The Journal of the
INSTITUTE OF METALS

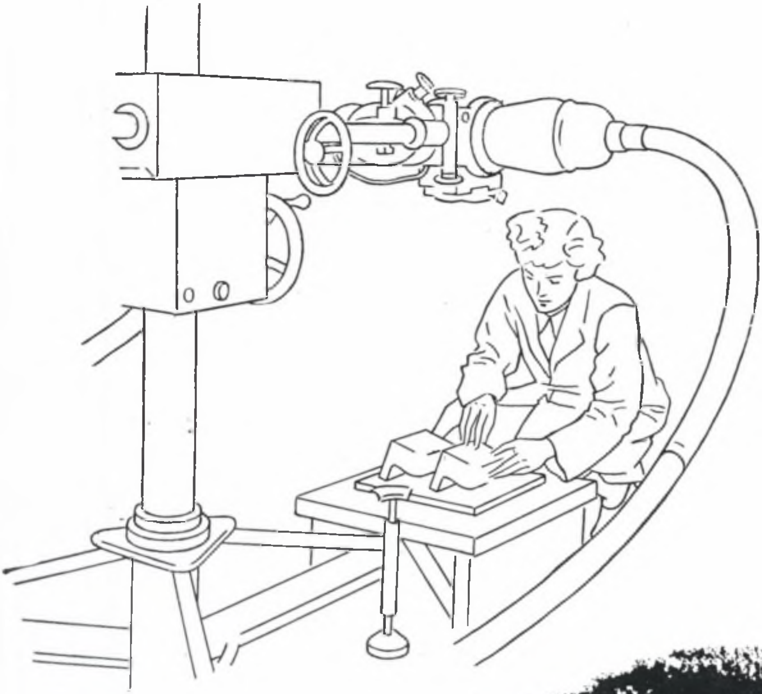
and

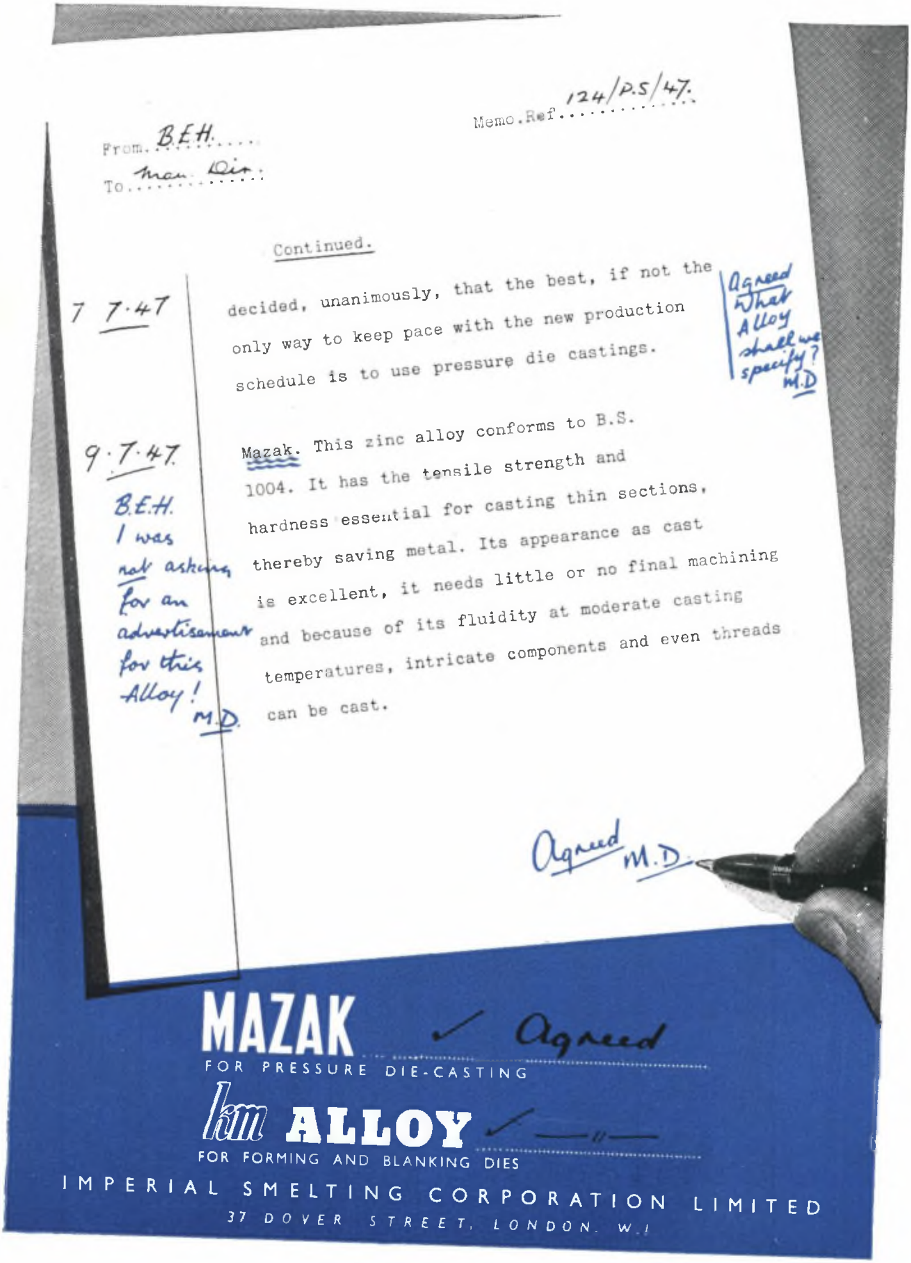
METALLURGICAL ABSTRACTS

In this Issue:

NOVEMBER 1947


A finger on
the world's metallurgical pulse





Aluminium makes progress economical

How

Reminiscent of a Roman chariot, this type of pony milk float was first used in 1880. Its carrying capacity was two 17-gallon churns.

became . . .

A present-day milk delivery van used by The Midland Counties Dairy Ltd., Birmingham — light, speedy and hygienic. The body is built of Noral aluminium alloy and weighs only 4 cwt. 63 lbs.

Progress in design has gone hand in hand with the development of light metals. Especially is this noticeable in the field of transport, where aluminium has long contributed to the solution of a great many vital problems—problems of weight, strength, corrosion, fabrication, performance and maintenance.

For, whatever the problem, aluminium emerges as the grand co-ordinating medium possessing those unique properties necessary to give substance to new ideas. What greater spur could the creative mind desire ?

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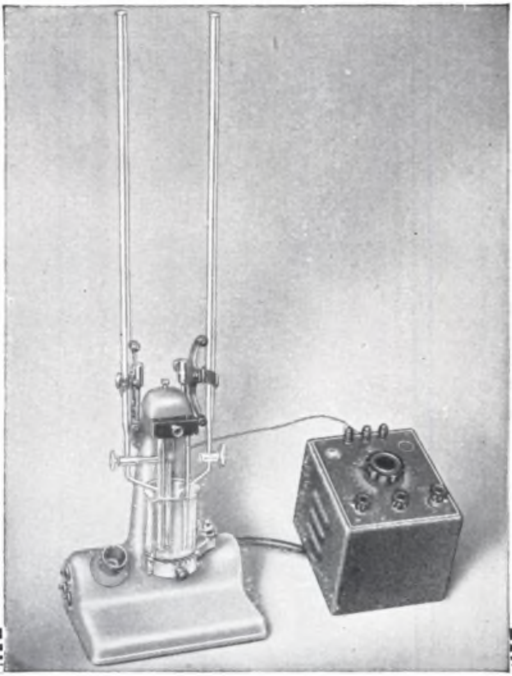

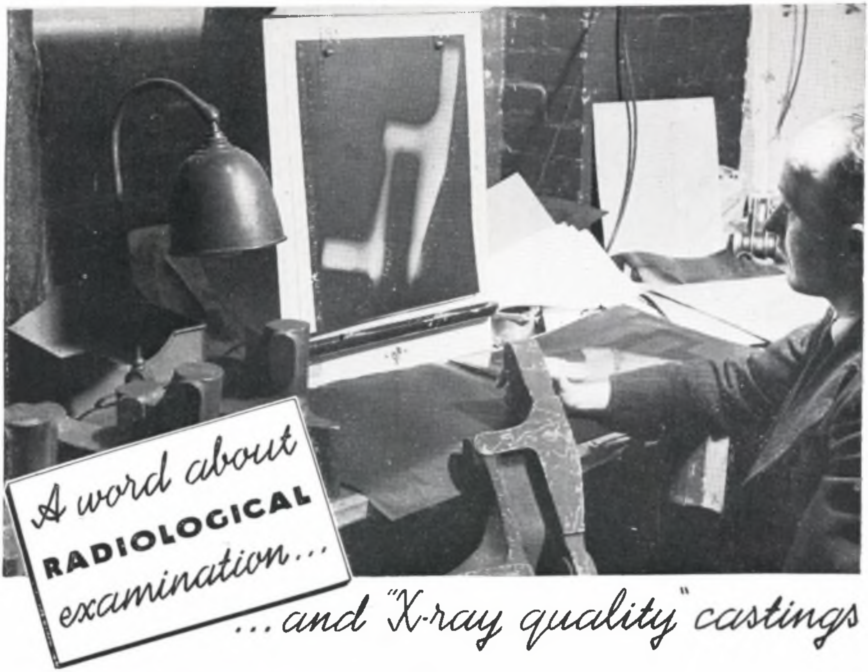

The fluorescent method of crack detection, involving the impregnation of the castings with a fluorescent material and their subsequent examination in ultra violet light, constitutes a useful supplement to X-ray inspection. The application of this method to a light alloy casting is shown above.

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.

