friction between particles is, however, necessary, as the local heating promotes cohesion, but with high compression ratios it may lead to variations in hardness and density throughout the compact.—M. A. V.

High-Temperature Equipment for Sintering Combinations of Ceramic Oxides and Metal Powders. A. R. Blackburn (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19**, (5), 24–28).—Combinations of ceramic oxides and metal powders are playing an important part in the development of material suitable for use in jet-propulsion mechanisms. A description is given of furnaces which have been designed for sintering these mixtures.—A. I. V.

[Discussion on Paper by Henry H. Hausner on] Metal–Ceramic Combinations. Louis R. McCreight (*Ceram. Ind.*, 1947, **48**, (4), 110).—Cf. *ibid.*, 1946, **47**, (5), 87; (6), 90; *Met. Abs.*, 1948, **15**, 106.—A. I. V.

Powder Metallurgy. J. A. Judd and W. H. Tait (*Brit. Eng. Export J.*, 1947, **29**, (16), 877–880, 894).—See *Met. Abs.*, 1947, **14**, 163.—R. L. B.

Where Does Powder Metallurgy Stand To-Day? H. R. Clauser (*Sci. Amer.*, 1948, **178**, (1), 12–15).—C. discusses the advantages, limitations, and future prospects of powder metallurgy.—H. Pl.

Powder Metallurgy. —— (*Chem. Age*, 1947, **57**, (1462), 93; (1464), 153–155).—*Iron Steel Inst. Special Rep.* No. **38**, 1947, is reviewed. See *Met. Abs.*, 1948, **15**, 341–346.—S. R.

Metal Powders. H. W. Greenwood (*Brit. Eng. Export J.*, 1947, **29**, (19), 1277–1279).—A review.—R. L. B.

Screening Materials. W. O. Carby (*Brit. Eng. Export J.*, 1947, **30**, (28), 977–980).—Screening and classifying machines for refractories and metal powders are mentioned.—R. L. B.

VI.—CORROSION AND RELATED PHENOMENA

***Influence of the Orientation of Grain Boundaries of High-Purity Aluminium on Their Attack by Hydrochloric Acid.** Nicolas Yannaquis and Paul Lacombe (*Compt. rend.*, 1948, **226**, (6), 498–499).—It has already been shown (*ibid.*, 1947, **224**, 921; *Met. Abs.*, 1947, **14**, 381) that the rate of intergranular attack at the grain boundaries of high-purity aluminium is greatly influenced by the relative orientation of contiguous grains. The effect of the crystallographic factor and in particular that of the orientation of the boundary itself in relation to the crystals, have been further studied. The investigation showed that the relative orientation of contiguous crystals is not a sufficient condition for the resistance to attack at their junction : it is also necessary that the boundary of the grains should possess a definite orientation in relation to the two neighbouring systems.—J. H. W.

The Mechanism of the Corrosion of Aluminium. J. M. Bryan (*Chem. and Ind.*, **1948,** (9), 135–136).—The special characteristics of aluminium which distinguish it from other metals are the resistant surface film of oxide or hydrated oxide and its amphoteric properties. These are discussed in relation to the known facts concerning aluminium and the electrochemical theory of corrosion. A modification of the usual electrochemical explanation is suggested to account for the behaviour of aluminium in alkaline solution.—H. Pl.

***First Report of the [BISRA] Methods of Testing (Corrosion) Sub-Committee.** —— (*J. Iron Steel Inst.*, 1948, **158,** (4), 463–493).—Eight different types of laboratory test were applied to steel specimens protected in various ways, and on the basis of this work, a sea-water spray test developed by the Armament Research Department was selected as most suitable for immediate development. In the A.R.D. test, the specimens are sprayed daily with natural sea water, using a hand-atomizing spray ; the specimens are enclosed in a steel cabinet so as to minimize evaporation. Results obtained with the different testing procedures are examined statistically and compared with the results obtained with similar specimens exposed to an urban atmosphere for 2 years. The means used to protect the specimens included spraying with aluminium, electrodeposition of lead and zinc, and galvanizing ; the specimens were tested both painted and unpainted. The specimens protected by a sprayed aluminium coating were found to have the best corrosion-resistance. The reproducibility of the A.R.D. test and its application to the testing of stove-enamelled parts are discussed at length.—R. W. R.

***Rating Exposure-Test Panels of Decorative Electrodeposited Cathodic Coatings.** W. A. Wesley (*Amer. Soc. Test. Mat. Preprint* No. **38, 1947,** 12 pp.). —After the inspection of thousands of specimens over a 6-year period, adopting the rating evolved by Blum and Strausser, W. recommends that reference standards should be used and that the scale of ratings should be raised, because of the influence of psychological factors and the fact that the lower ratings are useless from the user's point of view. It is recommended that the A.S.T.M. should adopt graphical reference standards for the corrosion of chromium finishes. The rating standards would be inversely proportional to the defective area.—R. L. B.

***Inspection of Exposure-Test Panels with Non-Decorative Electrodeposited [Lead] Cathodic Coatings.** H. A. Pray (*Amer. Soc. Test. Mat. Preprint* No. **39, 1947,** 4 pp.).—Weathering of electroplated lead, and its thickness, appear to control its protective life. A mottled white corrosion accumulation appears first, on atmospheric exposure, followed by pinhole rust spots (indicative of coating porosity). In the next stage, bleeding from these pores spreads over the coating surface, though the coating is still intact. Visual inspection cannot give a quantitative measure of the coating, but it helps an independent evaluator to judge the utility of a coating. Quantitative values of the corrosion damage on the coating are determined by loss-in-weight measurements before rust appearance. Present ratings are based on weight loss, in conjunction with loss in tensile strength.—R. L. B.

***Inspection of Exposure-Test Panels with Anodic Electrodeposited Coatings [Zinc or Cadmium on Steel].** Gustaf Soderberg (*Amer. Soc. Test. Mat. Preprint* No. **40, 1947,** 6 pp.).—The corrosion of zinc- or cadmium-plated outdoor-exposure specimens proceeds in two stages, an initial stage during which minute rust spots may be found, which may be significant in corrosion-fatigue resistance, and a final stage during which increasingly large areas are denuded of coating and exhibit rusting. The rusting during the former

stage may be evaluated by counting the spots, and during the latter by placing over the panel a shield of clear plastic ruled so as to facilitate measurement of the percentage of area rusted. The whole panel should be evaluated, including the edges, because the second stage usually begins at the lower edge. The extent of sacrificial protection may be judged by the width of the band of bare metal between the rusted and the still-coated areas.
—R. L. B.

***Report of [A.S.T.M.] Committee D-19 on Water for Industrial Uses [Corrosion of Metals].** —— (*Amer. Soc. Test. Mat. Preprint* No. **78,** 1947, 32 pp.).—Progress report. A proposed tentative practice for corrosion tests (NDHA method) in industrial waters is described in detail. It is particularly applicable for waters (up to 200° C.) relatively free of suspended materials. Three helical coils of wire are exposed for 30 days or until a 10% loss in weight is measured. Particulars of the corrosion rate of 21 non-ferrous and ferrous wires are tabulated.—R. L. B.

***Corrosion of Metals in Aircraft-Engine Cooling Systems.** —— (*Bull. Electrochem. Soc.*, **1947,** (Nov.), 4).—A summary of *Australian Council for Aeronautics Rep.* No. **ACA24,** 1946, by P. F. Thompson. See *Met. Abs.*, 1948, **15,** 38.—A. I. V.

***A Study of the Kinetics of Bearing Corrosion and Oil Oxidation : Correlation of Various Test Methods.** Hugh R. Lehman and L. Kermit Herndon (*Ohio State Univ., Eng. Exper. Sta. News*, 1948, **20,** (1), 45–52).—A method of graphical analysis for the corrosion curves exhibited by the MacCoull bearing corrosion tester is presented in condensed form. Use of this method produces a specific reaction-velocity constant. This constant obeys the classical Arrhenius equation relating the reaction-velocity constant to temp. The experimental energy of activation and the probability factor for lubricating oils have been calculated by applying the Arrhenius equation. It is suggested that these constants will express the tendency of a lubricating oil to promote bearing corrosion.—A. I. V.

[Corrosion by] Additive Lubricating Oils. —— (*Mech. Eng.*, 1947, **69,** (2), 150–152).—Factors entering into the corrosion of alloy exhaust-valve guides, causing excessive clearances are : (1) rocker-arm oil-base temp., (2) valve-guide temp., (3) valve-guide composition, and (4) oil composition. High-temp. stability of lubricating oils and especially of their additives appears to be of the first importance.—H. Pl.

***High-Temperature Oxidation.** H. M. McCullough (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19,** (5), 38–41).—An account is given of investigations of the mechanism of high-temp. oxidation of metals and alloys.—A. I. V.

***Erosion-Corrosion.** Walter A. Luce (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19,** (5), 29–32).—Some experimental results are discussed.
—A. I. V.

***Stress-Corrosion.** J. C. Chaston (*Nature*, 1948, **161,** (4101), 891–892).—Experiments on 9-carat gold in acidic ferric chloride support C.'s prior suggestion that protection of the grains is brought about by the corrosion product, where its structure corresponds to that of the underlying crystal. At the disordered grain boundary, this would not exist. Continuous removal of the product by brushing caused over-all corrosion without intercrystalline preference.—M. B. W.

***The Chemical De-Scaling of Boilers.** R. H. Burns (*Indust. Heating Eng.*, 1947, **9,** (39), 85–87, 96).—See *Met. Abs.*, 1948, **15,** 40.—R. L. B.

Corrosion [and Protection]. D. H. Garside (*Indust. Heating Eng.*, 1947, **9,** (34), 47–50).—Electrochemical corrosion is explained, giving the example of copper and zinc. Oxide-skin-forming metals and alloys, such as gun-metal and bronzes, have good corrosion-resistance. Aluminium brasses and bronzes

are supplanting plain bronzes and brasses, copper, and lead for certain uses in marine engineering. Protective coatings for metals are discussed.
—R. L. B.

Corrosion-Testing Facilities Expanded at Kure Beach. Richard K. Lotz (*Steel*, 1947, **121**, (2), 88–90, 92, 130, 132).—The researches now in progress are described, with some corrosion-test results for Monel metal, nickel, Inconel, and steels.—M. A. V.

Co-operation Hits Corrosion. T. C. Du Mond (*Sci. Amer.*, 1947, **177**, (5), 210–212).—A description of work at the Kure Beach test station.—H. Pl.

VII.—PROTECTION

(Other than by Electrodeposition)

How to Select Coatings for Aluminium. Ray Swan and N. P. Ruther (*Canad. Metals*, 1947, **10**, (8), 23, 40–41).—The protection of castings, extrusions, and sheet is discussed.—R. L. B.

Anodizing: What It Is and How It Is Done. Rick Mansell (*Canad. Metals*, 1947, **10**, (9), 23, 25–26).—Porous films 0·0001 in. thick result from anodizing in a 6% chromic acid solution, while denser films 0·00004 in. thick are produced in a 3% solution. A c.d. of 1 amp./ft.^{2} will produce a film to withstand the 720-hr. salt-spray test.—R. L. B.

Indium Coating to Protect Steel. —— (*Chem. Age*, 1947, **56**, (1451), 569).—A thin coating of indium, electrodeposited, sprayed, or otherwise deposited on steel is highly corrosion-resistant.—S. R.

Must Iron Rust? [Use of Tin Coating]. ——(*Tin and Its Uses*, 1947, **(18)**, 5–7, 11; and *Tin*, **1948**, (Mar.), 11–12).—Refers to the use of an extremely thin coating of tin on steel before painting to give protection.—P. L.

Prevention of Sulphur Staining [of the Interior of Tin Cans During Processing]. —— (*Tin Printer*, 1947, **23**, (272), 4, 6).—Staining may be avoided by the application of lacquer, by anodizing, or by chemical treatment.
—R. L. B.

***Phosphate Treatments for Zinc Surfaces.** E. E. Halls (*Metallurgia*, 1948, **37**, (222), 299–305).—Exposure tests were carried out on zinc die-castings, electrogalvanized steel, hot-dip galvanized steel, and zinc-sprayed steel, some of which were phosphatized by various processes (not specified) and all finished with organic enamel. The test conditions were (*a*) fluctuations from 55° to 60° C. by day, with 65–75% humidity, to atmospheric temp. and 100% humidity by night; (*b*) open semi-industrial atmosphere; and (*c*) salt spray. For comparison, a special chromate treatment was included among the finishes, and this gave the best results. Apart from this, the phosphatized specimens withstood the conditions much better than the untreated ones. It is concluded that chromate and phosphate treatments each have their particular spheres of application, and are to be regarded as complementary; and it is noted that phosphate coatings tend to have electrical insulating properties, and are unsuitable for resistance welding.—M. A. V.

Hot-Dip Galvanizing: What It Is and How It Is Done. Rick Mansell (*Canad. Metals*, 1947, **10**, (12), 20–21).—Aluminium is added to the spelter bath to reduce the iron–zinc layer; passing the sheets through a lead bath before galvanizing has the same effect. Cadmium tends to embrittle the outer layer; sometimes 1 or 2% tin is added to the spelter to control the appearance of the spangle.—R. L. B.

Metal Spraying by the Wire Process. W. E. Ballard (*J. B'ham. Met. Soc.*, 1948, **28**, (1), 37–50; discussion, 51–61).—The first part of the paper consists of B.'s introductory remarks to a film on the technique and applications of metal-spraying processes. The script of the film commentary is reprinted in the second part of the paper.—R. W. R.

Maintenance Metallizing. Gilbert C. Close (*Modern Machine Shop*, 1947, **19**, (11), 136–160).—C. points out the importance of the process in a general way and gives information on surface preparation and techniques of spraying. —A. I. V.

No Electric Current Used in New Method of Plating Nickel and Cobalt on Metal Surface. —— (*Steel*, 1947, **121**, (4), 84, 86, 88, 100, 102).—A digest of papers at the 34th American Electroplaters' Society Convention. It includes a description of Brenner and Riddell's "electroless plating" process for depositing nickel and cobalt. The process depends on the catalytic action of iron, nickel, cobalt, gold, palladium, or aluminium in the solution, but the deposition usually takes place only on the metallic surface. Non-catalytic vessels (e.g. glass or plastic) must be used. Bath compositions are given. —M. A. V.

Electroless Plating on Metals by Chemical Reduction. —— (*Bull. Electrochem. Soc.*, **1947**, (Aug.), 4–5; and *J. Franklin Inst.*, 1947, **244**, (6), 479).—Cf. *Met. Abs.*, 1948, **15**, 414.—A. I. V.

Report of [A.S.T.M.] Committee D-1 on Paint, Varnish, Lacquer, and Related Products. —— (*Amer. Soc. Test. Mat. Preprint* No. **59**, 1947, 51 pp.).—A revised standard for metallic zinc powder is described.—R. L. B.

Improved Protective Coatings Reported. —— (*Chem. Eng. News*, 1947, **25**, (41), 2975).—A brief report of the Third Annual Symposium on Modern Metal Protection, sponsored in Cleveland by the local sections of the American Chemical Society, American Institute of Chemical Engineers, and Electrochemical Society, 27 September 1947.—H. A. H.

Corrosion Protection. —— (*Mech. Eng.*, 1947, **69**, (2), 161–162).—Examples of cathodic protection are given. Complex organic corrosion inhibitors find increasing use. To prevent corrosion in high-pressure steam plants dissolved oxygen is first removed in specially designed de-aerators. Bacteria found in sea water, some soils, and even in certain deep wells must be killed to prevent corrosion.—H. Pl.

***The Use of Magnesium, Zinc, Aluminium, and Their Alloys in the Cathodic Protection of Steel in Salt Water.** R. R. Rogers and C. E. Viens (*Canad. Metals*, 1947, **10**, (9), 16–18, 36, 38).—Experiments using cylindrical sheet-steel cathodes with the anode fastened near the cathode centre, the whole being completely immersed in synthetic sea water at 35° C. for 16 hr., showed that the steel cathode was protected except when aluminium was the anode. Long steel-strip cathodes, to which an anode was clamped at one end, immersed in synthetic sea water at 35° C. for 19 hr., were protected for certain lengths of time. Cathodic protection is successful in small-scale experiments, and magnesium or high-magnesium alloys give optimum protection.—R. L. B.