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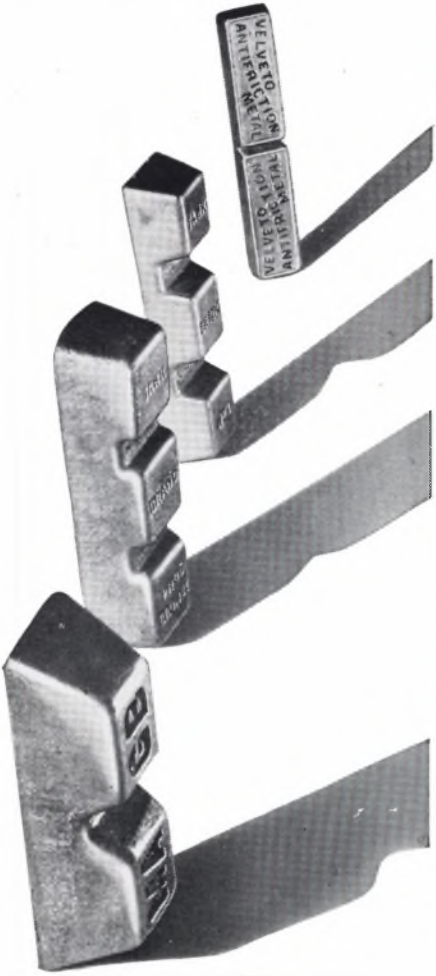
DEPTFORD & CHARLTON. *London Offices :* **OCEANIC HOUSE, 1a COCKSPUR STREET, LONDON, S.W.1.**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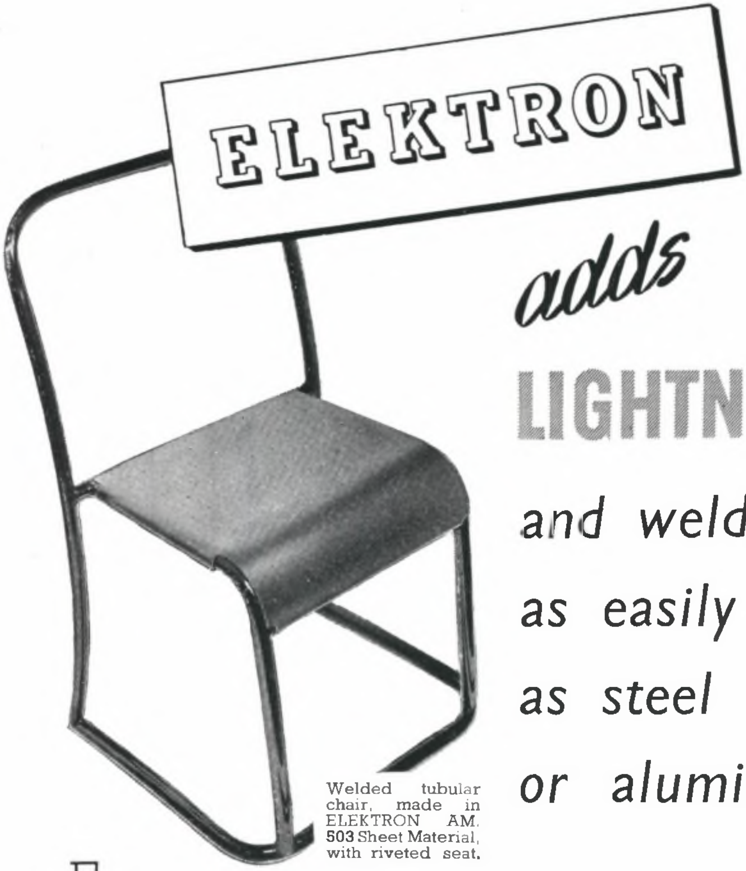

adds

LIGHTNESS

and welds
as easily
as steel
or aluminium

Welded tubular chair, made in ELEKTRON AM. **503** Sheet Material, with riveted seat.

ELEKTRON is welded by standard oxy-acetylene equipment and the technique employed is similar to that adopted for aluminium alloys, although special fluxes and welding rods (readily obtainable) should be used. Owing to its comparatively low melting point, low latent heat of fusion and low specific gravity, the amount of heat required to weld ELEKTRON is less than with most other metals that are welded. On the other hand, the fact that the thermal conductivity of ELEKTRON is lower than that of aluminium means that heat is concentrated under the welding flame and welding can be carried out more rapidly.

The latest technique is Argonarc Welding, in which Argon—an inert gas—is passed through the torch and acts as a shroud to protect welds from contamination by atmospheric oxygen and nitrogen. Argonarc welding removes the fear of corrosive after-effects, as no fluxes are used.

CHANGING TO ELEKTRON

Your first step is to consult F. A. Hughes & Company Ltd., who can help you with further information. There's not a lot of difference between the handling of ELEKTRON and that of other lightweight alloys, but there is a tremendous improvement in the results you obtain once you change to ELEKTRON. Write to **Metals Department**.

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QUIZ No. 4

"Next question, Mr. Bigtiffin . . . How do pukka engineering sahibs set about solving their corrosion problems in the tropics?"

Mr. Bigtiffin squared up to the microphone with the air of a man shouldering the white man's entire burden. "I have been out East 35 years," he said. "I have built in swamps that wanted draining and jungles that had to be cleared, and wherever I've built, I have had to reckon with conditions of heavy rains five months out of twelve. Corrosion has always been one of our biggest bugbears, and it wasn't until a few years ago we discovered a satisfactory method of dealing with it. Metal Coatings. That's what we use nowadays. Sprayed in situ by the British wire process."

"Just how do you spray it?" asked the announcer.

"With a Metallisation Pistol," replied Mr. Bigtiffin emphatically. "That Pistol has meant as much to us as a 15″ gun to the Navy."

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BEARING METALS ETC
TO ANY ANALYSIS

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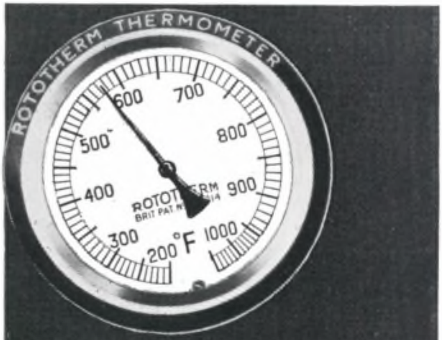

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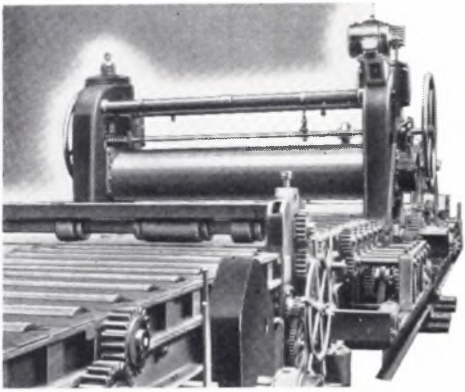

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Hydraulic Presses for making pipes, glazing bar covers, window lead wire, lead bends, traps, syphons, etc.

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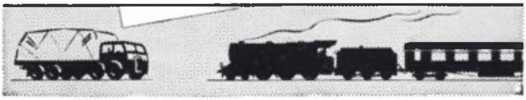

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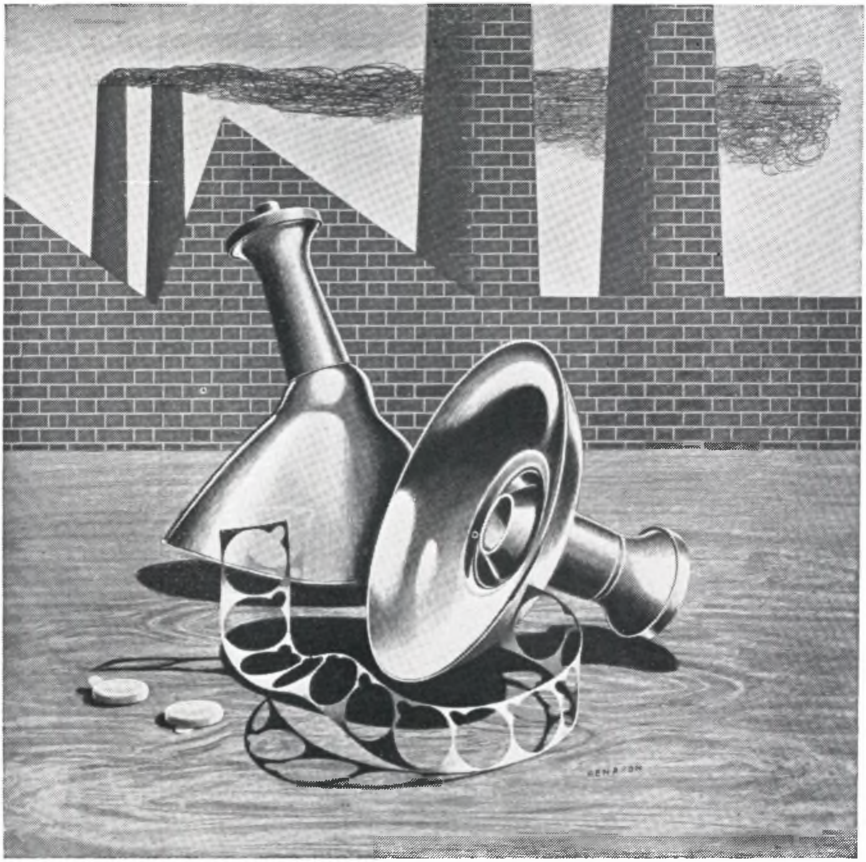

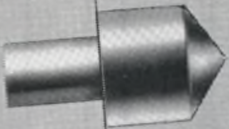

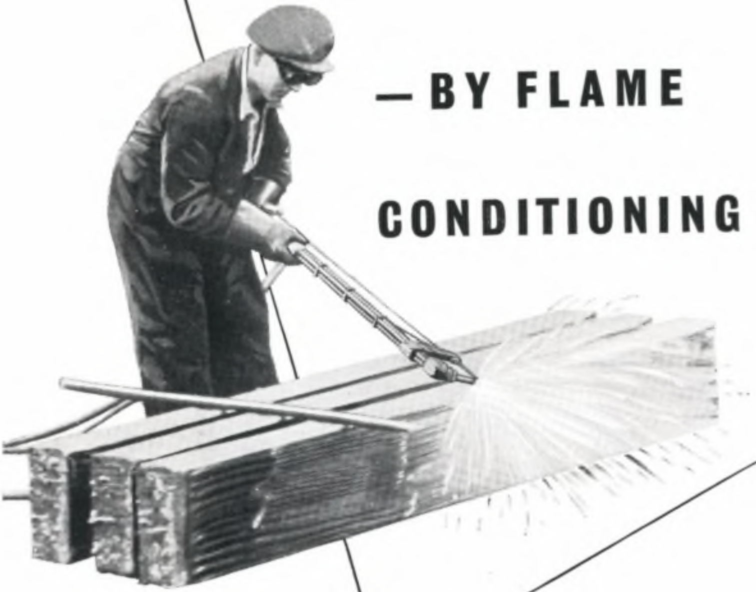

THE JOURNAL OF THE INSTITUTE OF METALS
NOVEMBER 1947

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THE INSTITUTE OF METALS

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INSTITUTE NEWS AND ANNOUNCEMENTS

ELECTION OF FELLOWS

The Council has unanimously elected the following Past-Presidents to be Fellows, in recognition of their eminent services to the Institute:

Cecil Henry Desch, D.Sc., Ph.D., Hon.LL.D., F.R.S.

Lieutenant-Colonel Sir John Greenly, K.C.M.G., C.B.E., M.A.

ELECTION OF HONORARY MEMBERS

The Council has unanimously elected the following to be Honorary Members of the Institute, in recognition of the very distinguished services that they have rendered to science and the non-ferrous metals industry.

Professor Pierre Antoine Jean Chevenard, Officier de la Légion d'Honneur, Membre de l'Institut de France, Directeur Scientifique de la Société de Commentry-Fourchambault et Decazeville.

Professor Sir Geoffrey Taylor, M.A., D.Sc., D.C.L., F.R.S., Yarrow Research Professor of the Royal Society, Cambridge.

John Fairfield Thompson, Ph.D., Executive Vice-President and Director, The International Nickel Company, Inc.

VISITORS TO AUSTRALIA

The Council of the Australian Institute of Metals has kindly offered to help members of the Institute of Metals who may be visiting Australia in the future, by providing information regarding metallurgical activities, suggesting visits of interest, and effecting introductions to members of the Australian Institute who have similar interests. The Honorary Federal Secretary of the Australian Institute of Metals is Mr. R. S. Russell, B.Sc., c/o The Broken Hill Associated Smelters Pty., Ltd., Collins House, 360 Collins Street, Melbourne, C 1.

The Council of the Institute has expressed its appreciation of this offer. Members who desire to avail themselves of it should give the Secretary of the Institute full particulars regarding their visits and some guidance as to their interests.

NEWS AND ANNOUNCEMENTS

SYMPOSIUM ON INTERNAL STRESSES IN METALS AND ALLOYS

The symposium, which was referred to in detail in our September issue (pp. xxix–xxxii), was held in London on 15 and 16 October 1947. Thirty-six papers were presented and valuable discussions took place. A notable feature of the meeting was the large attendance that was maintained throughout the sessions, over 300 members and visitors being present.

The conversazione held on the evening of 15 October was very successful, and some interesting exhibits—including a film of Sir Lawrence Bragg's bubble model—were shown.

The papers contributed to the symposium, together with a report of the discussions, will be published as a special volume. The price of the book and approximate date of publication will be announced later, but in the meantime it is requested that all who may desire to purchase this volume will notify the Secretary to that effect, if they have not already done so on the reply form which was sent to them.

The supply of advance copies of the papers is exhausted.

PROFESSIONAL QUALIFICATIONS

Reversing a rule that has been in force for many years, the Council has decided that, in addition to rank, honorific distinctions and university degrees, there may now be printed, in the Institute's publications, such letters denoting membership of *qualifying* bodies as are desired by authors and other contributors. Membership of non-qualifying bodies will not be indicated.

JOINT LIBRARY

Members resident in the United Kingdom are reminded that they may borrow books or periodicals from the Joint Library, on application to the Librarian.

Those who desire them should apply to the Librarian, Joint Library, 4 Grosvenor Gardens, London, S.W.1, to be regularly supplied with the printed copies of the " Additions to the Library ".

Certain books and periodicals which are not received in the Library are obtainable for members, on loan, from other sources.

ABSTRACTING AND REVIEWING

The Editor requests that authors of papers published in the more obscure publications, which may not be regularly abstracted in *Metallurgical Abstracts*, shall send to the Institute copies of their papers—where of metallurgical interest—for abstracting, and for subsequent filing in the Joint Library.

Authors of books suitable for notice are also requested to arrange for review copies to be sent to the Editor by their publishers.

AUTUMN MEETING PHOTOGRAPHS

Members may obtain copies of the photographs taken at the Glasgow Autumn Meeting from the photographers, as detailed below:

Group Photograph: Northern Press Photo Agency, Ltd., 29 Waterloo Street, Glasgow, C.2. (Prices, 8½ × 6½ in., 10*s.* 6*d.* each; 15 × 12 in., 17*s.* 6*d.* each.)

NEWS AND ANNOUNCEMENTS

Dinner and Loch Lomond Photographs : Scottish Studios and Engravers, Ltd., 196 Clyde Street, Glasgow, C.1. (Price 3*s.* 6*d.* each.)

REMITTANCES OF MONEY FROM ABROAD

It is requested that when remittances of money are made from abroad, in payment of subscriptions or for publications, a covering note shall be sent *clearly stating the name of the sender* and the purpose for which the money is sent.

Cheques and International Money Orders are frequently received bearing no indication of the name of the sender or of the person or firm to which the goods are to be despatched.

Members whose firms send cheques, &c., on their behalf are also requested to ensure that, in a covering note, it is clearly stated for whom the money is remitted.

MEMBERSHIP ADDITIONS

The undermentioned 12 Ordinary Members and 11 Student Members were elected on 15 October 1947 :

Ordinary Members

CHAUMELLE, Pierre Roger, Manager, Centre of Documentation for the French Iron and Steel Industry, 12 rue de Madrid, Paris 8^{e}, France.

CHILTON, Leonard Vincent, M.A., Manager, Intelligence Department, The British Aluminium Company, Ltd., Salisbury House, London Wall, London, E.C.2.

COLLIER, Thomas William, Production Metallurgist, Thomas Bolton and Sons, Ltd., Froghall, Stoke-on-Trent, Staffordshire.

FINLAY, Walter Leonard, B.S.Ch.E., M.Eng., Research Metallurgist, Remington Arms Company, Bridgeport, Conn., U.S.A.

GUY, Professor Albert Glasgow, D.Sc., Associate Professor, Mechanical Engineering Department, North Carolina State College, Raleigh, North Carolina, U.S.A.

HISCOCK, Walter George, Ph.D., B.Sc., General Manager, National Smelting Company, Ltd., Avonmouth, Bristol.

MORGAN, Stephen William Kenneth, B.Sc., A.R.S.M., Manager, Research Department, National Smelting Company, Ltd., Avonmouth, Bristol.

NELSON, Ferguson Ross, B.Sc., Metallurgist, Armstrong Siddeley Motors, Parkside Works, Coventry, Warwickshire.

RAMA CHAR, T. L., Ph.D., M.Sc., Industrial Chemist and Officer-in-Charge, Bureau of Industrial and Statistical Information, Indian Institute of Science, Bangalore, India.

VIODE, Jean Alfred Auguste, Powder Metallurgist, 17 rue Collette, Paris 17^{e}, France.

WATKINSON, Herbert Henry, Officer-in-Charge, Metallurgical Test House, A.I.S. Test Centre, Middle East.

WILKINSON, Robert Geoffrey, B.Sc., Deputy Chief Metallurgist, Magnesium Elektron, Ltd., Clifton Junction, Manchester.

Student Members

ALLARD, Robert William, B.Sc., Student of Metallurgy, King's College, University of Durham, Newcastle-on-Tyne.

BARTLETT, William Leslie, B.Sc., Student of Metallurgy, University College, Cardiff.

BELLAMY, Roy Graham, B.Sc., Student of Metallurgy, University College, Cardiff.

CAULFIELD, Kenneth William, M.Sc., Research Metallurgist, Tin Research Institute, Fraser Road, Greenford, Middlesex.

GRIEVE, Alan, B.Sc., Student of Metallurgy, University College, Cardiff.

MACK, Kenneth Alexander, B.Sc., Student of Metallurgy, University College, Cardiff.

TIPLER, Hedley Roy, B.Met., Assistant Experimental Officer in Metallurgical Research, National Physical Laboratory, Teddington, Middlesex.

TOMALIN, Peter Frank, B.Sc., Metallurgist, Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester.

UPTON, John Charles, B.Sc., Technical Officer (Met.), Imperial Chemical Industries, Ltd., Billingham Division, Billingham, Co. Durham.

VARLEY, John Henry Oliver, Student of Metallurgy, The University, Birmingham.

YEOMANS, Donald Eric, Student of Metallurgy, The University, Birmingham.

PERSONALITIES

Dr. C. H. Desch

Dr. Cecil Henry Desch, F.R.S., who has been elected a Fellow of the Institute of Metals, was born in London in 1874, and was educated at Birkbeck School, Kingsland; Finsbury Technical College; University College, London (D.Sc.); and Würzburg University (Ph.D.). In 1902 he joined the Metallurgical Department at King's College, London, and in 1909 was appointed Lecturer in Metallurgical Chemistry at Glasgow University, at which he remained until the end of the 1914–18 war. He was then appointed Professor of Metallurgy at the Royal Technical College, Glasgow, a position which he held until 1920, when, on the death of Professor J. O. Arnold, he succeeded to the Chair of Metallurgy at Sheffield University.

In 1931 Dr. Desch visited the United States, where he was George Fisher Baker Lecturer at Cornell University, and in 1932 was appointed Superintendent of the Department of Metallurgy at the National Physical Laboratory, Teddington, where he remained until his retirement in 1939. More recently Dr. Desch has been closely connected with the iron and steel industry. He was appointed to the Board of Directors of Messrs. Richard Thomas and Company, Ltd., in 1943, to direct the research and development activities of that firm, but, on the amalgamation of the

Company with Messrs. Baldwins, Ltd., in 1945, he resigned his directorship and has since been associated with the Whitehead Iron and Steel Company, Ltd.

Dr. Desch was President of the Institute of Metals from 1938 to 1940. He was elected a Fellow of the Royal Society in 1923, was President of the Faraday Society from 1926 to 1928, and has been President of the Iron and Steel Institute since 1946. He was awarded the Institute of Metals (Platinum) Medal in 1941; the Bessemer Gold Medal of the Iron and Steel Institute in 1938; and received the honorary LL.D. degree of Glasgow University. He was recently elected a Corresponding Member of the French Academy of Science.

He delivered the Eighteenth May Lecture to the Institute of Metals in 1928 on "The Chemical Properties of Crystals" (*J. Inst. Metals*, 1928, vol. 39), and is the author of numerous papers on metallurgical and chemical subjects, seven of which are published in the *Journal of the Institute of Metals*. In 1914 and 1919, respectively, he presented the First and Second Reports to the Beilby Prize Committee on "The Solidification of Metals from the Liquid State" (*J. Inst. Metals*, 1914, vol. 11, and 1919, vol. 22). He is also the author of several books, including his "Metallography", "Intermetallic Compounds", "The Chemistry of Solids", and (with F. C. Lea) "Chemistry of Cement and Concrete".

Lieut.-Colonel Sir John Greenly

Lieut.-Colonel Sir John Henry Maitland Greenly, K.C.M.G., C.B.E., M.A., who has been elected a Fellow of the Institute of Metals, was born on 25 July 1885, and is the second son of the late E. H. Greenly, J.P., D.L., of Titley Court, Herefordshire, and Sarah, daughter of the late Lieut.-General Bowes Foster.

Educated at Charterhouse and Trinity College, Oxford, where he graduated, he was trained as a Civil Engineer. Commissioned in 1906 in the Herefordshire Regiment (T.F.), he was promoted Captain in 1912, and served in the 1914–18 war, being appointed to be a Staff Captain and Brigade Major in 1916, promoted to Lieut.-Colonel in 1917, and twice mentioned in despatches. He was Assistant Controller of Inspection of Munitions of War at the Ministry of Munitions from 1916 to 1919. In 1919 he was made a C.B.E.

In 1920 he was appointed Joint Managing Director of Messrs. William Foster, Pascoe, Grenfell and Company, copper manufacturers and smelters of London and Swansea, and subsequently Joint Managing Director of Messrs. British Copper Manufacturers, Ltd. He joined the Board of Messrs. Babcock and Wilcox, Ltd., in 1929, and became Chairman of the Executive Committee and Deputy Chairman of the Company in 1932, and Chairman in 1937. He is also a Director of other Companies.