VIII.—ELECTRODEPOSITION

Bright Copper Plating. —— (*Amer. Exporter* (*Indust.*), 1947, **140**, (6), 524–525).—H. Pl.

Nickel Plating. —— (*Chem. Age*, 1947, **56**, (1459), 848).—S. R.

Electroplated Tin [Alloy] Coatings. —— (*Canad. Metals*, 1947, **10**, (8), 20).—Speculum plating is discussed.—R. L. B.

Automatic Electroplating Line. A. H. Allen (*Steel*, 1947, **121**, (8), 80–83, 126, 128).—The Pontiac copper–nickel–chromium automatic electroplating plant is described and illustrated, and the sequence of operations tabulated. —M. A. V.

Modern Electroplating Equipment. A. Smart (*Brit. Eng. Export J.*, 1947, **29**, (17), 982–988).—Mention is made of simple manually operated plating shops, partially mechanized shops, and fully mechanized plants. —R. L. B.

Metal Rectifiers. W. A. Flint (*Brit. Eng. Export J.*, 1947, **30**, (26), 682–686).—Some developments in rectifiers for electroplating purposes are discussed.—R. L. B.

Production Electroforming. Thomas S. Blair (*Iron Age*, 1948, **161**, (14), 72–75).—B. describes an installation that is electroforming over 40,000 small articles a week. The great advantages of the process are the precision of the pieces and the possibility of forming intricate shapes of high design, especially of tubular, conical, and cup-like patterns. Electrodeposition on plastics and electropolishing operations are briefly considered.—J. H. W.

***Investigation of the Figure of Small Concave Metal-Replica Mirrors [Electrodeposited on Glass].** John N. Shive (*J. Opt. Soc. Amer.*, 1947, **37**, (10), 849–851).—Electrodeposited coatings on a convex glass surface, primed by evaporation of a metal film, can be used for the quantity production of replica mirrors which have a form differing from the glass surface by about 5 μ/cm. along the diameter. Mirrors up to 12 in. dia. have been made in this way, and S. describes the method of testing the precision of 3 in. paraboloid mirrors of wide aperture ratio.—E. VAN S.

X.—REFINING

***Vacuum Melting and Casting of Beryllium.** A. R. Kaufmann and E. Gordon (*Metal Progress*, 1947, **52**, (3), 387–390).—The apparatus developed for the vacuum melting and refining of beryllium is described in detail. After volatile impurities, such as magnesium and magnesium fluoride, had been distilled off, argon was admitted to the system and casting carried out under a positive pressure of 2–5 lb. Many experiments were made in order to find the most suitable materials for the crucible and mould. Finally, a beryllia crucible enclosed in a graphite ring to support it and aid in the induction heating, was chosen, with a graphite mould having an alundum hot top. Such a mould gave a moderate rate of cooling which avoided the formation on the one hand of internal cracks and on the other of coarse grains. By these means, ingots 4 in. dia. × 6 in. long were successfully produced, as well as smaller ingots (2 in. dia.) and $1\frac{1}{8}$ in.-dia. rods of an alloy containing 2% aluminium.—N. B. V.

Factors Which Control Liquation in Metallurgy. E. A. Peretti (*Eng. and Min. J.*, 1947, **148**, (12), 76–78).—The fundamental principles of effective separation of two constituents are discussed, and consideration is given to phase diagrams, particle size, viscosity, and surface tension of the liquids, &c. Reference is made to metal refining in relation to the subject.—R. GR.

XI.—ANALYSIS

***On the Detection of Aluminium by Means of Aluminon.** C. J. van Nieuwenburg and G. Uitenbroek (*Anal. Chim. Acta*, 1948, **2**, (1), 88–91).—[In English]. A method in which the reaction of Al with aluminon is made specific for this element. If Fe is present in the unknown solution, it is removed by repeatedly shaking 3 ml. of the solution with 2 ml. of benzyl alcohol + carbon tetrachloride (3 : 1); shaking is continued until the red colour with KCNS is discharged. The aqueous solution of aluminon is made up in a special way and contains ammonium acetate and sulphurous acid and is rendered neutral with NH_4OH. The test is carried out in a test-tube. Three drops of the reagent are added to 1 ml. of the nearly neutral solution. The tube is heated to 70° C. and cooled; 2 ml. of alcohol are added and the mixture shaken. Then 1 ml. of 2*N*-HCl is added and the tube again shaken. A pink colour persists if Al is present (sensitivity $1 : 5 \times 10^5$). Only Cr, Co, and U interfere. —R. W. R.

Volumetric Determination, by Alkalimetry, of Cadmium and Zinc. Émile Carrière (*Chim. Analyt.*, 1947, **29**, (4), 83–84).—In the potentiometric titration of $CdSO_4$ with NaOH the following end-points are found: (*a*) *p*H 3·3–7 corresponding to neutralization of the free acid, (*b*) *p*H 9–10·6, formation of $SO_3.4CdO$, and (*c*) *p*H 11·2–12·6, formation of $Cd(OH)_2$. The following end-points are found in the similar titration of Zn: (1) as $Zn(NO_3)_2$ and $ZnCl_2$, (*a*) *p*H 3–6·5, neutralization of free acid, (*b*) *p*H 8·5–11·8, formation of $Zn(OH)_2$; (2) as $ZnSO_4$, (*a*) *p*H 2·8–6·4, neutralization of free acid, (*b*) *p*H 7·6–9·2, precipitation of basic sulphate $SO_3.5ZnO$, and (*c*) *p*H 9·4–11·5, formation of $Zn(OH)_2$.—E. N.

***Critical Study of the Gravimetric Estimation of Calcium in the Presence of Magnesium.** Simonne Peltier and Clément Duval (*Anal. Chim. Acta*, 1947, **1**, (6), 408–420).—[In French]. Only four convenient methods exist for the gravimetric determination of Ca in the presence of Mg. These are: precipitation as (*a*) tungstate, (*b*) oxalate in the presence of glycerol, (*c*) oxalate in the presence of formic acid, and (*d*) sulphate followed by oxalate. The tungstate method is the simplest and quickest. Pyrolysis curves taken with the Chevenard thermo-balance showed that the Ca oxalate precipitate has the formula $C_2O_4Ca.H_2O$; the Mg oxalate precipitate contains two molecules of water. Ca may also be determined by precipitation as a double hexanitritonickelate with K, and subsequent estimation of the Ni by electrolysis. —R. W. R.

***Titration of Cerium Ions with Permanganate.** G. Goffart (*Anal. Chim. Acta*, 1948, **2**, (2), 140–145).—[In French]. About 150 mg. of Ce should be contained as nitrate in 25 ml. of the unknown solution. This quantity of the solution is added to about 200 ml. of saturated sodium pyrophosphate solution which has been acidified to a suitable *p*H with HCl. This mixture is titrated with 0·02*M*-$KMnO_4$ solution. The end-point may be determined potentiometrically, using a polished Pt electrode and a calomel cell, or amperometrically, using a Pt indicating electrode connected through a 1000-ohm resistance to an Ag electrode covered with AgCl. Best results are obtained with the latter method. Only Mn interferes.—R. W. R.

***A Colorimetric Determination of Copper.** D. Monnier, I. Pardova, and P. E. Wenger (*Anal. Chim. Acta*, 1948, **2**, (1), 30–35).—[In French]. Cu may be estimated by dissolving its anhydrous chloride (cupric) in a 10% KCNS solution in acetone. A red complex is produced which allows Cu to be estimated with the Pulfrich spectrophotometer. The colour begins to fade after 10 min., so that the determination must be carried out quickly. Fe, Co, and Mo chlorides interfere.—R. W. R.

***Rapid Colorimetric Determination of Copper in Tin Alloys.** George Norwitz (*Analyt. Chem.*, 1948, **20**, (5), 469–470).—The sample is dissolved in *aqua regia*, H_3PO_4 added, and the solution boiled. It is then made ammoniacal, and, since H_3PO_4 prevents the precipitation of Sn, the blue colour of the Cu amine can be measured immediately on a photo-electric colorimeter.—F. M. L.

***Some Properties of Lead, Copper, and Antimony Applicable to the Analysis of Their Alloys [Anti-Friction Metals].** Arnold Lassieur and L. Martelli (*Chim. Analyt.*, 1948, **30**, (1), 9–11).—The determination of Pb by precipitation as $PbSO_4$ or PbO_2, filtering off on paper, and igniting at various temp. up to 700° C. gives varying results owing to partial reduction by organic matter present in the paper. For reliable results it is necessary, therefore, to filter on an inorganic support. When Sb is present the determination gives high results owing to entrapping of Sb in the $PbSO_4$ precipitate. The advantages of using K_2S or yellow $(NH_4)_2S$ for the separation of Cu and Pb from Sb and Sn are discussed.—E. N.

***On the Thermogravimetry of Analytical Precipitates. V.—Determination of Magnesium. VI.—Determination of Beryllium. VII.—Determination of Lithium.** Thérèse Duval and Clément Duval (*Anal. Chim. Acta*, 1948, **2**, (1), 45–52).—[In French]. Cf. *Met. Abs.*, 1948, **15**, 594. The Chevenard thermobalance was used to examine the pyrolysis of various compounds of Mg, Be, and Li proposed for the gravimetric determination of these elements. No definite formulæ can be assigned to precipitated magnesium fluoride or to precipitated ammonium magnesium carbonate. Beryllia can be determined after heating to only 951° C. instead of 1200° C. Be should be determined as pyrophosphate rather than as anhydrous sulphate. The salts normally employed for the estimation of Li should be heated to the following temp.: chloride 175°–606° C., sulphate above 160° C., phosphate above 450° C., and aluminate above 471° C.—R. W. R.

***Determination of Magnesium in Aluminium Alloys.** E. Bertrand (*Chim. Analyt.*, 1947, **29**, (11), 244).—To 6–8 g. NaOH add 1·5 g. sample and up to 70 c.c. H_2O, in small quantities. Warm, and when the reaction has ceased, filter and wash with H_2O. Wash the precipitate into 25 c.c. hot 1 : 1-HCl + 5 c.c. 1 : 1-HNO_3, dilute to 60 c.c., add 10 c.c. 50% tartaric acid solution and then NH_4OH to 5 c.c. in excess of neutral. Add 0·02 g. dimethylglyoxime to precipitate Ni, stir, add a small excess of $(NH_4)_2S$, cool, stand, and filter. To the filtrate add 40 c.c. NH_4OH and 15 c.c. $(NH_4)_3PO_4$, shake well for 10 min., filter off the precipitate, wash with 5% NH_4OH, dry, and calcine to $Mg_2P_2O_7$. —E. N.

Determination of Manganese in Nickel, Cupro-Nickel, German Silver, and Brass. M. Brut (*Chim. Analyt.*, 1947, **29**, (3), 59–61).—Modifications of the persulphate method are described, as the Cu and Ni present colour the solution. Interference due to Cu can be minimized by taking a smaller sample than usual; interference due to Ni is compensated by addition of $CoSO_4$. To oxidize the Mn to MnO_4, add $AgNO_3$ to the solution of the metal, neutralize with NH_4OH, acidify to excess with H_3PO_4, add $(NH_4)_2S_2O_8$, dilute, boil, and cool. The solution is then titrated in the usual manner.—E. N.

***Amperometric Titration of Manganese.** G. Goffart, G. Michel, and Th. Pitance (*Anal. Chim. Acta*, 1947, **1**, (6), 393–407).—[In French]. Between 50 and 100 ml. of the Mn solution (containing 2–100 mg. Mn) are poured into 200–300 ml. of saturated sodium pyrophosphate solution, and the *p*H adjusted to 6·0–8·0. The Mn^{2+} ions are oxidized to Mn^{3+}, forming a stable complex. An Ag wire and a Pt wire are dipped into the solution and their other ends connected to opposite terminals of a pointer galvanometer. The solution is titrated with potassium permanganate solution (0·02–0·002M). Near the end-point, instability of the galvanometer pointer is observed, and at the end-point a marked increase in the current occurs. There is little interference from foreign ions.—R. W. R.

***Ortho-Oxy-Phenylfluorone, a Reagent Specific for Either Molybdenum or Copper.** J. Gillis, A. Claeys, and J. Hoste (*Anal. Chim. Acta*, 1947, **1**, (6), 421–428).—[In French]. Describes spot-tests for Mo and Cu, using ortho-oxy-phenylfluorone reagent. A drop of 0·1% solution of the reagent is placed on a special filter paper and allowed to dry at room temp. A drop of the unknown solution rendered 1N with HCl is placed on the paper, followed by two drops of 20% KF solution and 2–3 drops of 0·5% H_2SO_4. A carmine-red coloration appears if Mo is present (sensitivity 1 in 3×10^4). Only Cu interferes. Cu may be detected by placing a drop of the neutral solution on a drop-plate and adding a drop of 20% KF, a drop of potassium tartrate + H_2O_2, and a drop of the reagent. An indigo precipitate is produced in the presence of the Cu^{2+} ion (sensitivity 1 in 3×10^4). Au and Ru ions interfere.—R. W. R.

Analysis of Industrial Nickel. L. Bertiaux (*Chim. Analyt.*, 1947, **29**, (6), 125–132; (7), 154–161; (8), 177–184).—Methods are described in detail for the complete analysis of all impurities in Ni cubes, Mond Ni pellets, Ni cathodes, and secondary Ni.—E. N.

***1 : 2-Cyclohexanedione Dioxime : A Reagent for Nickel.** Roger C. Voter, Charles V. Banks, and Harvey Diehl (*Analyt. Chem.*, 1948, **20**, (5), 458–460).—1 : 2-cyclohexanedione dioxime (nioxime), is similar to dimethylglyoxime in that it gives scarlet and yellow precipitates respectively with Ni and Pd. The reagent is soluble in water, and precipitation of Ni is complete at *p*H values of 3 and greater. 1 part of Ni in 10^7 can be detected, and separation is complete from Zn, Be, U, Al, Mn, Cd, Sb, As, and alkali and alkaline-earth metals. Separation from Fe is not possible.—F. M. L.

***The Detection, Separation, and Micro-Titration of Iridium.** W. B. Pollard (*Bull. Inst. Min. Met.*, 1948, (**497**), 9–18).—P. describes a procedure for the estimation of small quantities (0·100–0·001 mg.) of Ir in platiniferous ores and concentrates. The metals of the Pt group are dissolved as sulphates by heating with a mixture of strong H_2SO_4 and an alkali (Li) sulphate after first alloying with Sn; they form double sulphates with Li. The Pt metals in the sulphate solution may be separated from the base metals by reaction with thio-urea, when they are precipitated as sulphides. Ir may be separated from Pt and Rh by adding adurol followed by an excess of mercaptobenzothiazole to the sulphate solution; this precipitates the Pt. If titanous sulphate is then added, Rh separates, leaving the Ir in solution. Ir may be detected in this solution by reaction with perchloric acid, when a mauve coloration develops; the test may be made more sensitive by boiling off the Cl_2 and ClO_2 and adding dichlorbenzidine solution, which produces a yellow coloration (sensitivity: 0·001 mg. Ir in 2 ml.). This yellow coloration is discharged by hydroquinone, and a micro-titration for the estimation of Ir is based on this reaction.
—R. W. R.

***Colorimetric Determination of Iron with Nitroso-R-Salt.** Margaret Griffing and M. G. Mellon (*Analyt. Chem.*, 1947, **19**, (12), 1014–1016).—The spectrophotometric determination of Fe using nitroso-R-salt was critically studied, with particular reference to reagent concentration, *p*H, order of addition of reagents, time of reaction, Fe concentration, and foreign ions. Under certain conditions, the sensitivity is much greater than that of 1 : 10-phenanthroline or 2 : 2′-bipyridine.—F. M. L.

***Colorimetric Determination of Iron with Various Dioximes.** Margaret Griffing and M. G. Mellon (*Analyt. Chem.*, 1947, **19**, (12), 1017–1020).—Fe is determined either spectrophotometrically or by visual colour comparison by reducing it in ammoniacal solution with sodium dithionite then adding diethylaminobutanedionedioxime, butanedionedioxime, or 1 : 2-cylcohexanedionedioxime.—F. M. L.