Since 1937 Sir John has been Chairman of the British Non-Ferrous Metals Research Association, in which position he has given outstanding service to the industry. He has also held numerous other positions of eminence in the fields of science and industry. He was Chairman of the Coal-Burning Appliances Joint Consultative Board in 1936; a member of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research from 1937 to 1943; a member of the Industrial Advisory Panel to the Air Ministry from 1938 to 1939; Chairman of the Prime Minister's Advisory Panel of Industrialists on Rearmament from 1938 to 1939; Controller-General of the British Supply Board in Canada and the United States, 1939–1940; Deputy Chairman and Administrator, Fire Prevention Executive, 1941–1945; a member of the Fire Prevention (Operational) Committee (Ministry of Home Security), 1941–1945; member of the Fuel Research Board, 1942–1947; member of the Advisory Panel to the Minister of Reconstruction, 1942; Chairman of the Bricks Appeal Tribunal (Ministry of Works), 1942–1945; member of the Fuel and Power Advisory Council (Ministry of Fuel and Power), 1944–1946; Member of Council of the British Coal Utilization Research Association, 1938–1946; Vice-President of the Coal Utilization Joint Council, 1945–1946; and is a Member of Council of the British Welding Research Association; a Member of the Institution of Mechanical Engineers, the Institute of Fuel, and the Institution of Engineering Inspection, and a Fellow of the Institution of Metallurgists.

In 1941, he was created a Knight Commander of the Most Distinguished Order of St. Michael and St. George.

Sir John was President of the Institute of Metals from 1942 to 1944, and is also a Past-President of the Institute of Fuel, the Institution of Engineering Inspection, and the Combustion Appliance Makers' Association (Solid Fuel).

In 1946 he was awarded the Institute of Metals (Platinum) Medal in recognition of his outstanding services to the industry. As a Past-President he remains a Member of the Council, which thus continues to benefit from his advice and inspiration.

PERSONAL NOTES

Mr. J. L. Aston has left Cambridge and is now at Sheffield University, to undertake research on the rapid heat-treatment of steel, particularly from the point of view of the metallurgy of the induction hardening of steel.

Mr. K. W. J. Bowen, B.Sc., is now at the Goldsmiths' Laboratory, Cambridge University. His address is Sidney Sussex College.

Professor Sir Lawrence Bragg, O.B.E., Sc.D., F.R.S., has retired from the Advisory Council for Scientific and Industrial Research.

Mr. R. V. Bryan, L.I.M., has left the Ministry of Supply to take up an appointment as Personal Assistant to the Steel Dept. Manager, Sanderson Brothers and Newbould, Ltd., Sheffield.

Mr. Stanley W. Cadden has been appointed Managing Director of the Tomey Group of Companies, comprising Joseph Tomey and Sons, Ltd., Aston, Birmingham; Excelsior Gauge Company, Ltd., Erdington, Birmingham; L. Tomey, Ltd., Erdington, Birmingham; and J. L. Tomey (Coventry), Ltd., Bromsgrove.

Mr. R. W. Cahn has concluded his work at the Cavendish Laboratory, Cambridge, and has taken up an appointment with the Atomic Energy Research Establishment, Ministry of Supply, Harwell. His temporary address is Winnoway Farm, Harwell, near Didcot, Berks.

Major H. B. Deshpande, J.P., M.Sc., F.I.M., Chief Chemist and Metallurgist, East Indian Railway, who is in England on a long leave, made an extensive tour of Canada and the United States in August last and has now returned to London. His address is c/o Thomas Cook and Son, Ltd., 45 Berkeley Street, London, W.1.

Mr. V. J. Donnelly, A.I.M., has returned home to South Africa. His address is c/o National Bolts and Rivets, Ltd., 49 Rawbone Street, Ophirton, Johannesburg.

Dr. D. S. Eppelsheimer, D.S., has left the Metal Hydrides Corporation, Beverly, Mass., U.S.A., on appointment as Associate Professor of Metallurgical Engineering at the Missouri School of Mines and Metallurgy, Rolla, Miss.

Mr. K. S. Foster has sold his holding in Cookson Hermitage, Ltd., and, after a long illness, has now joined Associated Combustion, Ltd., Meonstoke, Southampton.

Mr. F. F. Gordon, Assoc.Met., has been appointed Managing Director of Spear and Jackson, Ltd., Sheffield.

Mr. A. T. Green, O.B.E., F.R.I.C., F.Inst.P., Director of Research of the British Refractories Research Association and of the British Ceramic Society, has been appointed Honorary General Secretary to the British Ceramic Society, in succession to the late Dr. J. W. Mellor.

Sir William T. Griffiths, D.Sc., F.R.I.C., F.I.M., Chairman and Managing Director of The Mond Nickel Company, Ltd., and a Past-President of the Institute, has been appointed by the Lord President of the Council to be a member of the Advisory Council for Scientific and Industrial Research.

NEWS AND ANNOUNCEMENTS

Mr. C. F. Harris, B.Sc., A.R.S.M., has completed his course a the Royal School of Mines and has been called up to serve in H.M. Forces. Correspondence should be addressed to The Homestead, 46 Murray Road, Northwood, Middlesex.

Mr. W. M. Hogendoorn has, since 1 July 1947, been in charge of the metallurgical laboratory, concerned with internal combustion engine development, of the N.V. Metaalindustrie "Johan de Witt" at Dordrecht, Holland. This Company is a branch of the N. V. Philips Gloeilampenfabrieken.

Mr. L. C. Hollyhead graduated in June with an Honours degree (B.Sc.) from the School of Industrial Metallurgy, Birmingham University.

Mr. E. Hunter has been appointed Manager of the Foundry Equipment Department of the Incandescent Heat Co., Ltd.

Dr. L. Jeníček has been appointed Research Director of the United Steelworks National Corporation, Czechoslovakia, but retains his connection with the Czechoslovak Mining and Metallurgical Institute at Ostrava.

Mr. Kenneth S. Jepson has been awarded the degree of B.Met. (Non-Ferrous) of the University of Sheffield.

Mr. H. O. Ludkey has acquired British nationality, and has changed the spelling of his name, from Luedke.

Sir Andrew McCance, D.Sc., A.R.S.M., F.R.S., has retired from the Advisory Council for Scientific and Industrial Research.

Mr. I. Manning, has left David Brown and Sons, Ltd., Lockwood, Huddersfield, and is now Assistant Technical Officer with Imperial Chemical Industries, Ltd., Billingham Division, Billingham, Co. Durham. His private address is 19 Oxford Road, Thornaby-on-Tees.

Mr. A. J. W. Moore, B.Sc., has left Cambridge, to return to the C.S.I.R. Section of Tribophysics, Melbourne University. His private address is 27 Summerhill Avenue, East Malvern, Melbourne, S.E.5, Vic., Australia.

Mr. James Naysmith now holds an appointment with the Anglo-Iranian Oil Company, Ltd. His address is: Reg. No. 6596, SQ 133/5 Braun, c/o Anglo-Iranian Oil Company, Ltd., Abadan, South Iran.

Mr. M. C. Nickson, B.Sc., A.I.M., has changed his place of employment with The Mond Nickel Company, Ltd., to Birmingham.

Mr. F. S. Paschek, B.Sc., A.R.S.M., has left the Royal School of Mines, London.

Sir Clifford Paterson, O.B.E., F.R.S., has been appointed Chairman of the General Council of the British Standards Institution.

Mr. B. W. Prince has left the David Brown Foundries Company, Penistone, to take up an appointment with Firth-Vickers Stainless Steels, Ltd., Sheffield.

Mr. Colin W. Roberts, B.Sc., A.I.M., has left the A.I.D. Test House, Harefield, and is now at the Research Department of the National Smelting Company, Ltd., Avonmouth.

Mr. J. A. Roberts, who graduated with honours in metallurgy from the University College of Swansea, is now engaged at the Wern Aluminium Works of the Light Alloy Section of Richard Thomas and Baldwins, Ltd. His new address is Lodway, 5 Upper Cimla, Neath, South Wales.

Mr. James B. Russell, B.S., has resigned his post as Metallurgist at the Naval Research Laboratory at Washington, in order to take up a full-time graduate study of physical metallurgy at the University of California. His present address is Hotel Carlton, Room 508, 2338 Telegraph Avenue, Berkeley 4, Cal., U.S.A.

Mr. E. C. Smith has been awarded the degree of Doctor of Science of the Case Institute of Technology, Cleveland, O., U.S.A.

Major P. L. Teed, A.R.S.M., on 9 October 1947, at the École Nationale Supérieure de l'Aéronautique, delivered a lecture to the Association Française des Ingénieurs et Techniciens de l'Aeronautique, on " Les Propriétés des Matériaux Métalliques aux Altitudes Stratosphériques ".

Mr. J. G. M. Turnbull, B.Sc., Chief Chemist to C. A. Parsons and Company, Ltd., Newcastle-upon-Tyne, was elected a Fellow of the Institution of Metallurgists in January 1947.

Mr. T. Henry Turner, M.Sc., has been elected a Member of the Institution of Mechanical Engineers.

BIRTH

Lees. On 22 September 1947, at Westminster Hospital, London, S.W.1, to May (née Roberton), wife of D. C. G. Lees, M.A., a daughter.

DEATHS

The Editor regrets to announce the deaths of:

Mr. G. C. Pitcairn, of Metallisation, Ltd., Dudley, on 17 October 1947.

Mr. J. S. Glen Primrose, A.R.T.C., Chief Metallurgist, The Rover Company, Ltd., Coventry, and an Original Member of the Institute, on 2 October 1947.

Mr. H. B. Pulsifer, Ch.E., M.S., Metallurgist, the Ferry Cap and Set Screw Company, Cleveland, O., U.S.A., on 1 September 1946.

Note : Will members (in addition to informing the Institute's administrative department 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 are matters which 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.

OTHER NEWS

GENERAL DISCUSSION ON THE PHYSICAL CHEMISTRY OF PROCESS METALLURGY

The Faraday Society plans to hold, in the latter half of September 1948, a general discussion on the physical chemistry of process metallurgy. It is intended that the discussion shall be devoted to the thermodynamics and kinetics of the high-temperature reactions involved in smelting and refining, and it is proposed to exclude reactions occurring in mechanical working and heat-treatment and also electrochemical processes in aqueous solutions. Thermodynamics will include thermochemical, free energy, and equilibrium studies, and kinetics will include both chemical reactions and diffusion processes.

Prospective contributors are requested to forward to the Secretary, The Faraday Society, 6 Gray's Inn Square, London, W.C.1, summaries of any papers that they would like to submit, indicating the subject matter and the method of treatment, as early as possible and not later than 1 February 1948. Papers accepted will be required to be submitted by 1 July 1948.

DEUTSCHE GESELLSCHAFT FÜR METALLKUNDE

It is learned that, under the direction of Professor Dr. Glocker, Technische Hochschule, Stüttgart, American Zone, the Deutsche Gesellschaft für Metallkunde has been revived.

AMERICAN FOUNDRYMEN'S ASSOCIATION RESEARCH PROJECTS

Three specific interest divisions of the American Foundrymen's Association have launched research projects on fundamental problems in foundry technology. Investigations proposed by the research groups of the aluminium and magnesium, brass and bronze, and malleable divisions, have been approved.

The light metals group will continue and expand the study of centrifugal casting of aluminium and magnesium alloys it has conducted during the past year. Plans for the immediate future include the design of experimental castings and the compilation of data on such aspects as operational requirements, density, grain-size, mechanical properties, production yield, and segregation. Mr. R. F. Thomson, Metallurgist with the International Nickel Co., Detroit, is Chairman of the Division Research Committee.

A comprehensive investigation of tin bronze test-bars is to be undertaken by the brass and bronze research body, headed by Dr. Blake M. Loring, Chief of the Non-Ferrous Division of the Naval Research Laboratory, Washington, D.C. Accurate determination of metal quality through the fracture test will be sought. As-cast structure of the bars will be examined by metallographic, radiographic, fractographic, and other means found desirable. It is anticipated that, through determination of the proper test-bar design, melting conditions, and means of breaking the specimens, the fracture test may be established as a reliable, rapid, and inexpensive method of analysing the quality of melts before castings are poured.

The malleable division project is intended to yield data on the most desirable microstructure for pearlitic malleable-iron castings to be selectively hardened by flame or induction heating.

BRITISH COUNCIL SCHOLARSHIPS

The British Council has awarded scholarships for 1947–48 to 256 graduates or others of like status from 62 countries, including the Dominions and Colonies, to enable them to undertake a year's specialist study in the United Kingdom. In addition, 106 British Council scholars have had their scholarships extended for a further year. The subjects of study cover a wide range, and the majority of scholars are studying in British Universities or University Colleges.

FOURTH PLENARY WORLD POWER CONFERENCE

The conference will be held in London in 1950. This decision was taken by the International Executive Council of the World Power Conference at its recent meeting at The Hague.

ACTA CRYSTALLOGRAPHICA

A new journal of crystallography, *Acta Crystallographica*, sponsored by the recently-formed International Union of Crystallography (see August issue of the *Journal*, p. xli) will start publication in 1948. It is intended to take the place of *Zeitschrift für Kristallographie*, but, in recognition of the rapid development of structural studies in recent years, it is intended to be somewhat broader in its scope and to concern itself with all those physical and chemical properties of matter intimately connected with atomic arrangement.

The journal will be under the editorship of P. P. Ewald, a former editor of the *Zeitschrift für Kristallographie*, and a panel of regional co-editors. It will appear in six issues per year. The annual subscription will be $10 or £2 10*s*. European subscribers should write to the Cambridge University Press, Euston Road, London, N.W.1. Arrangements have been made for those in the U.S.A. and Canada to obtain the journal through the American Institute of Physics, 57 East 55th St., New York 22, N.Y.

Articles for publication will be accepted in English, French, German, or Russian, and authors are now invited to submit manuscripts for consideration by the co-editors: in English, to R. C. Evans, Crystallographic Laboratory, Cavendish Laboratory, Cambridge, or to I. Fankuchen, Polytechnic Institute of Brooklyn, Brooklyn 2, N.Y., U.S.A.

QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS

Published quarterly by the Oxford University Press, under the editorship of Dr. V. C. A. Ferraro and Dr. G. C. McVittie, the first issue of this new journal will be published in April 1948. The journal will cover the fields of hydrodynamics including aerodynamics, sound and dynamical meteorology; elasticity and plasticity; numerical methods, including calculating machines and relaxation methods; non-linear dynamics; ballistics; classical electromagnetism including the propagation of electric waves in space and in wave-guides. Contributions on these subjects are likely to contain references to published experimental work; and when new experimental work is undertaken in this connection, it might be suitable for publication in the journal.

Papers to be considered for the early issues should be sent before December 1947, addressed by name to one or other of the executive editors, at King's College, Strand, London, W.C.2.

MEMORIAL TO DENIS PAPIN

The little commune of Chitenay (Loire-et-Cher, France) celebrated the tercentenary of the birth of Denis Papin on 20 July at the Closerie des Communes.

A commemorative plaque was unveiled by MM. Albert Caquot and Albert Portevin, members of the Institut de France, representatives of the Académie des Sciences. During the banquet which followed the ceremony, very appreciative speeches were made by Professor E. N. da C. Andrade, a Fellow of the Royal Society, of which Denis Papin was a corresponding member, by Mr. Dickinson, President of the Newcomen Society, by Mr. Cortesao, representative of UNESCO and by Professor Cabannes, Vice-Chancellor of the University of Paris.

LOCAL SECTIONS NEWS

At a special meeting of the London Local Section, to be held at 4 Grosvenor Gardens, London, S.W.1, on Thursday, 27 November 1947, at 7 p.m., Dr. W. J. Kroll will give a lecture on "Malleable Titanium and Zirconium—Two Metals of the Future Made on a Commercial Scale".

The title of the Swansea Local Section has been changed to South Wales Local Section.

DIARY FOR DECEMBER

LOCAL SECTIONS MEETINGS

Birmingham Local Section.—Students' Night. (James Watt Memorial Institute, Great Charles Street, Birmingham, Thursday, 4 December 1947, at 6.30 p.m.)

London Local Section.—Dance. (4 Grosvenor Gardens, London, S.W.1, Friday, 5 December 1947. Tickets (single), price 16*s*., obtainable from Dr. E. C. Rhodes, c/o The Mond Nickel Co., Ltd., Development and Research Department, Bashley Road, London, N.W.10.)

Scottish Local Section.—Mr. R. E. Wilson: "Electroplating Practice and Engineering Application." (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, Monday, 8 December 1947, at 6.30 p.m.)

Sheffield Local Section.—Mr. H. Evans, Assoc.Met.: "Surface Finish and Electrolytic Polishing." (Mining Lecture Theatre, Department of Applied Science, The University, St. George's Square, Sheffield, Friday, 19 December 1947, at 7.30 p.m.)

South Wales Local Section.—Dr. R. Higgins, B.Sc., and Mr. D. W. Hopkins, B.Sc.: Accounts of visits to Canada and the United States under the auspices of the Nuffield Foundation Scheme. (Y.M.C.A., Swansea, Tuesday, 2 December 1947, at 6.30 p.m.)

OTHER MEETINGS

British Society for International Bibliography.—Dr. Marjorie Plant: "A Project for a Periodicals Indexing Service"; and Henry Rottenburg: "The Fundamentals of Classifying, Indexing, and Filing References." (Institution of Electrical Engineers, Savoy Place, London, W.C.2, Wednesday, 17 December 1947, at 2.30 p.m.)

Cleveland Institution of Engineers.—W. Udall: "Combination Rolling Mills." (Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, Monday, 1 December 1947, at 6.30 p.m.)

Geological Society of London.—Ordinary evening meeting. (Burlington House, Piccadilly, London, W.1, Wednesday, 10 December 1947, at 5 p.m.)

Institute of Physics, Industrial Radiology Group.—R. Halmshaw: "The Radiographic Examination of Welded Repairs in Casting." (London, Friday, 5 December 1947, at 6.30 p.m.)

Institute of Physics, Midland Branch.—Dr. C. Sykes, F.R.S.: "Physics and Steel Making." (Birmingham, Thursday, 18 December 1947, at 6 p.m.)

Institute of Welding, South London Branch.—J. A. Dorratt: "Welding in Marine Engineering." (Institute of Marine Engineers, 85–88 The Minories, London, E.C.3, Thursday, 11 December 1947, at 6.30 p.m.)

Institute of Welding, West of Scotland Branch.—W. H. Millwood: "The Practical Application of Flash Butt Welding to Modern Production." (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, Wednesday, 17 December 1947, at 6.45 p.m.)

Institution of Civil Engineers.—Professor Sir Charles Inglis, O.B.E., M.A., LL.D., F.R.S.: "Mathematics in Relation to Engineering, with Special Reference to a Paper by the Lecturer on Shear-Stress Determination." (The Institution, Great George St., London, S.W.1, Tuesday, 16 December 1947, at 5.30 p.m.)

Institution of Electrical Engineers, North-Western Installations Group.—M. E. Haine, B.Sc.: "The Design and Construction of a New Electron Microscope." (Engineers' Club, Albert Square, Manchester, Tuesday, 16 December 1947, at 6 p.m.)

Institution of Mechanical Engineers, Applied Mechanics Group.—W. A. P. Fisher, M.A.: "Basic Physical Properties Relied on in the Frozen Stress Technique"; and R. B. Heywood, B.Sc.: "Modern Applications of Photoelasticity." (The Institution, Storey's Gate, London, S.W.1, Friday, 12 December 1947, at 5.30 p.m.)

NEWS AND ANNOUNCEMENTS

Institution of Mining and Metallurgy.—General Meeting. (Geological Society, Burlington House, Piccadilly, London, W.1, Thursday, 18 December 1947, at 5 p.m.)

Institution of Structural Engineers, Lancashire and Cheshire Branch, Graduates' and Students' Section.—J. Martin: "Welded Structures." (Milton Hall, Deansgate, Manchester, Tuesday, 2 December 1947, at 7 p.m.)

Institution of Structural Engineers.—Professor R. V. Southwell, LL.D., F.R.S.: "Relaxation Methods as Applied to Structures." (The Institution, 11 Upper Belgrave Street, London, S.W.1, Thursday, 18 December 1947, at 5.55 p.m.)

Leeds Metallurgical Society.—H. G. Warrington: "Aluminium Alloys." (Main Lecture Theatre, Chemistry Department, The University, Leeds, Wednesday, 3 December 1947, at 7 p.m.)

Leeds Metallurgical Society.—Buffet Dance. (Astoria Ballroom, Leeds, Thursday, 4 December 1947, at 8 p.m. to 2 a.m.)

Manchester Metallurgical Society.—Ivor Jenkins, M.Sc.: "Controlled Atmospheres for Heat-Treatment of Metals." (Engineers' Club, Albert Square, Manchester, Wednesday, 10 December 1947, at 6.30 p.m.)

Newport and District Metallurgical Society.—A. H. Waine: "Forged Steel Rolls." (Technical College, Newport, Saturday, 13 December 1947, at 6.30 p.m.)

Sheffield Metallurgical Association.—Discussion on "Ingot Surface Defects", to be opened by T. Arnold, N. H. Bacon, and G. E. Howarth. (198 West St., Sheffield, Tuesday, 16 December 1947, at 7 p.m.)

Sheffield Society of Engineers and Metallurgists.—Symposium on "The Use of Liquid Fuel in Open-Hearth Furnaces". (Royal Victoria Station Hotel, Sheffield, Monday, 15 December 1947, at 6.15 p.m.)

Swansea and District Metallurgical Society.—Discussion on "Oil-Firing of Metallurgical Furnaces". Introduced by R. W. Evans, M.Met., A. M. Gabe, B.Sc., and J. S. Lewis. (Royal Institution of South Wales, Swansea, Saturday, 13 December 1947, at 6.30 p.m.)

West of Scotland Iron and Steel Institute.—G. S. T. Martin: "Maintenance of Steel Works Plant." (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, Friday, 19 December 1947, at 6.45 p.m.)

APPOINTMENT REQUIRED.

APPOINTMENTS VACANT.

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

ANALYTICAL CHEMISTS required who should preferably be qualified and have experience in the assaying of non-ferrous metals, minerals, and by-products, including the rarer metals. Liberal salary will be paid. Apply to Derby and Co., Ltd., Cheyne House, 62–63 Cheapside London, E.C.2.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION.