Miscellaneous Inorganic Reagents for Potassium. R. Belcher (*Indust. Chemist*, 1948, **24**, (279), 213–216).—B. reviews a number of less common methods for the detection and estimation of K. These include precipitation with per-iodic acid, zirconium sulphate, sodium bismuth thiosulphate, fluosilicic acid, fluoboric acid, fluotitanic acid, uranyl nitrate plus sodium chromate, sodium cobaltithiosulphate, calcium ferrocyanide, phosphomolybdic acid, and phosphotungstic acid.—R. W. R.

***Qualitative Detection of Sodium.** P. Galet (*Chim. Analyt.*, 1947, **29**, (1), 17).—After separation of other cations, Na gives a characteristic reaction with triethanolamine orthodinitro-cyclohexylphenate (cold, 10% solution). The precipitate of sodium orthodinitro-cyclohexylphenate consists of brilliant golden spangles which are soluble on warming or in alcohol.—E. N.

***On the Thermogravimetry of Analytical Precipitates. VIII.—Estimation of Sodium.** Thérèse Duval and Clément Duval (*Anal. Chim. Acta*, 1948, **2**, (2), 97–102).—[In French]. Cf. *Met. Abs.*, this vol., p. 21. The authors investigated with the thermo-balance various precipitates used in the analysis of Na. The triple acetates (Na–Zn–uranyl acetate and Na–Mg–uranyl acetate) should only be weighed as pyro-uranates, obtained by heating the precipitate to above 360° C. The triple nitrite of Bi, Cs, and Na, obtained by Ball's method, is recommended for the estimation of Na.—R. W. R.

***On the Thermogravimetry of Analytical Precipitates. X.—Estimation of Potassium.** Thérèse Duval and Clément Duval (*Anal. Chim. Acta*, 1948, **2**, (2), 105–109).—[In French]. Cf. preceding abstract. The authors examined 10 compounds of K with the thermo-balance and determined the correct drying temp. for accurate estimation by weighing. The following precipitates are suitable for the gravimetric estimation of K: chloride, perchlorate, sulphate, perrhenate, hexachloroplatinate, chloro-6-nitro-5-toluene-*m*-sulphonate, hydrogenotartrate, picrate, and dipicrylaminate. The hexanitritocobaltate is unsuitable for gravimetric determination.—R. W. R.

***On the Thermogravimetry of Analytical Precipitates. XI.—Estimation of Rubidium.** Thérèse Duval and Clément Duval (*Anal. Chim. Acta*, 1948, **2**, (2), 110–114).—[In French]. Cf. preceding abstract. The thermo-balance was used to examine the following compounds of Rb: chloride, perchlorate, sulphate, hexanitritocobaltate, hexachlorostannate, and hexachloroplatinate. The acid and neutral sulphate precipitates differ in that the acid sulphate cannot be dried to a fixed composition. The hexanitritocobaltate is not suitable for gravimetric analysis, and the hexachlorostannate is not recommended for accurate work. The correct ranges of drying temp. were found for the other precipitates.—R. W. R.

***The Estimation of Thallium.** B. S. V. Raghava Rao (*Current Sci.*, 1947, **16**, (12), 376).—The use of methyl orange or similar indicators leads to faulty end-points on the volumetric estimation of Tl. A rapid gravimetric method is proposed in which the metal is weighed as $TlIO_3$. The cold thallous solution containing not more than 0·2 g. of metal/50 ml. is well stirred with 20 ml. of a 5% solution of iodic acid and 10 ml. of alcohol. The heavy white granular precipitate, after filtering, washing, and drying, is weighed. The factor for Tl is 0·67836. The effect of the very slight solubility of the salt in water is discussed.—D. M. L.

***The Photometric Determination of Tungsten.** C. H. R. Gentry and L. G. Sherrington (*Analyst*, 1948, **73**, (863), 57–67).—5–10 c.c. of the W solution are placed in a 50-c.c. graduated flask and 16 c.c. of 12*N*-HCl and 1 c.c. of 10% $SnCl_2$ in 6*N*-HCl added; after cooling the solution to room temp. 2 c.c. of Sn amalgam are added and the mixture shaken for 2–5 min. 5 c.c. of 12% KCNS solution are added, the solution made up to 50 c.c., and the yellow colour measured absorptiometrically, using 2 cm. cells and an Hg vapour lamp in conjunction with Chance No. 8 (OV.I.) and Ilford 601 filters.—F. M. L.

Report of [A.S.T.M.] Committee E-3 on Chemical Analysis of Metals. —— (*Amer. Soc. Test. Mat. Preprint* No. 82, 1947, 4 pp.).—A new tentative method for sampling slab Zn (E65–46T), and a revision of tentative methods for the chemical analysis of Pb- and Sn-base solders (E46–46T) were accepted.
—R. L. B.

***2 : 7-Diaminodiphenylene Oxide as a Reagent in Analysis.** N. M. Cullinane and S. J. Chard (*Analyst*, 1948, **73**, (863), 95–97).—This reagent can be used with advantage in place of benzidine for the detection of radicals with oxidizing properties. The sensitivity of this reagent and benzidine are compared for the detection of Ag, Fe^{III}, Pt, Au, Tl^{III}, Ce^{IV}, Pb, Cu, Mn, Co, chromate, vanadate, bismuthate, and silicate.—F. M. L.

***Preparation of Standard Chromous Sulphate or Chromous Chloride Solutions of Determinate Concentration.** James J. Lingane and Robert L. Pecsok (*Analyt. Chem.*, 1948, **20**, (5), 425–428).—A known amount of pure $K_2Cr_2O_7$ is reduced with amalgamated Zn in slightly acid solution to yield a chromous solution of known normality. The reduction and storage of the solution over amalgamated Zn and under H_2 is carried out in the same apparatus, which is described. The potentiometric titration of Cu in 4–6*N*-HCl is discussed, and experiment shows it to be accurate to ±0·1%.—F. M. L.

Some Recent Advances in Analytical Technique. R. Belcher (*Indust. Chemist*, 1948, **24**, (281), 400–402).—Includes brief accounts of the determination of mercuric Hg with dithiane and the detection of Mo and Cu with fluorone derivatives.—R. W. R.

On the Phenomena of Oxidation–Reduction in Analytical Chemistry. G. Charlot (*Anal. Chim. Acta*, 1948, **2**, (2), 150–166).—[In French]. A general review of oxidation–reduction methods in analytical chemistry. Many reactions important in metallurgical analysis are considered.—R. W. R.

***Reversion: a New Procedure in Absorptiometry.** H. Irving, G. Andrew, and E. J. Risdon (*Nature*, 1948, **161**, (4099), 805–806).—By means of a reagent which will decompose only the desired metal complex, previously formed with dithizone, changes in optical density can be measured which are independent of the concentration of the dithizone used.—M. B. W.

***A Method of Spectrographic Analysis of Impurities in Materials for Oxide Coating of Thermionic Cathodes.** T. J. Organ and S. L. Parsons (*J. Opt. Soc. Amer.*, 1948, **38**, (2), 191–195).—Pellets of specimens in the form of nitrates are burned in a high-voltage A.C. arc, and the spectra are recorded with a quartz spectrograph. Plate calibration is by means of Fe arc line measurement and synthetic standards are made from solutions evaporated to dryness. The double carbonates of Ba, Sr, and Ca are tested for Cu, Al, Fe, Pb, Mn, and Mg down to about 1 p.p.m. with fair reproducibility and excellent agreement between different laboratories.—E. van S.

Economic Method of Adapting Basic Spectrographic Equipment to Precision Quantitative Analysis. Philip H. Brotzman and Herman E. Hemker (*Steel*, 1947, **121**, (2), 83, 118, 121–122).—Modern technique is described, including stabilizing the arc with a magnetic field round the carbon electrode (using 4600 V. A.C. for the arc), controlling the light by introducing a diaphragm between the arc and spectrograph, and the provision of standards. The operator should be able to analyse 50–60 samples per day.—M. A. V.

Quantitative Analysis of Mixed Powders with the Geiger-Counter X-Ray Spectrometer. Zigmond W. Wilchinsky (*J. Appl. Physics*, 1947, **18**, (10), 929).—W. develops an expression for the calculation of the weight fraction of a crystalline component in a mixed sample, from the observed diffracted X-ray intensities.—D. W. W.

[X-Ray] Metal-Analysis Unit. —— (*Sci. Amer.*, 1948, **178**, (2), 85). —H. Pl.

XII.—LABORATORY APPARATUS, INSTRUMENTS, &c.

(See also " Testing " and " Temperature Measurement and Control ".)

A Recording Dilatometer for Metallurgical Research. J. O. Lord (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19**, (5), 9–11).—Description of an instrument with which dimensional changes can be studied in the temp. range +2400° to −250° C. The equipment is specially intended for the study of the behaviour of metals and alloys at sub-zero temp.—A. I. V.

The Influence of Temperature Variations on Precision-Type Instruments. Edmond Guyot (*Microtecnic*, 1947, **1**, (1), 5–8).—Three ways to overcome the effect of temp. variations are: placing the instrument in a room kept at const. temp.; calibration for different temp., corrections being made on subsequent observations; and modification of the constants of the instrument by calculation.—R. L. B.

Laboratory Vacuum Pumps. —— (*Engineering*, 1948, **165**, (4293), 440).—After a brief account of the requirements of a vacuum pump, a detailed description is given of a particular type of manufactured pump with a swept volume of 4 ft.^{3}/min. to vacuum of 0·01 mm. mercury.—R. Gr.

Vacuum Furnace for Laboratory Use. R. Kiessling (*Tekn. Tidskr.*, 1947, **77**, (32), 586–587; *Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (12), 578–579).—A vacuum furnace, originally suggested by R. D. Evans, for use at temp. up to 2200° C. has been built at the Chemical Institute at Uppsala. For heating, A.C. at 200–500 amp. is passed through a split graphite tube. Details of the furnace construction are given; water cooling is employed. The furnace is evacuated by an oil diffusion pump, of 4 l./hr. capacity, and a rotary pump. Temp. is measured optically to an accuracy of 15° C. The furnace has been used to investigate the chromium–boron and the nickel–boron systems.
—R. L. B.

Limits of Resolution of the Visual Microscope. N. G. Neuweiler (*Microtecnic*, 1947, **1**, (3), 62–64).—The limit of resolution is analysed mathematically, and means of increasing resolving power are mentioned. The *pleurosigma angulatum* test is described, and an equation is presented giving the useful magnification of a microscope.—R. L. B.

***A Large Field Compensator of the Berek Type.** W. A. P. Fisher (*Nature*, 1948, **161**, (4100), 848).—Note describing a compensator using frozen stress in a plate of C.R. 39 resin in which the sensitivity becomes greater for smaller retardations. The range is from 0 to 3 fringes at 69° tilt, sensitivity 1/20 fringe or better.—M. B. W.

***A New Microscopic Principle.** D. Gabor (*Nature*, 1948, **161**, (4098), 777).—A description of a means of improving the resolving power of electron microscopes beyond 5 Å, dispensing with electron objectives. A photographic record is produced by interference of a divergent primary wave with the coherent part of a secondary wave emitted by the object. The plate is then illuminated by an optical imitation of the electronic wave, and an image of the original object is formed. The principle has been tested optically, and the preparation of an electronic instrument is in hand.—M. B. W.

***The Optics of Three-Electrode Electron Guns.** S. G. Ellis (*J. Appl. Physics*, 1947, **18**, (10), 879–890).—Mainly theoretical. E. calculates the position of the image of the cathode, the magnification, and the divergence of the beam leaving the anode, for a three-electrode gun of the type used in electron microscopes, for the simplifying assumption that the electrostatic lenses are thin. The results are compared with experiment for an emission microscope. The extension of the results to the gun used in transmission electron microscopes is discussed for both fixed-bias and cathode-bias guns.—D. W. W.

A Rapid Mechanical Method of Transforming Weissenberg X-Ray Photographs Into a Reciprocal Lattice. V. Vand (*J. Sci. Instruments*, 1947, **24**, (12), 326–328).—A simple mechanical method for transforming Weissenberg photographs into a reciprocal lattice is described. The general theory of the method, which is applicable to other types of moving-film cameras, is described in detail. The necessary apparatus consists essentially of a rotating table bearing a sheet of paper, linked to a movable arm *B* which carries the photograph, in such a way that the turntable makes half a revolution when the photograph traverses a distance corresponding to a rotation of the crystal in the camera of 180°. The photograph moves over a fixed glass plate on which is inscribed a curve *H* given by the theory. A second movable arm *A* holds a stylus over the paper, and carries a celluloid sheet on which is inscribed a curve *G* given by the theory. In operation, arms *A* and *B* are moved so that each spot on the photograph is brought over curve *H*, and curve *G* brought over the spot. The stylus is then depressed. Operation is rapid, and easily reversed to indicate positions missing or which expected reflections would occupy on the photograph.—G. V. R.

Equipment for X-Ray Crystallography. T. L. Tippell (*Instrument Practice*, 1948, **2**, (5), 189–190, 196).—T. refers to three types of X-ray sets using respectively: a completely sealed-off X-ray tube; a continuously evacuated, hot-cathode, demountable X-ray tube; and a demountable gas-discharge tube. The advantages and disadvantages of each type are discussed, and an example of the second type is described.—P. L.

Remarks on Some Recently Developed Devices for Summing Fourier Series for Crystal-Structure Analysis. C. L. Christ (*J. Appl. Physics*, 1947, **18**, (12), 1133).—Cf. *ibid.*, 601–604; *Met. Abs.*, 1948, **15**, 358.—D. W. W.

Facilities and Activities in Metallurgical Research. Mars G. Fontana (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19**, (5), 3–4).—An account of facilities for metallurgical research and the activities in this field at Ohio State University, with special reference to the Corrosion Research Laboratory and the Mechanical Testing Laboratory, particularly adapted for investigations at very low temp.—A. I. V.

XIII.—PHYSICAL AND MECHANICAL TESTING, INSPECTION, AND RADIOLOGY

Testing Hardness Up to 700° F. A. L. Pranses (*Metal Progress*, 1947, **52**, (2), 249–250).—Specimens are heated in a tubular electric furnace and the temp. indicated by "Tempilstiks", before indentation tests are made on a Rockwell machine.—N. B. V.

A New Hardness Tester of the Poldi Steel Works. V. Jareš (*Strojn. Obzor*, 1947, **27**, (10), 213–214; *Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (12), 582).—The new hardness tester is transportable (weighing only 14 lb.) and is based on the Vickers principle. Load, which is applied by a special helical spring giving an accuracy of 0·2%, can be varied between 5 and 30 kg., and imprint measurement is effected by a micrometrically adjustable microscope giving readings to within 0·001 mm.—R. L. B.

***A New Design of Micro-Hardness Tester and Some Factors Affecting the Diamond Pyramid Hardness Number at Light Loads.** R. F. Campbell, Q. Henderson, and M. R. Donleavy (*Trans. Amer. Soc. Metals*, 1948, **40**, 954–982).—The instrument consists of four units; (1) the indenting mechanism, which is a counterbalanced lever carrying the indenter at one end and a load pan midway between the indenter and the fulcrum; the load is applied electrically; (2) a microscope for setting the field and measuring the impression; (3) a mechanical stage which carries the specimen and is arranged to move along a runway between the microscope and the indenter; accuracy of the apparatus is such that the indentation coincides with the selected spot within 5 μ; and (4) a control box which controls the loading cycle (30 sec.); if required the indenter can be made to traverse the specimen automatically, making impressions at any predetermined intervals. A square-base 136° diamond pyramid indenter is used; the load range is 5–100 g. Results obtained with the instrument on 0·74%-carbon steel specimens are compared with those obtained with the standard Vickers machine using 10 and 30 kg. loads. Using loads of 50 and 100 g. results agree well with the Vickers figures in the range 225–900 D.P.H. At loads below 50 g. the hardness number obtained decreases progressively with the load. This is shown to be largely due to deviations from the specified geometry of the tip of the indenter, resulting in an oblong impression. The absolute error is least but the percentage error is greatest at low hardnesses. With loads below 50 g. unetched surfaces yield lower figures than etched ones. Some examples are given of the application of the instrument to the measurement of the hardness of micro-constituents.—R. W. R.