PHYSICIST or METALLURGIST with X-ray crystallographic experience required by the above Association for research on the surfaces of metals and coatings. University degree in physics or metallurgy essential. Appointment is in the Scientific Officer grade, age range 22–30. Salary £350–£550 according to age, qualifications, and experience. Location of work Swansea. Written applications only giving full curriculum vitæ to the Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

METALLURGIST required by the above Association for research on the surfaces of metals and coatings. University degree essential, higher degree desirable. Appointment is in the Scientific Officer grade, age range 25–30. Salary £400–£550 according to age, qualifications, and experience. Location of work Swansea. Written applications only giving full curriculum vitæ to the Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

MECHANICAL AND ELECTRICAL ENGINEER with University degree, aged about 35, preferably but not essentially with some experience in the rolling section of the iron and steel industry, required by medium-sized public limited company in North-West. Commencing salary £1250 per annum. Reply giving particulars of education, experience, position held, and age to Box No. 216, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

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Forms of application are obtainable from the Secretary, Civil Service Commission, Scientific Branch, 27 Grosvenor Square, London, W.1, quoting No. 2032, to whom completed application forms should be returned not later than 9 December 1947.

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1. **Papers will be considered for publication from non-members as well as from members of the Institute.** They are accepted for publication in the *Journal*, and not necessarily for presentation at any meeting of the Institute, and should be addressed to The Editor of Publications, The Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

2. **Papers suitable for publication** may be classified as :

   (*a*) Papers recording the results of original research;
   (*b*) First-class reviews of, or accounts of, progress in a particular field;
   (*c*) Papers descriptive of works methods, or recent developments in metallurgical plant and practice.

3. **Manuscripts and illustrations** must be submitted in duplicate. MSS. must be typewritten (*double-line spacing*) on one side of the paper only, and authors are required to sign a declaration that neither the paper nor a substantial part thereof has been published elsewhere. MSS. not accepted will be returned within 6 months of receipt.

4. **Synopsis.** Every paper must have a synopsis (not exceeding 250 words in length), which, in the case of results of research, should state its objects, the ground covered, and the nature of the results. The synopsis will appear at the beginning of the paper.

5. **References** must be collected at the end of the paper, and must be numbered. Initials of authors must be given, and the Institute's official abbreviations for periodical titles (as used in *Met. Abs.*) must be used where known. References must be set out in the style :

   1. W. Hofmann and W. Jäniche, *Z. Metallkunde*, 1936, **28**, 1 (i.e. year, volume, page).

6. **Illustrations.** Each illustration must have a number and description; only one set of numbers must be used in one paper. The set of *line figures* sent for reproduction must be drawn in Indian ink on smooth white Bristol board, tracing *cloth*, or good-quality drawing paper. Co-ordinate paper is not desirable, but if used must be blue-lined with the co-ordinates to be reproduced *finely* drawn in Indian ink. All lettering and numerals, &c., should be in in *pencil*. Figures should be drawn approximately twice the size intended for reproduction. *Photographs* must be restricted in number, owing to the expense of reproduction, and must be trimmed to the smallest possible of the following sizes, consistent with adequate representation of the subject: 3 in. deep by 4 in. wide (two photomicrographs to a plate); 3 in. deep by 2¼ in. wide (four to a plate); 2 in. deep by 2¼ in. wide (six to a plate). Magnifications of photomicrographs must be given in each case. Photographs for reproduction should be loose, not pasted down (and not fastened together with a clip, which damages them), and the figure number should be written on the back of each. Lengthy descriptions to photomicrographs should be avoided where possible, owing to the very limited space available on the plates. Owing to limitations of paper supplies, illustrations that are not *essential* to the appreciation of the paper should not be included. Only in exceptional cases will illustrations be reproduced if already printed and readily available elsewhere.

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A STUDY OF PROCESS VARIABLES IN THE PRODUCTION OF ALUMINIUM POWDER BY ATOMIZATION.* 1114

By J. S. THOMPSON,† B.Sc., Student Member.

Synopsis.

The process of molten-metal atomization has long occupied a position of major importance among the methods of production of metal powders, and its application to aluminium has been common, in various modifications, for many years. Presumably because of the numerous ways in which this process may be performed, there has been little information published about the subject, and therefore a study has been made of the effects of certain variables upon the most important characteristics of the product and the method of operation. Particular attention has been paid to the rate at which atomization proceeds, the size grading of the powder, and the ease and efficiency of operation.

Of the variables investigated, those concerned with nozzle design have been shown to be of relatively minor importance, giving results peculiar in form, as well as in magnitude, to a specific set of operating conditions. Rate of atomization has been found to be simply related to the variables: metal head, air pressure, metal temperature, and area of metal orifice, when each is considered separately, since linear relationships have been established by the use of very simple functions of these factors. The variables are interdependent, however, and when two or more are considered together the relationships become more complex. A general explanation of the mechanism of operation has been outlined and a tentative equation developed to cover the dependence of rate of atomization upon the most important variables. The principal advantages of the method are given together with a summary of the value of each variable as a means of process control. The determination of the size distribution of the powder of sub-sieve size is described briefly in the Appendix.

I.—Introduction.

Recent developments in the use of aluminium powder in a number of industries have made many demands upon the producers of this material, demands accentuated during the war period by the extensive use of aluminium powder as an ingredient of incendiary and explosive compositions. In addition to the high consumption, the uses of the material are so highly diversified that they necessitate the production of powders differing widely in their specific characteristics. Yet of the many methods at present available for the production of metal powders [1] only four are used for aluminium: milling, shotting, granulation, and atomization. Of these, milling produces aluminium in flake form, characterized by its use as a pigment, while shotting and granulation

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* Manuscript received 29 January 1947.

† Development Manager, Metals Division, Durham Chemicals, Ltd., Birtley.

give comparatively coarse products of uncertain oxide content. The remaining process, that commonly referred to as atomization, has been found to be of great flexibility with respect to the size distribution of the product, and, surprisingly enough when the underlying mechanism is considered, the oxide content is sufficiently low to permit the production of strong compacts by the normal devices of powder metallurgy.[2] A certain looseness of terminology exists in the current use of the word " atomization " since it is used to cover methods of metal-powder manufacture differing widely in their characteristics. The word is used here to refer to those processes, the essential principle of which is that a stream of molten metal is disintegrated by a controlled flow of compressed fluid; such a definition would exclude any methods of production of metal powders by mechanical disintegration of molten metal.

The idea of disintegrating a metal stream by a blast of compressed fluid is by no means new,[3] in its most elementary form it was the basis of a German patent taken out in 1882, the object being the production of lead powder for use in accumulators. Since that date there has been a steady improvement in both apparatus and technique, the principal trend being towards the development of a compact, self-contained nozzle as opposed to the original independent system. Two American patents [4] granted in 1924 and 1925 describe, respectively, a system for the atomization of metals and, in more detail, a nozzle for use with this system. The special feature of this nozzle is that the compressed gas issues from an annulus concentric with the metal orifice; this principle has been made the basis of many atomizing nozzles since then and is, indeed, characteristic of the nozzle with which the present work was performed.

Although there is abundant material, particularly patent literature, dealing with the construction of apparatus used for atomization, there appears to have been little or no published work indicating the scope of the process, its advantages over other production methods, or its more practical fundamental aspects. Doubtless this can be ascribed to the many modifications of apparatus which can be employed and the necessarily highly specific character of an investigation dealing with the details of any particular method. Nevertheless, it was felt that reasonably comprehensive tests, concerned with operational conditions and factors of nozzle design as means of control of the characteristics of the final product, might yield useful results and indicate, in at least a general manner, the fundamental factors underlying the process. For comparative purposes, some research was carried out on water spraying as a preliminary to aluminium; the results are included at appropriate places in the text because of their value in confirming those obtained with metal.

II.—SCOPE OF EXPERIMENTAL WORK.

The object of the research was to determine the effects of certain variable factors upon the nature of the product and the practicability of the method for the production of aluminium powder. It was decided that, under any set of conditions, the results of operation could be defined by three characteristics, so that, in essence, the work comprises a study of the effects of alteration in the variable factors upon these characteristics, viz. productive rate, quality of product, and ease of operation.

1. *Productive Rate.*

Many production methods for metal powders which have proved to be eminently satisfactory on a laboratory or pilot-plant scale have suffered because the rate of output has proved to be prohibitively low when applied on a works scale. Perhaps this has been more commonly experienced with iron powder than with aluminium; nevertheless, the productive rate is of immense importance since it greatly influences the manufacturing costs of the process.

2. *Quality of Product.*

The quality of a metal powder is essentially a composite property, and has several fundamental attributes inevitably associated with it. Of these, there are three which might be considered as primary; others, such as flow factor, apparent density, and pressing properties, which derive from these primary properties, were not therefore investigated.

(a) *Chemical Quality.* Obviously the suitability of a metal powder for a particular requirement is originally governed by conformation to the chemical specification for the material. When relatively pure metal (i.e. as distinct from alloys) is used in powder metallurgy, chemical considerations become almost solely limited to the quantity of oxide present and its mode of distribution; where this is important, reference to it will be found in the text.

(b) *Size Distribution.* Although the fundamental questions of size distribution of any given powder, and their relation to the processing of that powder, are not fully understood, it is nevertheless accepted as one of the most important factors of powder metallurgy and one which exerts considerable influence upon such properties as flow factors and apparent densities. In this work, size distribution was investigated by sieving and by representative sub-sieve size analyses carried out using an air elutriator of simple but effective design (see Appendix).

(c) *General Characteristics.* In this group are included those properties which are rather difficult of quantitative interpretation, such as shape of particles and surface characteristics, properties which almost certainly represent the " unknown factors " in flow, loose packing, and ease of pressing. Atomized particles are generally stated to possess an elongated tear-drop form. In actual practice they are, of course, highly variable in shape (atomized copper powder can be obtained in the form of almost perfect spheres because of the high surface tension of the molten metal), but their mode of formation is such that they are usually elongated, in the case of aluminium generally approximating to an ellipsoid in which the major axis is almost exactly twice that of the smaller dimension. This fact was determined statistically from microscopic measurement of a large number of particles, and was found to hold for all sizes from 36 mesh B.S. sieve (422 microns) down to 10 microns. During the trials, the particle shape showed no systematic change with alteration in any variable; it was felt that investigation of this factor could, therefore, be justifiably eliminated. Characteristically the particles were found to be irregular in outline but superficially smooth (see Figs. 22–25 (Plate XVII)) and appeared to be quite sound, almost completely lacking in large discontinuities such as are found in metal powders produced by certain other methods.

3. *Operational Characteristics.*

Certain conditions connected with the process, which, although permitting brief periods of satisfactory operation, rendered continuous atomization impracticable, were discovered during the trials. Where such conditions have militated against complete accuracy of results, the reason and possible solution have been indicated at the appropriate points in the text.

Owing to the tremendous number of possible combinations, any work which involves the investigation of the effects of a number of variable factors on the characteristics of a general process must necessarily be incomplete. It was decided therefore, in this case, that isolated treatment of each factor, while maintaining all others constant, would yield a representative set of data, sufficient to give at least a general picture of the process mechanism.

III.—APPARATUS.

1. *Layout of Plant.*

When considering erection of plant for the production and collection of even small quantities of aluminium powder, one of the governing factors is complete observance of all reasonably practical safety precautions.[5] When dispersed in air aluminium can be dangerously inflammable [6]; static dust clouds must therefore be strictly avoided at any point in the circuit, and the concentration of powder in suspension should be kept below the explosive limit throughout as great a part of the plant as is practicable. A number of systems for handling aluminium powder are at present in use, and that described below can probably claim safety and efficiency at least equal to any of the others. The principal features and general layout of the experimental plant are shown in Fig. 1.

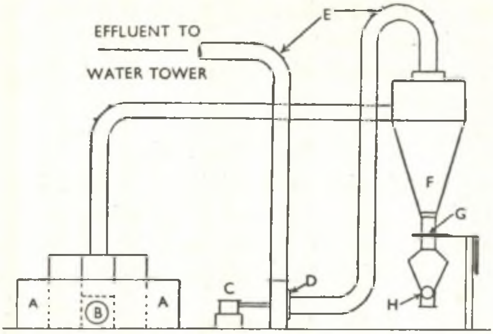

Fig. 1.—Diagrammatic Representation of Plant Layout.

Key.

A. Melting furnace.	E. Explosion vents.
B. Atomizing unit.	F. Cyclone.
C. Motor.	G. Shut-off slide valve.
D. Fan.	H. Off-take rotary valve.

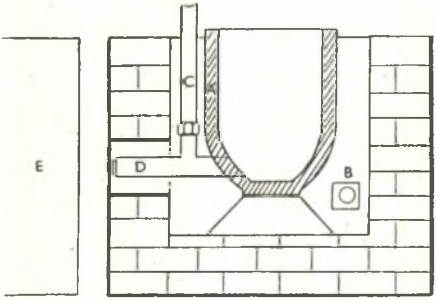

Fig. 2.—Detail of Atomizing Unit.

Key.

- A. Clay–graphite crucible.
- B. Gas Burner.
- C. Compressed-air line.
- D. Atomizing nozzle.
- E. Collecting trunking.

The metal is originally melted and raised to the requisite temperature in a gas-fired crucible furnace, from which it is transferred to a separate gas-heated crucible to which the atomizing nozzle is attached (Fig. 2). The powder is blown into a large-diameter conveying tube, the mouth of which is encased in $\frac{1}{2}$-in.

armour plate, and, by virtue of the suction created by a fan, is carried through trunking to a cyclone of conventional design, where the majority of the powder is deposited and continuously collected. A small amount of fine powder is drawn out of the cyclone by the effluent air and is conducted to a water scrubbing tower where it is trapped and carried away as a dilute slurry.

2. *Nozzle Design.*

During the atomization of aluminium, an operating temperature of about 800° C. is generally employed, and this imposes severe refractory-corrosive conditions on the nozzle material. Trials conducted with common ferrous materials gave highly unsatisfactory results, the rapid formation of $FeAl_3$ causing irreparable deterioration of the nozzles; even special heat-resisting steels lasted only several minutes. Graphite, although giving a slightly longer life, was nevertheless subject to corrosive attack and was mechanically unsatisfactory. Eventually, a special refractory material was tried and found to be eminently suitable; there appeared to be no corrosive attack, and refractory strength was sufficiently high to withstand any normal treatment required during operation. The essential features of this particular type of nozzle are that the metal stream, issuing from the central orifice, is caught up by an annular blast of atomizing medium (in this case compressed air) concentric with the jet, disintegrated, and expelled from the nozzle as a confined spray of originally molten droplets, which are chilled and solidify at some point distant from the nozzle. Details of nozzle design are shown in Fig. 3, and it will be noted that only the inner nozzle is constructed of refractory material, other parts not in contact with the aluminium being of mild steel.

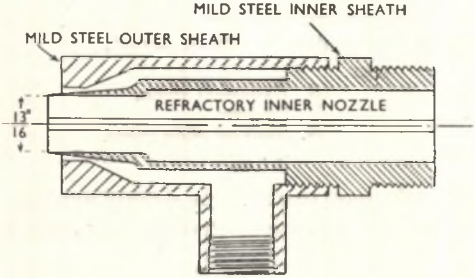

Fig. 3.—Atomizing Nozzle.

IV.—Experimental Procedure.

The original metal charged to the melting furnace was virgin aluminium in the form of 50-lb. ingots, the general analysis of which is indicated in Table II. On attaining the requisite temperature, this metal was transferred to the blowing unit and maintained at a constant head and temperature during atomization. The viscous and highly tenacious oxide skin which inevitably forms on aluminium at elevated temperatures proved highly detrimental to the atomization process, causing partial blockage of the orifice and consequent diminution of metal flow. For this reason, the metal was frequently fluxed and skimmed during atomization. As soon as a steady flow was obtained from the nozzle orifice, i.e. when sufficient head of metal was attained in the bath, the compressed air was applied. Previous tests had proved that air at atmospheric temperature could be used for the atomization of aluminium without causing undue risk of freezing at the nozzle. This fact is perhaps surprising when the details of the process are considered, but the use of such air was adhered to throughout the tests.

Figures given for rates of atomization were obtained from the material delivered at the cyclone. It was appreciated that this introduced a slight error, in that losses throughout the plant were disregarded, but recovery figures showed these losses to be of a low order (approximately 2%) and sufficiently constant to have little serious effect on the accuracy of the results. Previous experiments on water spraying had given highly reproducible results; Table I has been included for the specific purpose of showing that the degree of reproducibility obtained in the atomization of aluminium is also of quite a high order. The discrepancies which do arise can be attributed to the obstruction of the nozzle by particles of oxide, injected to the base of the blowing crucible when metal is transferred to it. These particles, although not causing complete stoppage of the metal flow, cause a considerable diminution, which may not be readily observed. Thus results can be recorded which are not truly typical of the operational conditions. The practical solution of the problem is to probe the nozzle with a rod of slightly smaller diameter than the nozzle bore; if this is done carefully the material causing the obstruction can be pushed into the body of the metal in the crucible, where it has an opportunity to move to the surface. Only by regular probing can the maximum productive rate be assured. During operation, metal temperature was measured at five-minute intervals by a bare immersion Chromel–Alumel thermocouple, previously checked against a standard couple. The temperature could be maintained within ±10° C. of any desired value.

The problem of representative sampling in this case, as in most others where relatively large quantities of material are handled, was not solved completely satisfactorily. Recourse was made to the use of a conventional sampling "thief", one sample being taken from each 2 cwt. of powder produced; subsequent quartering reduced the sample to a workable size. Full precautions were taken to avoid segregation and classification, and all tests were performed in triplicate. Sieving analyses were carried out,[7] using a set of British Standard Specification Fine Test Sieves which had been calibrated microscopically and shown to agree closely with their nominal sizes. It rapidly became obvious that to report, say, 50% of a powder as passing the 200-mesh sieve without further specification of the fine material was highly unsatisfactory, but considerable difficulty was experienced in finding an apparatus suitable for the analysis of sub-sieve-size powder. Eventually, determinations of size distribution of material in this range (i.e. finer than 76 microns) were made using a four-tube elutriator described in the Appendix. A further matter affording some difficulty of solution was that of suitable graphical means of representing size distribution. Finally, it was decided that two simple, but nevertheless effective, methods might be employed :

TABLE I.—*Effect of Variation in Metal Head on Rate of Atomization.*

Test Designation.	Metal Head, in.	Temp., ° C.	Rate of Atomization. lb/hr.
A. 1. *a*.	10½	773	415
b.	10½	770	412
c.	10½	773	409
A. 2. *a*.	9½	760	413
b.	9½	765	407
c.	9½	770	410
A. 3. *a*.	7½	773	406
b.	7½	780	408
c.	7½	775	404
A. 4. *a*.	5½	771	403
b.	5½	775	400
c.	5½	773	400
A. 5. *a*.	3½	773	396
b.	3½	773	387
c.	3½	775	390

Average values from Table I give the results shown graphically in Fig. 4, and the comparable results obtained with water are shown in Fig. 5.

(*a*) As an indication of the trend of powder quality throughout a series, the percentage weight of powder which passed the 200-mesh sieve (76-micron aperture) was plotted against the variable factor of the series. It can be taken that such a plot indicates the general effect on the fineness of the powder through the series.

(*b*) The complete picture of the nature of any variations in size distribution is afforded by the use of the cumulative percentage oversize plot, which indicates whether a change is merely a general shift towards increased fineness or coarseness, or whether the actual character has changed, e.g. accentuation or diminution of peaks in the curve, introduction of double-peaked distribution, &c.

V.—EXPERIMENTAL RESULTS.

1. *Pressure of Metal Head.*

(a) *Constant Factors:* metal orifice, $\frac{5}{32}$ in.; air annulus, $\frac{1}{16}$ in.; protrusion, $\frac{1}{4}$ in.; inclination of external sheath, zero; air pressure, 75 lb./in.^{2}; metal temperature, 775° C.

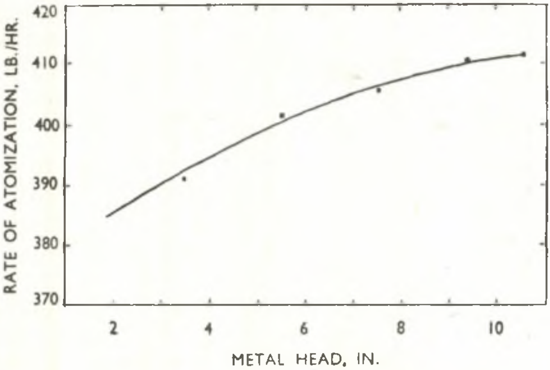

FIG. 4.—Effect of Metal Head on Rate of Atomization.

It will be seen from the graphs of Figs. 4 and 5 that, within a limited range (the limits being imposed by operating conditions), pressure of metal head has but slight effect on the rate of atomization. With water, the change is considerably more marked; as might be expected, a linear relationship exists between productive rate and the square root of water head. The shape of the curve of Fig. 4 (cf. the curves of Fig. 5) suggests that in all probability a similar relationship holds for aluminium but the working range is too short to permit accurate statistical correlation. Nevertheless, it can be said that, qualitatively at least, the results fall into line with theoretical expectations, and it is only in the magnitude of the change that the results are rather divorced from theory. It is perhaps interesting to note that when reduced to the same orifice diameters, aluminium production at 4-in. metal head and rate of atomization of water at 4-in. water head are nearly equal, in spite of the differences in physical characteristics such as specific gravity and viscosity (aluminium at 4-in. head : 395 lb./hr.; water at 4-in. head : 403 lb./hr.).