Micro-Hardness Tester. —— (*Mech. Eng.*, 1947, **69**, (5), 408).—The tester consists of the indenter with a square base, 136° diamond pyramid penetrator, the mechanical stage for holding the specimen, a microscope capable of magnifying the test field 500–1500 times, and a control box. The diameter of the indentation is measured in microns. The device makes possible the measurement of hardness gradients within areas too small to permit satisfactory exploration with any of the usual hardness testers.—H. Pl.

Laboratory for Mechanical Testing at Very Low Temperatures. John L. Zambrow (*Ohio State Univ., Eng. Exper. Sta. News*, 1947, **19**, (5), 4–9).—A description of the low-temp. mechanical-testing laboratory at Ohio State University, established primarily for a study of the mechanical properties of metals and alloys in the temp. range −78° to −253° C. The machines available are: Riehlé impact, Vickers hardness, Brinell hardness, Olsen universal, and Krause fatigue testing.—A. I. V.

***The Velocity Aspect of Tension-Impact Testing.** William H. Hoppmann II (*Amer. Soc. Test. Mat. Preprint* No. **32**, 1947, 12 pp.).—H. describes a guillotine impact-testing machine. The machine is 80 ft. high and consists of a tower with a pneumatic gun at the top and an anvil at the bottom; steel rails guide the 30-lb. hammer which drops on to a weight which falls on to the free end of the suspended specimen, while the fall of the hammer is arrested by the anvil. The machine was designed for an impact speed of 100 ft./sec., but has been used for tests at 125 ft./sec. The machine has been used for specimens having a rupture resistance of 10,000 ft.lb. The force/time oscillograms are obtained by means of electrical resistance strain-gauges, attached to the weight-bar above the specimen, and a standardizing synchronous spark. Results of guillotine impact tests on hard-drawn copper are graphically presented, and mention is made of the factors affecting " critical velocity ". —R. L. B.

***The Progress of Failure in Metals is Traced by Changes in Magnetic and Electrical Properties.** P. E. Cavanagh (*Amer. Soc. Test. Mat. Preprint* No. **26**, 1947, 9 pp.).—The relative changes in magnetic and eddy-current losses during normal fatigue tests in an Avery rotating-beam fatigue machine were determined for 6 metals at loads above and below their endurance limit. A Du Mont cyclograph recorded the changes in magnetic and electrical properties. For non-magnetic materials during fatigue testing these changes are due to eddy-current variations, and for ferrous materials to the eddy-current and hysteresis changes. The effect of normal-speed and high-speed fatigue testing on these properties was examined. Hardness and tensile tests showed no increase in yield stress but a slight increase in hardness. The results indicate the possibility of utilizing these phenomena to estimate the rate of propagation of slip in a metal. A *bibliography* of 27 references is appended. —R. L. B.

Report of [A.S.T.M.] Committee E-9 on Fatigue. —— (*Amer. Soc. Test. Mat. Preprint* No. **119**, 1947, 2 pp.).—R. L. B.

[Discussion on Paper by W. Siegfried on] Observations on Conducting and Evaluating Creep Tests. —— (*J. Iron Steel Inst.*, 1947, **157**, (3), 382–384; 1948, **158**, (4), 462).—Cf. *ibid.*, 1947, **156**, 189; *Met. Abs.*, 1948, **15**, 25. —R. W. R.

High-Temperature Testing. W. E. Kuhn (*Canad. Metals*, 1947, **10**, (5), 20–22, 43; (6), 27–29, 50).—Essential requirements for high-precision creep testing are discussed. The ability of a metal to resist attack by oxidation, corrosion, and erosion at high temp. is a most important consideration in high-temp. design. The magnitude and frequency of the alternating fatigue stresses set up in turbine blades are described. A *bibliography* of 14 references is given.—R. L. B.

Jet Alloys Tested by Rapid Spinning at High Temperatures. —— (*Sci. Amer.*, 1947, **177**, (2), 77–78; 1948, **178**, (2), 79).—1-ft. dia. discs of special alloys are heated to 1400° F. (760° C.) and spun at speeds of 35,000 r.p.m. until they fly apart under the combined action of centrifugal force and heat. —H. Pl.

***Dry Friction of Metals as Affected by Surface Finish and Surface Coatings.** N. Ludwig (*Technik*, 1947, **2**, (4), 166–170; *Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (11), 516–517).—An apparatus to measure sliding friction is shown diagrammatically. A pressure of between 0·025 and 0·5 kg./cm.^{2} is applied to press a test cube against a plane surface of 20 cm. length which slides at a velocity of between 0·1 and 10 cm./sec. The frictional force is measured by a spring mechanism with an accuracy of ±2·3%. A pressure of 0·15 kg./cm.^{2} and a velocity of 0·25 cm./sec. were chosen as most suitable. The effect of surface finish was examined on steel, cast iron, pure copper, and brass. Friction was highest with a copper/copper combination and smallest for the combinations steel/brass and cast-iron/brass. Combinations with brass gave results practically independent of surface finish. The friction of various surface coatings was also determined. The hard chromium-plated surface gave the lowest friction.—R. L. B.

New Indentation Method Determines Equipment Wear. (*World Oil*, 1947, **127**, (6), 104–110).—The McKee wear gauge was developed to measure extremely small increments of wear, as a result of investigations carried out at the U.S. National Bureau of Standards. The method consists of applying to the working surfaces narrow diamond-shaped markings, which show a definite change in one or more readily measurable dimensions after relatively small amounts of wear. The gauge provides a determinable indication of wear at the point where the marking is made, as little as 0·00001 in. being measurable under favourable conditions.—A. I. V.

Experimental Method of Stress Analysis. J. H. Lamble (*Engineering*, 1948, **165**, (4293), 436).—A brief description is given of the use of ordinary plumbers' resin as a coating, which, on cracking, indicates the distribution of stress.—R. Gr.

***Brittle-Lacquer Technique Used to Test [Aluminium] Impeller Design.** Herbert Dobkin (*Steel*, 1947, **121**, (9), 70–71, 98–99).—" Stress-coat " lacquer was used to investigate stresses in large forged aluminium alloy (14S-T or 24S-T) impellers used in gas turbines, &c. A cantilever beam was used as a calibration bar, and an allowance of 10% made for the dynamic loading of the test impeller. Results agreed reasonably well with calculated stresses. —M. A. V.

The Brittle-Lacquer Method of Determining Stresses. —— (*Metallurgia*, 1948, **37**, (222), 290–292).—Abstracted from Chapter IV of " Stress Determination in Machine Parts by Means of Tensometers and Lacquers ", by N. R. Goncharov, Leningrad and Moscow: **1946**. The choice of lacquer, effect of atmospheric conditions, and electrometric determination of continuity are discussed, and illustrations of the use of brittle lacquers given. —M. A. V.

Report of [A.S.T.M.] Committee E-1 on Methods of Testing. —— (*Amer. Soc. Test. Mat. Preprint* No. **81**, 1947, 6 pp.).—Progress report.—R. L. B.

A New Type of Magnetic Flaw Detector. Carlton H. Hastings (*Amer. Soc. Test. Mat. Preprint* No. **22**, 1947, 9 pp.).

Inspection Methods Using Magnaflux and Zyglo in Production Industries. W. E. Thomas (*Non-Destructive Test.*, 1947, **6**, (2), 9–14).—The factors governing the choice, scope, and application of inspection procedure are discussed, with particular reference to magnetic (Magnaflux and Magnaglo) and fluorescent (Zyglo) methods of crack detection. The factors governing the application of these last two techniques are discussed. It is emphasized that acceptance standards must be applied in such inspection procedures. Automatic machines for magnetic testing are described and illustrated. —L. M.

Applications of Supersonics in Industrial Inspection. James W. Dice (*Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (8), 352).—Examples are given in which the technique has been successfully employed for the inspection of aluminium, magnesium, brass, and bronze billets, castings, forgings, and extrusions.—R. L. B.

[Inspection of] Aluminium Alloy Castings [—VII]. Floyd A. Lewis (*Foundry*, 1948, **76**, (6), 96–97, 262, 264, 266, 268).—Cf. *Met. Abs.*, this vol., p. 30. L. discusses the use of stress-analysis methods and radiography as aids to the designer of aluminium castings.—R. W. R.

Inspection of Light-Alloy Components. F. A. Allen (*Eng. Inspection*, 1947, **11**, (3), 4–7).—Discusses the causes of pin-holing and porosity, blisters, flux inclusions, " drawing ", cavitation, hot cracking, forge-cracking, oxide inclusions, and weld-cracking.—R. L. B.

Determining Surface Roughness. Walter Mikelson (*Mech. Eng.*, 1947, **69**, (5), 391–393).—Roughness samples are produced by electroplating. A thin lead plate is pressed into the master surface to produce a negative impression. It is then pulled away from the master, and a thin coating of nickel (0·003–0·005 in.) is electrodeposited on the lead impression. The nickel is backed by electrodeposited copper. 4 micro-in. average is the limit below which roughness cannot be judged satisfactorily.—H. Pl.

Report of [A.S.T.M.] Committee E-11 on Quality Control of Materials. —— (*Amer. Soc. Test. Mat. Preprint* No. **87**, 1947, 2 pp.).—R. L. B.

Is the Study of Metals the Most Interesting of All the Sciences? — Hinsley (*Eng. Inspection*, 1947, **11**, (4), 22–24).—The usefulness of inspection in metallurgy is discussed, and a few topics of metallurgical interest mentioned. —R. L. B.

RADIOLOGY

The Value of High-Voltage X-Ray in [Casting] Automotive Parts. E. H. Grimm (*Non-Destructive Testing*, 1947, **6**, (2), 20–21).—The value of radiographic inspection as an aid to foundry practice and control is illustrated by examples of improved casting technique, resulting from X-ray inspection, in a foundry producing crankshafts, jacks, and motor housings.—L. M.

Naval Radiographical Laboratory to Assist Welding and Casting Technique. A. Wilson (*Instrument Practice*, 1948, **2**, (6), 236).—Describes the laboratory opened at Chatham in 1946 for radiographical purposes.—P. L.

Short Source–Object-Distance Exposure Techniques in Spot-Weld Radiography. R. C. McMaster, F. C. Lindvall, and J. W. Smith (*Non-Destructive Testing*, 1947, **6**, (2), 31–37).—A detailed description of the technique of spot-weld radiography and the equipment used, with particular reference to the inspection *in situ* of spot welds in aluminium alloy sheet assemblies. Soft X-radiation (below 50 kV.), ultra-fine-grain non-screen film, and target–film distances of $1\frac{1}{8}$–2 in. are utilized. Spot-weld radiography provides a sensitive low-cost means of controlling the quality of spot welds.—L. M.

Precision Radiography at Two Million Volts. E. Alfred Burrill (*Non-Destructive Testing*, 1947, **6**, (2), 42–45, 47, 51).—The scope of a 2000-kV. electrostatic (D.C.) X-ray generator is described. The fine focus (only 0·25 mm. dia.) permits the use of a target–object-distance/object–film-distance ratio as small as unity, a technique which offers certain advantages, e.g. in the elimination from the image of scatter from the object; and stereo-radiographic results are improved. The sensitivity for 12-in. steel is better than 1%. The nature of the generator circuit enables it to be used for making stroboscopic radiographs of rotating objects.—L. M.

Use of Radon for Industrial Radiography. A. Morrison (*Non-Destructive Testing*, 1947, **6**, (2), 24–26).—The relative merits of radon and radium for radiography are discussed. Radium is most suitable when radiographic inspection is continuous. Radon should be used when it is not practicable to keep radium available or when the cost of keeping a radium source at hand is greater than that of using radon for occasional work. Tables are given for calculating exposure times for radon from those required for radium sources. —L. M.

XIV.—TEMPERATURE MEASUREMENT AND CONTROL

Measuring Surface Temperatures. G. A. Williams (*Brit. Eng. Export J.*, 1947, **29**, (18), 1136–1139).—" Thermindex " temp.-indicating paints described can be used in research and development, heat-treatment of light alloys, inspection, and testing.—R. L. B.

Monitors for Molten Metals. John Markus (*Sci. Amer.*, 1947, **177**, (2), 64–66).—A standard electronic control for die-casting machines combines the principles of the bi-metallic strip with those of an electronic capacitance-responsive control.—H. Pl.

XV.—FOUNDRY PRACTICE AND APPLIANCES

Melting High-Magnesium Aluminium-Base Alloys. F. A. Allen (*Light Metals*, 1947, **10**, (118), 567–568).—A short review of important factors in melting aluminium-base and magnesium-base alloys. For melting aluminium-base alloys containing substantial amounts of magnesium, non-metallic melting pots must be used and the temp. must not exceed 750° C.; grain refinement is achieved by the addition of boron-containing compounds, and fluxes containing sodium salts should not be used. A dusting powder consisting of sulphur and boric acid is recommended to protect the pouring stream of the 10% alloy.—F. A. F.

Aluminium Alloy Castings. [**—IV, —V, —VI**]. Floyd A. Lewis (*Foundry*, 1948, **76**, (3), 90–93, 232, 234, 236; (4), 82–85, 196–197; (5), 142–145, 352–353).—Cf. *Met. Abs.*, 1948, **15**, 600. (IV.—) Describes the different melting furnaces available and discusses the choice of fuel. The control of melting and casting temp. is considered. Alloying and other melting problems are dealt with briefly. (V.—) An account of melting technique (including fluxing and grain refining), pouring procedure, and the care of melting equipment. (VI.—) Factors influencing the choice of casting process and alloy are explained, and the design of parts to be made as aluminium castings is examined. —R. W. R.

[Inspection of] Aluminium Alloy Castings [—VII]. (Lewis.) See p. 29.

New Sklenar Furnace [for Melting Aluminium Alloys]. (——). See p. 34.

***Vacuum Melting and Casting of Beryllium.** (Kaufmann and Gordon). See p. 19.

***The Degassing of Bronzes by Oxidation Treatment.** W. A. Baker. W. T. Pell-Walpole (*Metallurgia*, 1948, **37**, (222), 295–297).—B. compares the results obtained by the British Non-Ferrous Metals Research Association investigators with P.-W.'s results (see *Met. Abs.*, 1948, **15**, 361). Unlike him, they found that zinc over 0·5%, and phosphorus retarded the oxidation of hydrogen by the flux, but B. points out that his own results were obtained with sand castings, and P.-W.'s with chill castings, and that the two are not necessarily at variance. P.-W., in his reply, agrees that his conclusions do not relate to sand castings, which absorb hydrogen from the mould.—M. A. V.

Porosity in Bronze Castings. —— (*Chem. Age*, 1947, **56**, (1456), 745).—A review of a report by the U.S. Office of Technical Services.—S. R.

Bronze Founding—A Review of Some Recent Developments. F. Hudson (*Foundry*, 1948, **76**, (3), 86–89, 172, 174, 176, 178–179, 182–184).—See *Met. Abs.*, 1948, **15**, 202.—R. W. R.

Solidification Mechanism of Tin Bronzes. (Frear). See p. 8.

Church Bells Once Cast on the Site. F. R. Nichols (*Foundry*, 1948, **76**, (3), 80–81, 236, 238).—Describes early practice in the casting of church bells in England.—R. W. R.

Produces Wide Variety of Iron and Non-Ferrous Castings. Gerald E. Stedman (*Foundry*, 1948, **76**, (4), 92–94).—Describes a foundry producing both static and centrifugal castings in cast iron and copper-base alloys. —R. W. R.

Manufacture of Lead Shot. (Williamson). See p. 2.

***Beryllium in Magnesium Casting Alloys.** Jay R. Burns (*Trans. Amer. Soc. Metals*, 1948, **40**, 143–160; discussion, 160–162).—See *Met. Abs.*, 1948, **15**, 295.—R. W. R.

Valve Manufacturer Expands Foundry. Joseph C. Sullivan (*Foundry*, 1948, **76**, (4), 208–210, 212).—Describes the modernization of a foundry producing valve parts in cast iron and copper-base alloys.—R. W. R.

Effect of Sand Properties Upon Castings. N. J. Dunbeck (*Canad. Metals*, 1947, **10**, (6), 22–26, 35, 43).—The effects of moisture content are discussed. Synthetic sands give better flowability. Defects in castings due to too high or too low a mould hardness are described. Other properties mentioned are deformation yield under load, moulding-sand expansion, refractory value and sintering point, collapsibility, and durability.—R. L. B.

Foundry Sand—Uncontrolled. Harold E. Henderson (*Foundry*, 1948, **76**, (4), 95, 230, 234, 236).—A brief discussion of foundry sands and their control. —R. W. R.

***Expansion of Silica Sand.** Herbert H. Fairfield (*Foundry*, 1948, **76**, (5), 128–129).—Describes the results of dilatometric measurements carried out on a specimen of moulding sand. The length of the specimen increases with temp., at first slowly and then more rapidly. The rate of increase is a max. at about 620° C. and falls to zero at about 680° C. Between 680° and 950° C. the length of the specimen is nearly const.; above 950° C. the length decreases markedly, attaining its original value at about 1400° C. F. discusses the influence of sand expansion on the service behaviour of moulding sands. If defects are to be avoided it is important that the sand be plastic in the temp. region of greatest expansivity.—R. W. R.

***Factors Influencing Core Baking.** E. C. Troy (*Foundry*, 1948, **76**, (6), 92–95, 252, 254, 256).—T. describes the results of an investigation of the effect of various factors on the drying of cores. Moisture removal from large cores is relatively slower than from small cores (longer time per inch thickness). Drying time increases with the moisture content of the core, and decreases with the oil content. Drying time is also decreased by (1) addition of resin, (2) coarse grain-size, and (3) the addition of fines. The hardening of cores was also examined.—R. W. R.

Plaster Moulds for Casting Intricate Aluminium Torque-Converter Parts. Herbert Chase (*Iron Age*, 1948, **161**, (7), 60–68).—Describes a new moulding technique employing an unusual combination of plaster sections and dry sand and plaster sections for the production of aluminium castings. The method permits of the production of intricate castings with high physical properties and with as-cast tolerances down to ±0·010 in.—J. H. W.

Westinghouse is Operating an Automatic Moulding Unit. John A. Sharritts (*Foundry*, 1948, **76**, (6), 78–85, 216, 218, 220, 222).—The unit consists of a moulding machine, sand-conditioning plant, mould and sand conveyor systems, and knock-out. Multiple moulding is employed, the flasks being stacked 6 high; each stack produces 25 castings. The plant is hydraulically operated and is almost completely automatic; only coring-up, pouring, and one or two other minor operations are done manually.—R. W. R.

Multiple Moulding Can Increase Production. William G. Gude (*Foundry*, 1948, **76**, (3), 66–69, 198, 200).—Discusses the advantages and limitations of multiple moulding for the production of large numbers of small castings; in this process pattern plates containing a number of impressions run from a central running system are employed. The allied process of stack moulding is also described. In stack moulding, the impressions are in one half of the mould only; a number of boxes are placed one on top of another and all are cast at the same time through a common running system.—R. W. R.

Mould Dryness Measured by New Device. R. E. Hadady (*Foundry*, 1948, **76**, (5), 322, 324, 326).—H. describes an electrical device, the Electric Hydro-Cel, for measuring the moisture content of mould surfaces. The instrument consists of a moisture-sensitive element, the resistance of which is greatly affected by humidity changes, and a measuring circuit and indicator. When the sensitive element is placed on the surface of the mould, the instrument gives a reading in terms of the relative humidity of the atmosphere at the mould surface. Some curves are given which show the evaporation from the surfaces of typical moulds.—R. W. R.

Announcing the New Nonflex Cut-Off Wheel for Foundry Use. E. T. Larson (*Grits and Grinds*, 1948, **39**, (5), 1–4).—L. describes a new cutting wheel designed expressly for the fettling of non-ferrous castings. The wheel cuts fast and is very tough and hard to break.—R. W. R.

Grinding Practice in Non-Ferrous Foundries. A. E. Wilson (*Grits and Grinds*, 1948, **39**, (5), 4–10).—A brief review of the uses of grinding in non-ferrous foundries. Recommendations are made with regard to the choice of wheel for each operation.—R. W. R.

Hoods and Piping for Foundry Dust-Control Systems. E. A. Carsey (*Canad. Metals*, 1947, **10**, (10), 20–22).—Describes the planning, design, and construction of hoods for use in the foundry.—R. L. B.

Overhead Handling System Speeds Foundry Operations. Francis A. Westbrook (*Foundry*, 1948, **76**, (3), 218–219).—A description of an overhead mono-rail system for handling sand and molten metal in a foundry.
—R. W. R.

Handling Materials in the Foundry Yard. Robert H. Herrmann (*Foundry*, 1948, **76**, (3), 70–77).—A description of modern handling plant and methods.
—R. W. R.

The Modernization and Mechanization of the [French] Foundry Industry. R. Norguet (*Found. Trade J.*, 1947, **83**, (1633), 325, 332).—An outline of the reorganization plan for French foundry activities.—J. E. G.

Screwball Ideas Sometimes Work in the Foundry. J. W. Horner, Jr. (*Foundry*, 1948, **76**, (6), 91, 238, 240).—Describes: (1) the use of low-m.p. alloy patterns for making cores by a method analogous to the lost-wax process; (2) the use of semi-permanent moulds for making castings in pure aluminium; (3) the addition of granulated asbestos to moulding sand in order to cure shrinkage troubles in bronze castings—the asbestos also has the effect of improving the refractory qualities of the sand.—R. W. R.

Casting is Changing. Edwin Laird Cady (*Sci. Amer.*, 1947, **177**, (2), 67–69).—New operating techniques, such as the filling of the mould with inert gas and its exhaustion under vacuum pressure as the melt enters, are resulting in casting products with wrought properties. Chilling moulds to

−50° C. has proved effective in the production of light-alloy castings free of hydrogen inclusions. Better grain structure and strength properties are often obtained by heat-treatment of a casting before removal from the mould.
—H. Pl.

The Experimental Foundry at the [Canadian] Bureau of Mines. J. E. Rehder (*Canad. Metals*, 1947, **10**, (11), 14–16).—The work done by the foundry may be divided into : (*a*) routine analysis, and commercial work, (*b*) Government-sponsored projects on industrial and fundamental research, and (*c*) projects sponsored by private industry.—R. L. B.

The Value of High-Voltage X-Ray in [Casting] Automotive Parts. (Grimm). See p. 29.

A New Approach to Foundry Instruction. Erle F. Ross (*Foundry*, 1948, **76**, (5), 140–141, 176).—A description of the method of teaching pattern design and foundry practice at the Chicago Undergraduate Division, University of Illinois.—R. W. R.

Young Men for the [U.S.] Foundry Industry. Frederick G. Sefing (*Foundry*, 1948, **76**, (3), 100).—Describes recommendations, made by the Educational Division of the A.F.A., for the recruitment for the foundry industry of young men from schools and technical colleges.—R. W. R.

Personnel Recruitment [for the Foundry]. R. O. Patterson (*Found. Trade J.*, 1947, **83**, (1632), 307–308).—An address to the Scottish Branch of the Institute of British Foundrymen.—J. E. G.

[Foundry] Management. E. M. Currie (*Found. Trade J.*, 1947, **83**, (1626), 171–173).—Read before the London Branch of the Institute of British Foundrymen. An appeal for enlightened management as a means of raising the status of the foundry industry.—J. E. G.

Centrifugal Casting [of Bearings]. —— (*Amer. Exporter* (*Indust.*), 1946, **138**, (1), S56–S57).—A centrifugally cast bearing, operated without lubrication, ran at a temp. 50° F. (28° C.) lower than a sand-cast bearing under identical conditions of loading and speed.—H. Pl.

Finer Castings. —— (*Sci. Amer.*, 1948, **178**, (2), 76).—Salt-free silica solution may be used as a pre-coat for precision-investment castings.—H. Pl.

Investment Casting. Edwin Laird Cady (*Sci. Amer.*, 1948, **178**, (3), 119–121).—A brief review.—H. Pl.

Vacuum-Melting Techniques. J. D. Nisbet (*Iron Age*, 1948, **161**, (12), 79–82, 122).—N. describes the advantages of vacuum melting for maintaining rigid purity specifications in the melting of many high-temp. alloys and such metals as tungsten, molybdenum, and chromium. He points out the effect of gases on the properties of the metals and compares the various methods used for their removal involving the use of carbon and hydrogen. Difficulties met with in vacuum melting are discussed and means of overcoming them indicated.—J. H. W.

Industrial Vacuum Melting. Kenneth Fox, R. A. Stauffer, and W. O. Dipietro (*Iron Age*, 1948, **161**, (8), 64–70 ; (9), 78–84).—The authors describe various factors in the design of vacuum-melting equipment and indicate the influence of these factors in the production, maintenance, and measurement of vacua ranging from 1 to 25 μ. They discuss various problems of design, construction, and operation in the application of vacua to the melting of metals on a commercial basis and, in particular, such factors as materials of construction, types of heat sources, and techniques of casting under a vacuum. A *bibliography* is appended.—J. H. W.

Die-Casting Magnesium. Herbert Chase (*Iron Age*, 1948, **161**, (9), 68–72).—Describes the equipment used in the production of a large variety of magnesium die-castings and gives notes on injection techniques and die design. Runs of up to one million on some parts are effected with this equipment.—J. H. W.

How to Make Die-Castings. James Van Voast (*Machinist* (*Eur. Edn.*), 1948, **91**, (50), 1637–1652).—Discusses the fundamentals of die-casting alloys of magnesium, aluminium, zinc, copper, lead, and tin from the points of view of casters, machine builders, metal producers, and users.—J. H. W.

1000-Ton Die-Casting Machine. —— (*Iron Age*, 1948, **161**, (13), 78–79). —A cold-chamber, all-hydraulic die-casting machine for aluminium castings up to 15 lb. is described. The machine embodies an automatic feeding system in which a tilting crucible furnace pours a measured amount of aluminium for introduction into the injection chamber.—J. H. W.

XVI.—SECONDARY METALS: SCRAP, RESIDUES, &c.

Gas Fluxing in Production of Secondary Aluminium.—I, —II. G. W. Birdsall (*Steel*, 1947, **121**, (5), 88–89, 115–116, 120, 122, 124; (6), 86–88, 104–105).—(I.—) Aluminium alloy scrap is melted in oil-fired furnaces, with sloping hearths, using a reducing flame. Iron remains on the hearth, while the aluminium melts, and runs off into the holding hearth. Metallic sodium is used for degassing. The requirements of a suitable flux are discussed. (II.—) Purifying methods other than fluxing include overheating, standing, slow solidification, and the use of an inert gas, or of an active gas. Chlorine has proved an effective refining agent, because of its combined chemical activity and mechanical agitating action. A practical installation, using chlorine, is described.—M. A. V.

Celluloid and Silver from Waste. —— (*Canad. Metals*, 1947, **10**, (8), 37).—Silver and celluloid are being recovered from discarded cinematograph film by various baths, rollers, and drying chambers.—R. L. B.

XVII.—FURNACES, FUELS, AND REFRACTORY MATERIALS

New Sklenar Furnace [for Melting Aluminium Alloys]. —— (*Brit. Eng. Export J.*, 1947, **30**, (24), 380).—This reverberatory furnace, designed for copper-base alloys, has been successfully adapted for melting aluminium alloys. The furnace, which is oil-fired, is capable of melting 1400 lb. of aluminium in 49 min.—R. L. B.

Heat-Treatment [Furnaces]. —— (*Brit. Eng. Export J.*, 1947, **29**, (17), 990–991).—Two new heat-treatment furnaces are described. One is of the horizontal forced-air-circulation type, designed for heating light-alloy billets and for low-temp. heat-treatments.—R. L. B.

Heat-Treatment [Furnaces]. —— (*Brit. Eng. Export J.*, 1947, **30**, (24), 375–376).—The gas-fired forced-air-circulating furnaces constructed at the De Havilland Aircraft Co., Ltd., for the large-scale heat-treatment of Duralumin sheets, are described.—R. L. B.

High-Temperature Resistors. —— (*Engineer*, 1948, **185**, (4817), 505).—A brief review is given of methods of producing high temp. with resistors and a new form is described consisting of an aluminium oxide tube, into which is introduced a relatively free and flexible tungsten or molybdenum component, suitably arranged to give max. heat at the centre zone, the connection terminals at the sealed extremities being of silver.—R. Gr.

The Development of Refractories for High-Temperature Industrial Processes. A. Hilliard and J. H. McKee (*Bull. Brit. Coal Utilisation Research Assoc.*, 1947, **11**, (11), 457–468).—A brief review of the subject. The authors discuss the physical considerations in the manufacture of refractories, and the allotropic and chemical changes which occur on heating. The more common refractories are classified according to their chemical properties. Special refractories such as oxides, carbides, nitrides, and borides are considered briefly. The various types of insulating refractories are described. A *bibliography* of 118 references is given.—R. W. R.

Report of [A.S.T.M.] Committee C-8 on Refractories. —— (*Amer. Soc. Test. Mat. Preprint* No. **43**, 1947, 8 pp.).—Progress report.—R. L. B.

XVIII.—HEAT-TREATMENT

Annealing of Nickel, Monel, and Inconel. —— (*Rev. Nickel*, 1947, **13**, (2), 17–23).—Reprint of Bulletin T-20 of the International Nickel Co., New York.—R. W. R.

Gas-Heated Ovens and Tin-Flowing Unit Featured in Crown Cork and Seal Plant. —— (*Indust. Heating*, 1947, **14**, (3), 449–450, 452, 454–458).—Methods used for the manufacture of crown corks at a Baltimore, Md., factory are described and illustrated. The tinned strip is produced on a high-speed strip mill, the tin-flowing being done by a system of gas burners placed in the mill line following the pickling and plating tanks. Illustrations show the lay-out of the tin-plating equipment and some of the other manufacturing processes. —D. M. L.

Gas Chemistry: Its Role in Metallurgy. O. E. Cullen (*Steel*, 1947, **121**, (1), 86–88, 120, 122, 124).—A brief discussion of protective atmospheres for various purposes, including the bright annealing of copper. Compositions and approx. comparative costs of various gases are given.—M. A. V.

The Domain of Radio-Frequency Heating. T. P. Kinn (*Sci. Amer.*, 1948, **178**, (2), 66–69).—Radio-frequency heating has been successfully used to flow an electrodeposited 0·0003 in.-thick tin coating after deposition.—H. Pl.

Infra-Red Rays in Industry. G. FitzGerald-Lee (*Far and Wide*, **1947**, (May), 49–50).—Painted aluminium castings of over 2 cwt. have been stoved in 23 min., compared with 1 hr. by convection heating. A useful application in the foundry is for drying certain types of sand moulds.—R. L. B.

XIX.—WORKING

Extrusion Method of Manufacturing [Nickel, Monel, and Inconel] Tubes. Hugo Lorant (*Mech. Eng.*, 1947, **69**, (6), 471–474; and (summary) *Mech. World*, 1947, **122**, (3159), 113–115).—A 4000-ton double-acting press is being used to extrude billets of Monel, Inconel, and nickel, 7–12 in. dia., into tubes 3–8 in. outside dia. To prevent metal being welded on to the mandrel, a loose head of slightly larger diameter than the diameter of the mandrel is placed on the mandrel point. A cupping method is used which reduces piercing scrap from 50 to 4%.—H. Pl.

Mass-Produced Tube. —— (*Mass Prodn.*, 1948, **24**, (6), 66–68, 89).—A short description of a new machine, the Henderson Universal Tube and Section Mill, for producing steel and non-ferrous tubing by the electric fusion process; the machine can also make a wide variety of sections. Very high rates of production can be attained (up to 100 ft. of tubing or 150 ft. of section per min.).—R. W. R.

Tubes in Manufacture. Edwin Laird Cady (*Sci. Amer.*, 1948, **178**, (2), 60–62).—Silver-clad or silver-lined tubes, as used in radar and radio equipment, are deep-drawn from solid plates of base metal overlaid with solid silver-plate.—H. Pl.

Correspondence on: The First Report of the Rolling-Mill Research Sub-Committee (Special Report No. 34); and on the Papers: Fluctuations of the Distribution of Torque Between Rolling-Mill Spindles, by E. A. W. Hoff, and

The Application to Shaping Processes of Hencky's Laws of Equilibrium, by E. Siebel. —— (*J. Iron Steel Inst.*, 1947, **157**, (2), 208–214).—Cf. *ibid.*, **156**, 511; *Met. Abs.*, 1948, **15**, 117.—W. G. A.

[Discussion on Papers by W. W. Franklin and by P. F. Grove on] Mechanical and Electrical Features of Primary Hot-Rolling-Mill Auxiliaries. —— (*J. Iron Steel Inst.*, 1948, **158**, (3), 376–386).—Cf. *ibid.*, 1947, **157**, 262; *Met. Abs.*, 1948, **15**, 206.—R. W. R.

Electric Control Gear for Steel-Mill Auxiliaries. R. A. West (*J. Iron Steel Inst.*, 1948, **158**, (3), 357–375).—W. discusses and makes recommendations with regard to the following: (1) switchgear, (2) the exclusion of dust from contactors, (3) the control of the acceleration of electric motors, (4) the applications of time- and current-limit systems, (5) the choice of field windings for mill-auxiliary motors, and methods of electrical braking, (6) the use of graduated braking on cranes and floor plant, (7) the application of inductive time-limit control to a ladle-tilting winch, (8) the use of Ward–Leonard control, (9) the diverter-control of series motors, and (10) dynamic control of series motors. Only D.C. systems are considered.—R. W. R.

Electronic and Servo-Electronic Controls and Their Application to the Iron and Steel Industry. W. G. Thompson (*J. Iron Steel Inst.*, 1948, **158**, (4), 497–509).—T. describes the application of electronic control methods to metal-working and melting processes. The theory of these methods is described in some detail.—R. W. R.

What Size is [Aluminium and Magnesium] Hot Work? L. W. Macomber and C. N. Weiler (*Machinist* (*Eur. Edn.*), 1948, **91**, (47), 1557–1560).—Since both warm weather and operating heat have an appreciable effect on all extremely close-tolerance shop operations with aluminium and magnesium, air-conditioning and temp.-controlled coolants are recommended to eliminate these complications.—J. H. W.

†**A Critical Survey of Wire-Drawing Theory.** G. D. S. MacLellan (*J. Iron Steel Inst.*, 1948, **158**, (3), 347–356).—Cf. *Met. Abs.*, 1948, **15**, 303. Theories relating to the determination of the stresses in the wire during drawing are reviewed. After a brief historical review of the subject, M. considers the plasticity conditions; the von Mises criterion gives the best agreement with experiment, while the max. shear stress condition is accurate to within 15%. Theories derived by Lewis; Sachs and Van Horn; Sachs; Davis and Dokos, Pöschl, and others are described and compared. The early elementary treatments, in which strain-hardening and, in some instances, external friction are neglected, yield drawing-force curves which do not greatly differ from those obtained by the use of the more complete treatments, such as that of Davis and Dokos, in which friction and strain-hardening are both taken into account. It is unlikely that a wholly satisfactory solution will be obtained until recent advances in the theory of the plasticity of metals have been applied to the problem. Some recommendations are made with regard to future work; the significance should be confirmed of the values of the coeff. of friction found by back-pull experiments, based on the Lunt and MacLellan method of analysis.—R. W. R.

Note on a New Method for Checking the Profile of Wire-Drawing Dies. J. G. Wistreich (*J. Iron Steel Inst.*, 1948, **158**, (4), 496).—A disadvantage of the usual methods of examining the profile of wire-drawing dies is that nothing is revealed about the re-entrant parts of the die. This difficulty can be overcome by making a cast of the die in a dental compound "Zelex". This compound when mixed with water forms a smooth paste which sets in the die within 2–5 min. to the consistency of a hard-boiled egg; the replica thus formed can easily be pushed out of the die. The replica must be examined (by projection) immediately after withdrawal, since it shrinks within ½ hr. The method gives reasonably accurate results.—R. W. R.

Wire-Drawing Problems: Drawing Solutions and Die Life. —— (*Indust. Diamond Rev.*, 1948, [N.S.], **8**, (89), 101–102).—Discusses wire-drawing technique with particular reference to the influence of the lubricant on the life of sintered-carbide and diamond dies.—R. W. R.

Microscopic [Tungsten] Wire. —— (*Mech. Eng.;* 1947, **69**, (5), 418).—A tungsten wire 0·00018 in. in dia. has been drawn by the Westinghouse Lamp Division, Bloomfield, N.J.—H. Pl.

Use of Wire-Drawing Compounds. E. L. H. Bastian (*Wire and Wire Products*, 1947, **22**, (8), 577–580).—The characteristics desirable in wire-drawing compounds are discussed and recommendations given for seven types of lubricants for drawing various ferrous and non-ferrous wires.—J. C. C.

The Wire-Drawers of Bristol, 1312–1797. H. R. Schubert (*J. Iron Steel Inst.*, 1948, **159**, (1), 16–22).—An historical account.—R. W. R.

***Stretching Characteristics of Aluminium Alloy Sheet.** J. M. Taub (*Trans. Amer. Soc. Metals*, 1948, **40**, 180–207; discussion, 207–208).—See *Met. Abs.*, 1948, **15**, 303.—R. W. R.

Straightening Machinery. E. L. Tinley (*Brit. Eng. Export J.*, 1947, **29**, (20), 1429–1437).—Machines for straightening or flattening high-tensile ferrous and non-ferrous alloys are described and illustrated.—R. L. B.

Bending Machinery. E. L. Tinley (*Brit. Eng. Export J.*, 1947, **30**, (26), 667).—Equipment for bending rolled and extruded bars and sections, plates, and sheets is reviewed.—R. L. B.

The Rubber Die Press as a Tool for Forming Aluminium. E. R. Yarham (*Modern Machine Shop*, 1947, **20**, (5), 144–168).—Data on British practice in the use of rubber press tools.—A. I. V.

Fabricating Aluminium Air Ducts. —— (*Steel*, 1947, **121**, (1), 93, 124).—Descriptive.—M. A. V.

The Requirements of a Lubricant for Successful Deep Drawing with Special Provision for Easy Removal. P. D. Liddiard (*Inst. Vitreous Enamellers, Advance Copy*, **1947**, 7 pp.).—L. applies the fundamental theories concerning rubbing surfaces to deep-drawing lubrication. The fundamentals of boundary lubrication are discussed in the light of the topography of the surface and the function of the lubricant. The theories of friction and boundary lubrication are explained, together with the function of the lubricant and the influence of fatty materials. It is believed that reaction takes place between the metal and the fatty acids in the oils to produce a metallic soap, one molecular layer of which is sufficient to give effective lubrication. Additives such as sulphur, chlorine, and phosphorus form simple inorganic compounds which are particularly suitable lubricants for high-pressure conditions. Solid, relatively inert additives, such as talc, zinc oxide, and the lead oxides, function mechanically. Soft lead or tin coatings function in a similar manner. Drawing troubles increase with rise in temp.; it is thus desirable to employ oil-in-water dispersions, not water in oil. The lubricant residues to be removed after the drawing operation are water and decomposition products of the lubricant. A summary of cleaning methods which may be employed is given.—R. L. B.

Spinning and Panel-Beating of Aluminium Alloys. E. R. Yarham (*Modern Machine Shop*, 1947, **20**, (7), 124–132).—An outline of some of the principles on which British methods of fabrication of aluminium alloys are based.—A. I. V.

Spinning Magnesium. Leslie F. Hawes (*Iron Age*, 1948, **161**, (8), 72–73).—Discusses practical considerations in magnesium spinning operations, the lubricants used for both hot and cold work, chromic acid cleaning solution formulæ for removing graphite and other lubricants, and heating procedures for jobs demanding severe forming of the metal.—J. H. W.

Practical Aspects of Metal Spinning. Robert J. Schneider (*Iron Age*, 1948, **161**, (7), 76–80, 133–134).—S. describes the advantages and limitations of spinning aluminium alloys and explains where the method can most profitably be applied. He states what other metals can be spun and discusses spinning technique and equipment, tolerances, control of dimensions, flow of the metal, and design.—J. H. W.

High-Speed Stamping of Electrical Terminal Plugs. Herbert Chase (*Iron Age*, 1948, **161**, (12), 64–72).—By means of intricate tooling, a progressive die arrangement blanks and forms hard brass and beryllium–copper strip into electrical terminals at rates of up to 3/sec., keeping extremely close dimensional tolerances at critical points. Owing to the complexity, close tolerances, and smallness of the parts, this forming technique constitutes a very economical, high-production method.—J. H. W.

Machining Wrought Aluminium Alloys. E. R. Yarham (*Modern Machine Shop*, 1947, **19**, (9), 164–200).—A survey of industrial practice.—A. I. V.

***Some Fundamental Factors Involved in Intermittent Metal-Cutting Processes, with Special Reference to Shaping.** K. J. B. Wolfe (*Trans. Amer. Soc. Metals*, 1948, **40**, 120–142).—The fundamental difference between continuous and intermittent cutting is the presence of repeated impact loads in the latter process. In shaping, the max. tool velocity V, the tool striking velocity S, and tool life N are related by $V^P S^Q N^R = \theta$, where P, Q, R, and θ are constants. These constants are affected by tool shape and material, and the material being cut. The constant θ is a "figure of merit" and a max. value corresponds to optimum tool shape and surface finish. The ratio Q/R is a measure of the dynamic toughness of the tool. W. presents data obtained from shaping experiments on various steels, in support of his conclusions. —R. W. R.

Use of Soluble-Oil Coolants. L. B. Johnson (*Steel*, 1947, **121**, (1), 110–113).—Suitable dilutions of "Oakite" for coolants for machining brasses, bronzes, and aluminium are given. Straight cutting oils are preferred for magnesium.—M. A. V.

***Recrystallization as a Measurement of Relative Shot-Peening Intensities.** K. B. Valentine (*Trans. Amer. Soc. Metals*, 1948, **40**, 420–427; discussion, 427–434).—See *Met. Abs.*, 1948, **15**, 304. Some further results and examples are presented in the discussion.—R. W. R.

XX.—CLEANING AND FINISHING

Fundamental Aspects of Metal Cleaning. Jay C. Harris (*Amer. Ceram. Soc. Bull.*, 1947, **26**, (12), 389–392).—The cleaning treatment to be employed is largely dictated by the chemical reactivity and chemical and physical condition of the metal surface. Soiling agents may be classified as (*a*) inert, (*b*) hydrophilic, and (*c*) hydrophobic. Soiling agents may be attracted to the metal surface by (i) physical forces (surface tension), (ii) chemisorption, (iii) electrophoretic charge, and (iv) chemical combination. The means by which these attractive forces may be neutralized are considered; cleaning may also be effected by mechanical means.—R. W. R.

Clean Rinsing After Metal Cleaning. L. W. Collins (*Indust. Finishing*, 1947, **23**, (6), 35–36, 38).—The importance of proper rinsing after each cleaning operation is stressed. Failure of coating operations is frequently due to inefficient removal of the cleaning reagents. C. recommends the adoption of spray rinsing whenever possible.—D. M. L.

An Alternative Method of Cleaning Mercury. Leon Segal (*Science*, 1947, **105**, (2737), 625).—The vacuum filtration of mercury is described.—A. I. V.

Developments in Shot Blasting. R. Ankers (*Manchester Assoc. Eng., Advance Copy*, **1948**, 23 pp.; and (summary) *Mech. World*, 1948, **123**, (3188), 209–211).—Various types of sand- and shot-blasting machines are described, including the tumbling barrel, employing direct-pressure or injection types of abrasive propulsion. Shot-blasting nozzles are made of chilled iron, tungsten carbide, or boron carbide; the latter is claimed to last for 1500 hours' operation. Shot-peening equipment for cold working to increase fatigue life is considered. The liquid honing process is explained, and examples of its use are presented.—R. L. B.

Colloidal Graphite in Assembly Lubrication. E. A. Smith (*Engineering*, 1948, **165**, (4296), 505–507).—Discusses the influence of the surface finish of various metals, including bearing metals, on the degree of wear on assembly before running-in. The beneficial effects of graphite as a lubricant at this stage are emphasized.—R. Gr.

Special Smooth Finish on Jet Airplane. Gilbert C. Close (*Indust. Finishing*, 1947, **23**, (6), 31–33).—Special surface finishes are essential on aircraft designed for very high speeds. C. discusses research work done by Douglas Aircraft Co. to produce a surface finish to satisfy the exacting conditions. Important requirements are: (1) finish flexibility, to withstand transonic vibrations in the metal skin and expansions and contractions due to rapid temp. fluctuations, (2) heat-resistance, to withstand the heat generated by air–skin friction and from the exhaust tubes of the power unit, (3) impact resistance, and (4) hardness. C. describes the finishing processes used on aluminium and magnesium alloy skins and other components. The final product of these treatments is a hard, flexible, high-gloss, very smooth surface. —D. M. L.

Spraying Colour on Parts of Plated Ornaments. George Hilfinger (*Indust. Finishing*, 1947, **23**, (7), 47–50, 52).—Describes methods of masking plated articles for the application of spray-painted designs.—D. M. L.

XXI.—JOINING

Tin Solders in Mass-Production Methods. —— (*Tin*, **1948**, (Mar.), 7–8).—Soldering is used in an increasing number of industries.—P. L.

Aluminium Solder [Alsoco]. —— (*Sci. Amer.*, 1947, **177**, (3), 129–130).—The solder resisted shearing after a 250-hr. salt-spray corrosion test, although the aluminium base metal itself broke.—H. Pl.

Brazing in Electric Furnaces. S. de Domenico and J. A. Comstock (*Metal Progress*, 1947, **52**, (1), 71–76).—The advantages of electric-furnace brazing are detailed, furnace atmospheres are discussed, and methods of brazing ferrous and non-ferrous materials are briefly described. Finally, some notes are given on production equipment.—N. B. V.

Furnace-Brazing 12 Per Cent. Chromium Low-Carbon Steel. T. H. Gray (*Steel*, 1947, **121**, (3), 105–106, 124, 127).—The steels were brazed without fluxes in a controlled atmosphere, paying particular attention to (1) minimum spacing, (2) capillary feeding, (3) using oxygen-free copper or copper alloy brazing metals, (4) avoiding contaminated surfaces, and (5) ensuring the purity of the prepared atmosphere. By these means an improvement of 50% in joint strength was achieved. Tensile- and bending-test data are given.—M. A. V.

Assembly by Brazing. H. R. Brooker (*Mass Prodn.*, 1948, **24**, (4), 67–72).—B. describes the low-temp. silver-bearing brazing alloys, and discusses the applications of the various techniques available, namely torch heating, furnace heating, induction heating, and resistance heating.—R. W. R.

Use of Silver Alloys in Brazing. H. A. Smith and P. A. Koerner (*Aero Digest*, 1947, **55**, (1), 54–56, 87, 89).—Radial clearances between faying surfaces of joint components must be between 0·002 and 0·007 in. The molten brazing alloy from any one pre-placed ring must not be expected to penetrate a distance more than 0·625 in. of faying surface.—H. Pl.

Silver-Brazing Alloy [Easy-Flo 45]. —— (*Sci. Amer.*, 1947, **177**, (3), 131).—H. Pl.

Low-Temperature Silver Alloy Brazing. —— (*Steel*, 1947, **121**, (10), 76–77, 108, 110).—Technique is described, with applications of brazing machines having multiple fixed burners.—M. A. V.

Low-Temperature Welding. —— (*Amer. Exporter* (*Indust.*), 1947, **140**, (6), S25).—Low-temp. welding rods for use on aluminium, copper, brass, steel, and cast iron are discussed.—H. Pl.

Uses of Oxy-Acetylene Welding. —— (*Power and Works Eng.*, 1947, **42**, (495), 273–274).—A brief review.—R. L. B.

***An Apparatus for the Butt-Welding of Fine Wires.** L. D. Armstrong and T. M. Dauphinée (*Canad. J. Research*, 1947, [F], **25**, (3), 221–225).—A. and D. describe an apparatus developed primarily for the butt-welding of thermocouple wires; the method is, however, suitable for joining any fine wires. The energy for the welding is obtained from the discharge of a bank of condensers; the capacity in use can be varied between 5 and 600 μF. The condensers are charged from a 300-V. D.C. supply through a variable resistance. The wires to be welded are held in clips so that the two ends are touching. Discharge of the condensers causes the tips of the wires to become ball-shaped; a second discharge effects the weld. The successful operation of the apparatus depends on the capacity, potential, series resistance, and polarity used; these quantities are critical. Suitable values are given for the welding of various sizes of rare and base-metal wires. The apparatus is suitable for wires up to 28 B. & S. gauge.—R. W. R.

***Argonarc Welding of Magnesium-Rich Alloys.** R. E. Doré, L. C. Percival, and L. R. Sillifant (*Argonarc Welding: Brit. Weld. Research Assoc. Publ.* No. **LM3/28**, 1947, 1–25).—This and the following three papers are collected papers on argonarc welding, presented to the British Welding Research Association LM3 Committee on Fusion Welding of Magnesium-Rich Alloys. A summary is given of work done in the authors' laboratories during the previous four years, and the argonarc welding equipment is discussed. Tests on magnesium–manganese and magnesium–aluminium–zinc alloys are described, which show that the former are rather more readily weldable, but the latter give better and more consistent mechanical properties in the weld; using suitable welding conditions, strengths of welds in the fomer alloys are about 8 tons/in.^{2}, and in the latter, about 15 tons/in.^{2} Automatic welding with this process is also mentioned.—F. A. F.

***Argonarc Welding of Magnesium Alloys at High Duty Alloys, Ltd.** E. J. Grimwood (*Argonarc Welding: Brit. Weld. Research Assoc. Publ.* No. **LM3/28**, 1947, 26–34).—Cf. preceding abstract. A summary is given of the experience in experimental argonarc welding at High Duty Alloys, Ltd. The tests were made on magnesium–manganese and magnesium–aluminium–zinc alloy sheet, mainly manually, but partly automatically. The weld efficiencies were 50–80% for the first, and 75–95% for the second alloy.—F. A. F.

***Some Notes on an Investigation of the Hand Method of Argonarc Welding as Applied to Magnesium-Base Alloys.** F. A. Fox (*Argonarc Welding: Brit. Weld. Research Assoc. Publ.* No. **LM3/28**, 1947, 35–39).—Cf. preceding abstract. A summary is given of investigations to determine the ranges of weld strength to be expected in magnesium alloys welded by the argonarc process. Mechanical-test results were encouraging, but the manual operation of the process was regarded as very difficult. The method is useful for the repair of castings. A comparison between argon and helium as the shield gas indicated some superiority in the latter.—F. A. F.

***Argonarc Welding of Magnesium Alloys at Metropolitan-Vickers Electrical Co., Ltd.** I. H. Hogg (*Argonarc Welding: Brit. Weld. Research Assoc. Publ.* No. **LM3/28,** 1947, 40–44).—Cf. preceding abstract. A summary is given of investigations at Metropolitan-Vickers Electrical Co. to develop apparatus and technique for welding magnesium alloys in an argon atmosphere. The magnesium–manganese sheet alloy was exclusively used, and the welding was mainly automatic. Weld efficiencies ranging from 61·5 to 75% were obtained, the latter after hot peening.—F. A. F.

Production Jobs for Inert-Gas-Shielded Arc Welding. H. T. Herbst (*Steel*, 1947, **121,** (9), 73–74, 92, 94, 96).—Heliarc welding technique and some typical applications are described.—M. A. V.

Inert-Gas-Shielded Arc Welding. H. T. Herbst (*Engineer's Digest* (*Amer. Edn.*), 1948, **5,** (1), 4).—Cf. *Met. Abs.*, 1948, **15,** 70, 211.—R. L. B.

Safety Device for A.C. Welding Equipment. —— (*Engineer,* 1948, **185,** (4802), 143).—Refers to a timed relay, controlling an auxiliary circuit to decrease the p.d. of 80 V. on open circuit to 30 V.—R. Gr.

Distortion of Metals [in Arc Welding]. —— (*Sci. Amer.*, 1947, **177,** (4), 174).—A brief account.—H. Pl.

A Note on the Shrinkage and Distortion of Welded Joints. F. Guyot (*Weld. J.* (*J. Amer. Weld. Soc.*), 1947, **26,** (9), 519–529s).—Translation of "Note sur le Retrait et les Déformations des Soudures", *Arcos,* 1946, (**100**), 2357–2380; (**101**), 2399–2404. The factors affecting shrinkage in welded structures are discussed and formulæ quoted permitting the (approx.) calculation of shrinkage in practice. Several worked examples are included.—P. H.

Recent Trends in Structural Welding. O. Bondy (*Structural Eng.*, 1947, **25,** (11), 462–481; discussion, 1948, **26,** (3), 187–206).—The welding of light alloys is briefly considered.—R. L. B.

Functions and Advantages of the Canadian Welding Bureau. —— (*Canad. Metals,* 1947, **10,** (4), 22–24).—R. L. B.

Submerged-Melt Welding of Corrosion-Resistant Metals. R. J. Anderson and H. J. Roberts (*Weld. J.* (*J. Amer. Weld. Soc.*), 1947, **26,** (4), 338–342; and (abridged) *Canad. Metals,* 1947, **10,** (2), 18–19, 29, 34).—The mechanical properties of submerged-melt-welded Everdur are described; the weld picked up manganese and silicon. Satisfactory welds were made in nickel and Monel metal plates; the strength of Monel weld metal was approx. 80% that of the plate, and welds in nickel had about 70% of the plate strength. —R. L. B.

Developments in Cold Welding. —— (*Mech. World,* 1948, **123,** (3200), 559–561).—A short review of recent advances made at the General Electric Company's research laboratories in the technique of cold-welding aluminium alloys.—R. W. R.

***Instruments for the Measurement of the Main Variables in Resistance-Welding Machines.** —— (*Welding Research,* 1947, **1,** (5), 19–24).—A report of Committee FR5 of the British Welding Research Association. Describes specially developed instruments for the measurement of welding time, the cyclegrapher; and of welding current, the impulse ammeter.—F. A. F.

Hard Faces Live Long. H. R. Clauser (*Sci. Amer.*, 1947, **177,** (6), 255–257).—Describes the composition and application of hard-facing alloys. —H. Pl.

Resin Bonding of Aluminium. —— (*Amer. Exporter* (*Indust.*), 1947, **140,** (5), S31).—H. Pl.

Metal-to-Metal Adhesives. Thomas D. Perry (*Aero Research Tech. Notes,* 1947, (**56**)).—The use of adhesives has opened up a wide range of industrial uses for thin metals.—A. I. V.

The Strength of a Joint Under Tension. —— (*Aero Research Tech. Notes*, 1948, (**81**)).—A discussion of the effect of the thickness of the adhesive layer on the tensile strength of a joint (in nickel, aluminium, &c.).
—A. I. V.

XXII.—INDUSTRIAL USES AND APPLICATIONS

Simplifying Bodywork Construction and Assembly [Use of Aluminium Alloys]. —— (*Light Metals*, 1947, **10**, (119), 629–633).—A description is given of the use of aluminium alloys by the firm of E. W. Campion and Sons, Leicester, in the construction of driving cabs and bodywork of vans.
—F. A. F.

[Uses of] Aluminium [in Building]. —— (*Brit. Eng. Export J.*, 1947, **29**, (16), 852–853).—R. L. B.

[Aluminium] Heat-Tube Material. —— (*Sci. Amer.*, 1947, **177**, (5), 221).—Alclad 3S is suitable for use in condenser and heat-exchanger tubes.
—H. Pl.

[Use of Aluminium in] Telephone Cable. —— (*Sci. Amer.*, 1948, **178**, (2), 80).—Describes a telephone-cable sheath consisting of a thin sheet of aluminium covered with a polyethylene compound.—H. Pl.

Aluminium in the Theatre. —— (*Rev. Aluminium*, 1947, (**136**), 271–274).—A description is given of an aluminium turntable for a scene in the Folies Bergère revue, and also of various portable accessories for the Propaganda Theatre of French Art in the French zone of Germany.—F. A. F.

Aluminium Wiring. —— (*Sci. Amer.*, 1948, **178**, (1), 32).—H. Pl.

Recent Developments in the Uses of Aluminium. G. R. Black (*Canad. Metals*, 1947, **10**, (12), 16–19).—R. L. B.

Prefabricated Light-Metal Coachwork in France. Graham Davies (*Light Metals*, 1947, **10**, (118), 586–601).—A description is given of the activities of the Société des Prototypes de Carrosseries Légères, which has been formed co-operatively by about 60 French coachbuilders. The methods of prefabricated production are described; the alloys used are those covered by the French designations A-G3, A-G5, and A-U4G.—F. A. F.

***Application of Light Alloys to Superstructures of Ships.** W. Muckle (*Shipbuilder*, 1947, **54**, (459), 224).—See *Met. Abs.*, 1947, **14**, 34.—R. L. B.

Prefabricated [Hiduminium] Framework for Bus Bodies. —— (*Brit. Eng. Export J.*, 1947, **30**, (22), 100).—R. L. B.

Sleeve Bearings and Bearing Metals. H. Warburton (*Mech. World*, 1948, **123**, (3202), 606–608).—W. discusses modern bearing materials and modifications in engineering design necessitated by their use.—R. W. R.

Present-Day Bearing Practice. W. H. Tait (*Indust. Diamond Rev.*, 1948, [N.S.], **8**, (89), 118–124).—A summary of *J. Inst. Prodn. Eng.*, 1947, **26**, 75–92, 111–125; *Met. Abs.*, 1948, **15**, 554.—R. W. R.

Standard Half-Bearings. —— (*S. African Eng.*, 1948, **59**, (1), 6).—The production of white-metal-lined steel-backed half-bearings is briefly described.—R. L. B.

New Alloy for Watch Industry [Elgiloy]. —— (*Amer. Exporter* (*Indust.*), 1947, **140**, (5), S32).—The alloy contains cobalt 40, chromium 20, nickel 15·5, iron 15, molybdenum 7, manganese 2, carbon 0·15, and beryllium 0·03%.
—H. Pl.

[Use of Brass or Copper Strip in] New Radiator Construction. —— (*Overseas Eng.*, 1947, **21**, (241), 128).—R. L. B.

Assault Bridge in Magnesium. S. K. Ghaswala (*Light Metals*, 1947, **10**, (116), 434–436).—A description is given of a magnesium alloy bridge developed for the Canadian Government during the recent war; the alloy used is not mentioned.—F. A. F.

Magnesium Industrial Doors. J. Mezoff (*Modern Metals*, 1948, **4**, (2), 38).—Large sliding doors represent an economic application of magnesium on account of their low weight, reduced maintenance cost, and longer life. —N. B. V.

The Economic Status of Magnesium. J. D. Hanawalt (*Modern Metals*, 1948, **3**, (12), 24–28).—H. surveys the variations in production and price of magnesium in the past and reviews the post-war fields of application of the metal and its alloys. Comparison is made with the other common non-ferrous metals.—N. B. V.

Magnesium Castings for the Allison Turbo-Jet Engine. J. Walraven (*Modern Metals*, 1948, **4**, (2), 20–22).—The Allison turbo-jet engine used in the Lockheed P-80 "Shooting Star" contains no fewer than 44 magnesium sand castings, weighing in all 452 lb. The heaviest individual casting weighs 104 lb. Magnesium foundry and heat-treatment practice is described and mention is made of a new magnesium casting alloy, E6, containing 6% cerium, which can operate at temp. up to 600° F. (316° C.).—N. B. V.

Eighty-Pound Piano [Incorporating Magnesium Alloy]. —— (*Modern Metals*, 1948, **4**, (2), 40).—The 64-note portable piano described incorporates considerable quantities of magnesium and plastics. The string plate is a magnesium alloy casting weighing 22 lb.—N. B. V.

The Quartermaster Corps Designs for Magnesium. J. W. Millard (*Modern Metals*, 1948, **4**, (3), 22–25).—M. enumerates seven advantages of magnesium which commend its use in military equipment and gives a number of typical applications at present being developed.—N. B. V.

The Role of Nickel in American Public Works Plant. —— (*Rev. Nickel*, 1947, **13**, (4), 49–57).—Describes the use of nickel and its alloys in the manufacture of mechanical shovels, tractors, scrapers, heavy lorries, and other similar machines.—R. W. R.

Monel Metal in the [Metal-]Pickling Industries. —— (*Rev. Nickel*, 1947, **13**, (2), 24–25).—A brief review.—R. W. R.

Sleeping Beauty of Industry [Uses of Silver]. Edwin Laird Cady (*Sci. Amer.*, 1947, **177**, (4), 155–156).—A popular review.—H. Pl.

Silver and the Platinum-Group Metals in German Chemical Industry. J. M. Pirie (*Indust. Chemist*, 1948, **24**, (279), 231–239).—A survey based on a number of B.I.O.S. and F.I.A.T. reports. P. describes the use of the precious metals both as catalysts and as plant-construction materials.—R. W. R.

[Uses and Production of] Silver. Dickson H. Leavens (*Eng. and Min. J.*, 1948, **149**, (2), 73–75).—A general review of the changing uses of silver in the world. The production of silver by America, Canada, Mexico, Peru, and Australia for 1945, 1946, and the months of January to October of 1947 is tabulated.—R. Gr.

The Story of Tantalum. Clarence W. Balke (*Chem. and Ind.*, **1948**, (6), 83–86).—An address to the Society of Chemical Industry on receiving the Perkin Medal. B. traces the history and describes the early preparation of the metal by Werner von Bolton in the plant of the Siemens-Halske Co. in Berlin. The first commercial metallic-filament lamps contained tantalum until replaced by tungsten in 1911. It was extensively used in electrolytic rectifiers which found a wide application in the early days of radio. When sheet of sufficient size could be made, annealed and fabricated tantalum heat-exchangers were produced. Tantalum figures prominently in the surgery. It is "biologically acceptable" since body tissues adhere to and grow over the metal.—H. Pl.

Tin [Alloy] Die-Castings in Testing Equipment. C. N. Svenson (*Die-Castings*, 1947, **5**, (12), 31–32, 49).—S. describes the use of a tin alloy, containing antimony, copper, lead, and zinc, for die-casting instrument parts requiring exceptional dimensional stability.—P. L.

Designing Thoriated Tungsten Filaments. H. J. Dailey (*Electronics*, 1948, **21**, (1), 107–109).—Formulæ usually applied to pure tungsten filaments are presented and their application in the design of filaments of carburized thoriated tungsten described. The information presented in the form of tables and graphs applies mainly to calculations of heating current. Data are given for current and operating temp. for the filaments of a number of standard types of valves.—D. M. L.

[Zinc, Aluminium, and Copper] Die-Castings in the Construction of Electric Locomotives. P. W. Thompson, C. E. Mathews, and W. J. Simpson (*Die-Castings*, 1947, **5**, (12), 22–24, 39).—Heavy-duty transportation equipment makes use of about 400 die-castings in zinc, aluminium, and copper. Some are described.—P. L.

[Use of Zinc- and Lead-Base Die-Castings in a] Network Protector for Power Systems. J. T. Clenny and L. H. Sperow (*Die-Castings*, 1947, **5**, (12), 36–38).—P. L.

The Commercial Applications of Zinc Alloy Gears. —— (*Zinc Alloy Die-Casters' Assoc. Publ.*, **1947**, (Oct.), 15 pp.).—The process of pressure die-casting and its advantages are summarized. The applications of the gears, their design for various purposes, and their lubrication are discussed. The strength, elasticity, and resistance to wear of zinc alloys are compared with those of other metals.—J. L. T.

Developments in Aircraft Materials and Processes. Paul E. Lamoureux (*Trans. Canad. Inst. Min. Met.*, 1947, **50**, 104–126 (in *Canad. Min. Met. Bull.*, 1947, (**418**))).—L. discusses war-time experience in the aircraft industry and mentions a few of the most recent developments under the following headings: aluminium alloys, steel, super-alloys for gas turbines, wood, plastics, adhesives, fuels, lubricants, synthetic rubber, shot-peening, protection against corrosion, X-ray inspection, heat-treatment, cold treatment, metal joining, and electroplating.—W. A. M. P.

Prepared Metal Sheets for Large Precision Drawings. L. W. Nickols (*Machinist* (*Eur. Edn.*), 1946, **90**, (21), 853–855).

Use of Die-Castings Grows with Development of Better Production Equipment. —— (*Steel*, 1947, **12**, (12), 95).—A brief review of modern trends in the production and applications of zinc, aluminium, and brass die-castings. —M. A. V.

Woven Metal Fabrics. —— (*Steel*, 1947, **120**, (9), 137).—A brief description of "multi-weaving" decorative metal grilles for radio receivers and other purposes.—M. A. V.

New Metals in Industry. A. Martigny (*Usine Nouvelle*, 1948, **4**, (4), 13).

Metallurgical Substitutions. Albert Portevin (*Metal Progress*, 1947, **51**, (2), 271–272).—A letter. P. makes some general observations on factors to be considered in the choice of substitute materials, and stresses the importance of the "rules of corresponding temp.".—N. B. V.

Non-Ferrous Forgings. —— (*Chem. Age*, 1947, **56**, (1456), 743).—Non-ferrous forgings find increasing use in food machinery, agricultural implements, &c.—S. R.

The Manufacture of Photo-Electric Cells. J. Berthillier (*Électricité*, 1947, **31**, (126), 69–74; *Engineer's Digest* (*Amer. Edn.*), 1947, **4**, (11), 500–503).—In the preparation of cæsium for cæsium oxide cathodes, the metal, which is yellowish, is deposited on the walls of the ampoule containing the cup in which pellets of mixed cæsium salts and a reducing metal are heated to 700°–800° C. by means of induced eddy currents. The reducing agent may be zirconium, silicon, or aluminium. The cathode of the cæsium oxide cell is of silver (or electrodeposited copper covered with electrodeposited silver) with a layer of oxide, another of Cs_2O, and finally one of cæsium. The anode is usually of nickel. The oxidizing process and the activation of the cell are described. Antimony–cæsium cathodes are usually composed of a thin layer of an alloy of antimony and cæsium on a piece of antimony.—R. L. B.

Engineering Aspects of Atomic Energy [Uses of Metals in the Process]. Guy S. Dutton (*Overseas Eng.*, 1947, **20**, (232), 194–196).—The principles involved in the process of nuclear fission are reviewed. Beryllium, heavy water, and graphite make effective moderators. Cadmium and boron-steel absorb neutrons and are used to control the reaction. Aluminium was chosen from among the metals lead, bismuth, beryllium, aluminium, magnesium, zinc, and tin, to be made into cans in which the uranium slugs are sealed, on account of its ability to withstand corrosion.—R. L. B.

XXIII.—MISCELLANEOUS

Australasian Aluminium Industry. —— (*Chem. Age*, 1947, **56**, (1447), 402).—Survey of Australian and Tasmanian resources.—S. R.

Aluminium Industry in Australia. Charles Lynch (*Light Metal Age*, 1947, **5**, (11), 18–19).—A brief general survey.—M. A. V.

Canada's Aluminium Industry Three Times the Pre-War Tonnage. —— (*Times Rev. Ind.*, 1948, **2**, (13), 57).—P. L.

Aluminium and Magnesium [in 1947]. John D. Sullivan (*Min. and Met.*, 1948, **29**, (494), 99–101).—Annual review article, noting briefly significant trends in 1947. Monthly outputs of aluminium and magnesium in various forms are given. The principal use of aluminium in America is now in the building industry, which takes 18% of total output.—N. B. V.

The Production of Beryllium. Bengt R. F. Kjellgren (*J. Electrochem. Soc.*, 1948, **93**, (4), 122–128).—K. describes the production of beryllium metal by the reduction of beryllium fluoride with magnesium. The beryllium fluoride itself is produced by first dissolving impure beryllium oxides in solutions containing ammonium bifluoride or hydrofluoric acid or a mixture of the two. The solution is then purified by precipitating the heavy metals as sulphides and filtering them off. The purified filtrate is evaporated to produce ammonium beryllium fluoride which is then decomposed by heating, the ammonium fluoride formed being used over again in the process. The beryllium fluoride is heated with magnesium at a temp. below the m.p. of the beryllium. Calcium may be used instead of, or in addition to, magnesium. The temp. is finally raised above the m.p. of beryllium, which is recovered as a solid plate after cooling. The slag consists mainly of magnesium fluoride, but also contains a certain amount of beryllium fluoride. The latter is extracted by washing and returned to the process. The beryllium produced contains the following approx. amounts of impurities: aluminium 0·10, iron 0·10, silicon 0·03, copper 0·05, and manganese 0·05%.—G. T. C.

Aluminium from Clay. —— (*J. Chem. Education*, 1948, **25**, (3), 159–162).—Describes two processes developed by the U.S. National Bureau of Standards making it possible to use clay as an eventual alternative to bauxite for producing aluminium.—A. I. V.

Light-Metal Exports. —— (*Mech. World*, 1948, **123**, (3200), 552–553).—Discusses the marked increase in exports of aluminium from the U.K. which has taken place since the end of the war and describes the efforts being made to effect a further increase.—R. W. R.

America Needs a Million Tons of Copper. C. Donald Dallas (*Sci. Amer.*, 1947, **177**, (2), 52–55).—D. stresses the need for a copper stockpile in America.—H. Pl.

Gold [Production]. —— (*Eng. and Min. J.*, 1948, **149**, (2), 71–73).—The production of gold by North America, Central and South America, Africa, Australia, British India, and U.S.S.R. (partly estimated) for 1947, 1946, and 1940 is tabulated.—R. Gr.

Need for New Metals to Replace Iron. —— (*Canad. Metals*, 1947, **10,** (11), 26, 38).—Processes for the extraction and fabrication of tantalum, titanium, tungsten, and molybdenum have been developed; the physical properties of titanium compare favourably with those of iron, particularly in relation to strength.—R. L. B.

New Magnesium Plant. —— (*Chem. Age*, 1947, **56,** (1451), 565).—A new magnesium plant (capacity 1000 tons per day) has commenced operations in Arvida, Quebec.—S. R.

Notes on the Japanese Magnesium Industry. Donald L. Colwell (*Metal Progress*, 1947, **51,** (1), 67–70).—Notes are given on the location of the Japanese plants, their outputs, and the methods of extraction used. A number of alloy specifications are included. Practically all production was for war purposes. —N. B. V.

[Zinc Development Association] : A Report for 1947. —— (*Zinc Develop. Assoc. Rep.*, **1947,** 20 pp.).—Presents an account of the work done by the Association and its two affiliates—the Zinc Alloy Die-Casters' Association and the Zinc Pigment Development Association. Statistical tables are given showing the production of zinc in the British Empire, and shipments of zinc into and consumption in the U.K.—S. G.

Review of Figures [of Zinc Consumption] Received in January, February, and March 1948. —— (*Zinc Develop. Assoc. Statist. Rev.*, 1948, (22), 1–16). —P. L.

Zinc Development. —— (*Chem. Age*, 1947, **56,** (1451), 568).—A review of the 1945–46 report of the Zinc Development Association.—S. R.

"Coldest Cold" Bath Employed in Research on Super-Cooled Metals. —— (*Sci. Amer.*, 1947, **177,** (5), 222).—H. Pl.

New Metals for Old. (Sir) Edward Appleton (*New Zealand Eng.*, 1947, **2,** (12), 1230–1235).—See *Met. Abs.*, 1948, **15,** 132.—J. L. T.

Reducing Failures in Metal Parts. Arthur E. Focke (*Min. and Met.*, 1947, **28,** (490), 495–497).—Failures that are due to faulty design are often attributed to faulty or wrongly chosen material, for which the metallurgist is blamed. F. therefore advocates that the metallurgist should interest himself in questions of design as well as mechanical-testing results, in order that service failures may be avoided.—N. B. V.

To-Morrow's Metallurgy. Fred. P. Peters (*Sci. Amer.*, 1947, **177,** (2), 56–58).—A review of possible future advances in metallurgy.—H. Pl.

When Metal Atoms Wander. Edwin Laird Cady (*Sci. Amer.*, 1947, **177,** (1), 15–17).—Discusses changes in atomic arrangement which might account for the success of the pressure-welding and high-pressure-casting techniques.—H. Pl.

Development in Australian Metals. —— (*Chem. Age*, 1947, **56,** (1457), 775).—Starting of a zinc-recovery plant, a new process for alumina production without using caustic soda, and production of sintered-carbide tool tips are reported.—S. R.

The Gas Research Board—Report of the Director for the Year 1947. —— (*Gas Research Board Publ.*, **1948,** (GRB 37), 55 pp.).—Current research being carried out by the Board is described. This includes work on refractories and on the corrosion of gas mains and appliances.—R. W. R.

Use of High-Vacuum Techniques Increasing. —— (*Chem. Eng. News*, 1947, **25,** (46), 3359).—A report of the High-Vacuum Symposium sponsored by the National Research Corporation and the Division of Industrial and Engineering Chemistry of the American Chemical Society, 30–31 October 1947. Brief reference is made to papers presented on the vacuum metallurgy of magnesium, copper, and titanium, the sintering of copper powder, and the vacuum heat-treatment of steel and copper–beryllium springs. —H. A. H.

High-Vacuum Technology. Richard S. Morse (*Indust. and Eng. Chem.*, 1947, **39**, (9), 1064–1071).—A review of recent advances in high-vacuum technology, which has been stimulated by the atomic-energy programme. Special valves are required for pressures below 1 mm., and methods of introducing rotating shafts into vacuum systems are described. Among pressure gauges, the Alphatron gauge, in which ions are formed by α particles, is very useful, as problems of filament burn-out, temp. effects, &c., are eliminated, and it is not affected by vapours. Leak-detection methods and diffusion pumps are briefly described, common pumping speeds being 30,000 ft.^{3}/min. at 10^{-5} mm. Commercial applications of vacuum evaporation include the coating of lenses and the production of evaporated front-surface mirrors for the television industry. Vacuum metallurgy, of which there were no large-scale applications before 1940, is being developed rapidly, an example being the production of magnesium at pressures in the micron range. Gases may be removed from metals by melting under reduced pressures, and vacuum-cast metals have increased ductility and electrical and thermal conductivities. Other applications are in fine wire-drawing operations, precision alloys, thermocouple and resistance wires, &c. Vacuum techniques have been developed so far that problems of the vacuum *per se* are now secondary to other questions.—D. P. M.

Metallurgical Research and Training. —— (*Chem. Age*, 1947, **57**, (1460), 18).—Extracts from a paper by Cyril S. Smith before the American Iron and Steel Institute. S. discusses trends in metallurgical research and training of metallurgists.—S. R.

Laboratory Planning. —— (*Chem. Age*, 1947, **56**, (1450), 503–504).—Extracts from *J. Sci. Indust. Research, India*, 1946, **5**, (4), 155; *Met. Abs.*, 1948, **15**, 377.—S. R.

Abbott Laboratories Notebooks. Marlin T. Leffler (*J. Chem. Education*, 1948, **25**, (2), 99–100).—A description of the notebook system in use at the Abbott Laboratories, intended to provide adequate patent protection, without being inconvenient and troublesome.—A. I. V.

Multiple Correlation Applied to Steel-Plant Problems. W. T. Rogers (*Trans. Amer. Soc. Metals*, 1948, **40**, 935–950; discussion, 950–953).—See *Met. Abs.*, 1948, **15**, 377.—R. W. R.

The Work of a Process-Design Chemical Engineer. G. C. Gester, Jr. (*J. Chem. Education*, 1947, **24**, (12), 584–587).—A discussion of the problem of converting laboratory or pilot-scale developments into an operable and economical pilot or commercial plant.—A. I. V.

[Report on Government Research in the] Commonwealth of Australia. —— (*Australia. Ann. Rep. Council Sci. Indust. Research*, **1946**, 127 pp.).—Among brief references (no details are given) to work of non-ferrous interest are included: *Cement, Ceramics, and Refractories Section:* moulding sands; a bibliography of the literature of the permanent-mould process is being prepared. *Physical Metallurgy Section:* corrosion in aircraft engine cooling systems; corrosion of condenser tubes in power-generating plant; production of beryllium–copper alloys; deterioration of tin-plate containers for blow-fly dressings; selection of materials for the construction of tanks for retting flax; prevention of corrosion in copper heat-exchange coils of a hospital heating system. *Tribophysics:* mechanism of boundary lubrication; surface damage and wear; lubricants for wire drawing; problems relating to bearings; thermal fatigue; bearing-testing methods; abrasive wear; deformation and recrystallization of duplex alloys; wear of duplex alloys; electrolytic polishing of metals; preparation of metallic single crystals.—S. G.

†**Research in Physical Metallurgy.** G. S. Farnham (*Canad. Min. Met. Bull.*, 1947, (**420**), 205–214).—F. reviews outstanding physical-metallurgy accomplishments and discusses possible future developments; the physical-

metallurgy research facilities of three other leading industrial countries are compared with those of Canada. Brief reference is made to possible future methods of directing the efforts of the Canadian research physical metallurgist. —W. A. M. P.

***Metallurgical Research Programme of the [U.S.] Bureau of Mines Relating to the Non-Ferrous Metals.** R. S. Dean and B. Silkes (*U.S. Bur. Mines Rep. Invest.*, 1947, (**4064**), 22 pp.).—Tables are included showing the differences in mechanical properties of copper–manganese–nickel alloys; α/β copper–zinc alloys with manganese additions; and copper 50, manganese 35, and zinc 15% alloys, when made with electrolytic and furnace manganese, and also the properties of alloys of manganese 82·9%, copper remainder, rapidly cooled from 850° C. A process has been developed for the production of ductile titanium by reduction of titanium tetrachloride with magnesium; properties of sintered compacts are given; the metal has excellent corrosion-resistance. —S. G.

Non-Ferrous Physical Metallurgy [in 1947]. Walter R. Hibbard, Jr. (*Min. and Met.*, 1948, **29**, (494), 118–126, 155).—Annual review, in which the most important papers published in 1947 are summarized. The papers included are chiefly American and British. No references are given. —N. B. V.

War-Time Advances in Non-Ferrous Metallurgy in Britain. Basil J. S. Bard (*Metal Progress*, 1947, **51**, (3), 411–413, 460).—N. B. V.

Study of Metallurgical Research in Japan During the War. S. A. Herres (*Metal Progress*, 1947, **51**, (2), 273–290).—An abridgment of a report prepared for the U.S. Ordnance Dept. The organization of research in government and university laboratories is described, and the work carried out in various metallurgical fields is summarized. Much of the report deals with ferrous materials, but there is some account of work on light alloys and other non-ferrous metals. Owing to the shortage of high-grade bauxite, the quality of aluminium fell during the war and methods of refining were therefore investigated. Means of neutralizing the high impurity content were sought, and research was also carried out into the development of high-strength alloys free from nickel, which was very scarce. Much fundamental metallurgical research continued in war-time.—N. B. V.

Metallurgical Research and Industrialization. —— (*Current Sci.*, 1947, **16**, (2), 37–38).—Cf. *Met. Abs.*, 1948, **15**, 79. Brief report of an address delivered at the foundation-stone-laying ceremony of the National Metallurgical Laboratory at Jamshedpur, India.—D. M. L.

The National Metallurgical Laboratory, India. G. P. Contractor (*Current Sci.*, 1947, **16**, (2), 39–40).—Cf. preceding abstract. C. outlines the organization and programme of research work to be undertaken at the National Metallurgical Laboratory, Jamshedpur, India.—D. M. L.

The Use of Research in the Industrial Concern. R. K. Sanders (*Mech. World*, 1948, **123**, (3192), 313–315).—Abstract of a paper on “ The Use of Research by Individual Welsh Firms ”, presented to the Federation of British Industries and Industrial Association of Wales and Monmouthshire conference on “ Industry and Research in Wales and Monmouthshire ”.—S. G.

Nelson Research Laboratories [of the English Electric Co., Ltd., at Stafford]. —— (*Engineer*, 1947, **184**, (4790), 459–460; (4791), 480–481; *Electrician*, 1947, **139**, (20), 1427–1429; and *Overseas Eng.*, 1947, **21**, (242), 168).—S. G.


XIVTH OLYMPI
passing it on

All communications regarding Advertisements should be addressed to the Advertising Managers,
Messrs. T. G. Scott & Son, Ltd., Talbot House, Arundel Street, London, W.C.2.

Printed in Great Britain by Richard Clay and Company, Ltd., Bungay, Suffolk.