In the light of the results obtained for rate of production, it is relatively easy to explain the effect of metal head on the size grading of the resultant powders. Since the air pressure is constant, the quantity of energy available for atomization must also be constant. Further, since the energy required to disintegrate the metal stream to independent particles must be a function of total surface and therefore of particle size, it follows that an increase in the quantity of metal available for atomization must inevitably lead to a decrease in the energy available per unit weight of metal, with consequent increase in the general coarseness of the product. This allows a generalization to be made which should be verified by succeeding results : if any factor, which does not in itself affect the energy available for atomization, is altered so as to increase the rate of atomization, then there should be a corresponding decrease in the efficiency of atomization; the powder should become coarser. In cases where the actual available energy, or the energy required for disintegration, are altered, then factors appear which may compensate for, or even completely efface, the above effect. In this particular series, there is a definite decrease in atomization efficiency as the head of metal is increased; even the general characteristic, weight of material passing a 200-mesh sieve, shows a steady reduction throughout the series, and the cumulative plot indicates a general shift towards increased particle size. The typical distribution curve, which can be deduced from the cumulative curves of Fig. 6, is characterized by two peaks separated by a minimal trough

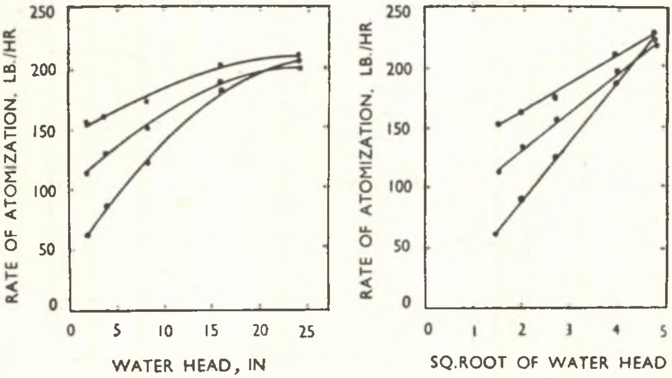

Fig. 5.—Effect of Water Head on Rate of Atomization.

at about 80 microns. The major peak occurs at about 25 microns, and is typical of an asymmetric or skew probability distribution; the other peak is less sharply defined, occurring at about 130 microns and falling away smoothly to zero value at a very large particle size.

Operation throughout the series was good, although at the lower heads, particularly 3½ in., difficulty was experienced with excessive injection of dross into the nozzle, and it became necessary to resort to more frequent probing than was the case with the higher heads. In spite of this, however, atomization was generally quite satisfactory down to 3½-in. head; below this figure the metal issuing from the orifice possessed a very low velocity, and fouling at the nozzle tip was greatly facilitated.

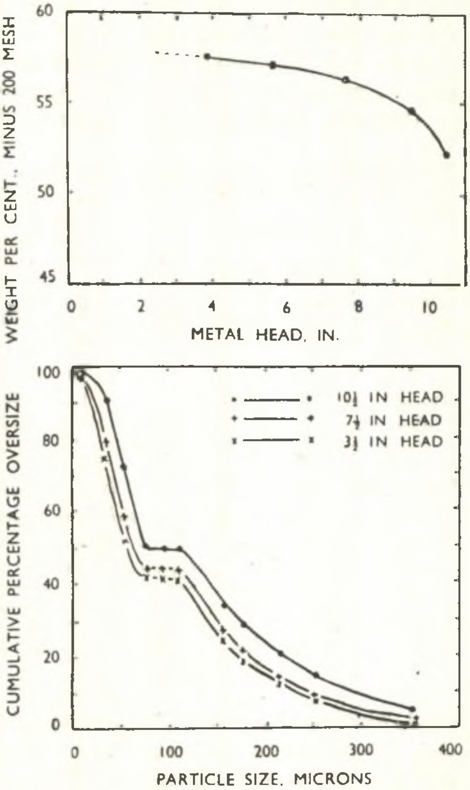

Fig. 6.—Effect of Metal Head on Size Distribution.

As stated previously in connection with chemical quality of the powder, the only important factor is the quantity of oxide present; this is substantiated by the figures given in Table II. If the assumption, stated earlier, that the oxide is principally concentrated on the surface of the particles, is true, then it would be expected that with increased fineness of powder the oxide content would increase, owing to the very much greater specific surface. This was tested in a general manner by taking three rather broad sieve groups and determining the quantity of metallic aluminium present in powder from each of the groups; a marked decrease in this constituent was apparent as the fineness increased.

It is interesting to note in this connection that it has been shown by Cremer and Cordiano [2] that superficial oxide envelopes, if not too thick, do not militate seriously against the value of atomized aluminium for fabrication of articles by powder-metallurgical technique; in fact, for such purposes atomized powder is preferred to other forms of comminuted aluminium. Only very slight modifications of normal pressing procedure are required, and in certain cases the slight oxide coating which is inevitably present may be of actual value in the finished pressing, e.g. for grain-size control.

(b) *Spray Form.* Characteristically the spray consists of a conical shell, which comes to a focus at about 1¼ in. from the tip of the nozzle and then diverges quite regularly. (The position of the focal point naturally varies with operating conditions, but is generally between 1 and 1½ in. from the nozzle tip.) The stream of liquid metal which initially issues from the orifice persists as a jet for a certain distance from the tip and then "fountains" quite abruptly to the periphery of the cone. Since the cone appears to begin at the outer rim of the refractory nozzle, the film of aluminium must actually be drawn back on to this surface, from which it is subsequently expelled to take the conical form typical of the process. Obviously, the air in the vicinity of the nozzle must be in a complex state of turbulence, so that at various points in the field the operative forces will vary considerably, both in magnitude and direction. Probably within the shell there exists a

TABLE II.—*Composition of Original Aluminium and Aluminium Powders.*

Constituents.	Virgin Aluminium Ingots, %.	Powder *A.1.c*, %.	Powder *A.5.b*, %.
Total aluminium	99·3	99·0	99·1
Metallic aluminium . . .	99·0	98·35	98·5
Combined aluminium (by difference)	0·3	0·65	0·6
Zinc	0·05	0·08	0·05
Iron	0·30	0·25	0·30
Copper	0·02	0·03	0·03
Lead	0·01	0·01	0·02
Silicon	0·10	0·10	0·08

TABLE III.—*Effect of Particle Size on Metallic Aluminium Content of Aluminium Powder.*

Group Size.	Metallic Aluminium, %.
+ 44	99·50
85–100	98·52
− 200	96·67

slight but nevertheless effective positive pressure directed towards the nozzle, while outside the cone the effluent air creates a force directed away from the nozzle. Thus a two-way motion must go on in the shell of the cone, there being an inner stream flowing towards the periphery and also an outer stream in which the particles are moving in exactly the opposite direction and are ejected to the atmosphere (Fig. 7).

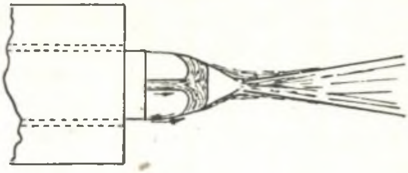

Fig. 7.—Diagrammatic Representation of Spray Form.

2. *Pressure of Atomizing Medium : Compressed Air.*

(a) *Constant Factors :* metal orifice, $\frac{5}{32}$ in.; air annulus, $\frac{1}{16}$ in.; protrusion, $\frac{1}{4}$ in.; inclination of external sheath, zero; metal head, $9\frac{1}{2}$ in.; metal temperature, 775° C.; volume of free air through nozzle, 250 ft.^{3}/min.

From the early results it appeared that a direct linear relationship existed between air pressure (i.e. gauge line pressure) and rate of atomization, but closer examination revealed that the points actually lie on a smooth curve, as shown in Fig. 8. Fig. 9 shows that, in a series of curves at different heads, relating rate of atomization and air pressure, as the head is increased the curves approximate more closely to straight lines of decreasing slope, until at large heads it appears probable that alteration in air pressure will cause no change in rate of atomization. Therefore, it follows that the effluence of the compressed air from the annulus produces a force which acts upon the metal stream and imparts to it a greater velocity of flow through the orifice. In the previous section, it was shown that immediately in front of the nozzle

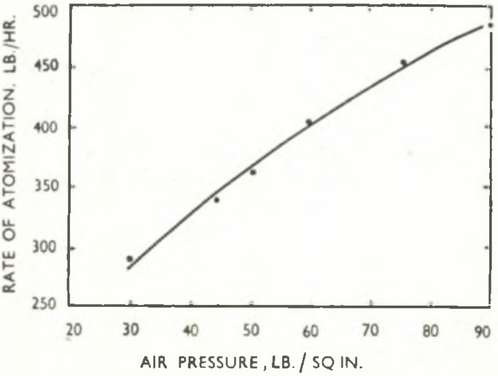

Fig. 8.—Effect of Air Pressure on Rate of Atomization of Aluminium.

there must exist a slight force, due to the compressed air, directed towards the nozzle. The fact that the results of this series show that there must be a force directed away from the nozzle must at first sight appear anomalous, but it is feasible that these forces operate at quite different points within the field, and can therefore exert an effect simultaneously. A further fact revealed by the curves of Fig. 9 is that the force exerted by the compressed air on the effluent liquid is not constant, but depends upon the head of liquid causing flow. Thus the increase in rate of atomization effected by increasing the air pressure from 0 to 100 lb./in.^{2} becomes progressively less as the head alters from 2 to 24 in. Since at constant head the force due to the head of liquid cannot be affected by alteration in air pressure, it follows that any variations which do occur must be due to changes in the magnitude of the force caused by the compressed air.

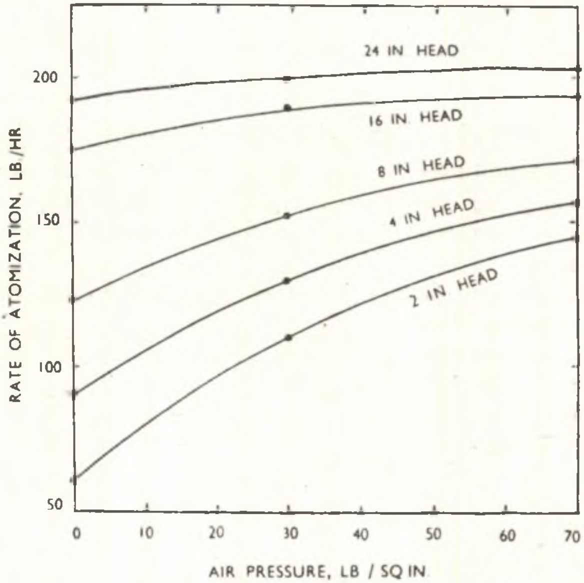

Fig. 9.—Effect of Air Pressure on Rate of Atomization.

Momentarily considering only isolated series at fixed heads, it has been found that a relationship similar to that between liquid head and rate of atomization exists, i.e. the rate is directly proportional to the square root of the air pressure, and not to the air pressure itself. In conformity with the previous series, this suggests that the velocity of the effluent air, and not the actual gauge line pressure, is the controlling factor. The application of this explanation is extended in the discussion of the results.

Such conditions render it rather difficult to predict the effect of change in air pressure upon the fineness of the resultant powder. In the simple case where the rate of flow is increased without altering the conditions of atomization, it has been shown that there is a coarsening of the product; but in this case there is a compensatory factor, in that any increase in air pressure gives a greater available energy, and thus the final effect will be governed by the relative magnitudes of these two factors. Castleman,[8] engaged on work of a similar nature but different in application, has suggested that particle size should decrease as the air pressure increases. In this particular case, the results obtained are shown in Fig. 10, and it will be appreciated that the shape of the curve does not lend itself to simple interpretation. The fact has been substantiated, however, by more recent work on other metals, i.e. increased air pressure causes an increase in fineness up to a maximum, after which there is no further increase; in some cases there may actually be a decrease. It is feasible that a maximum may occur on

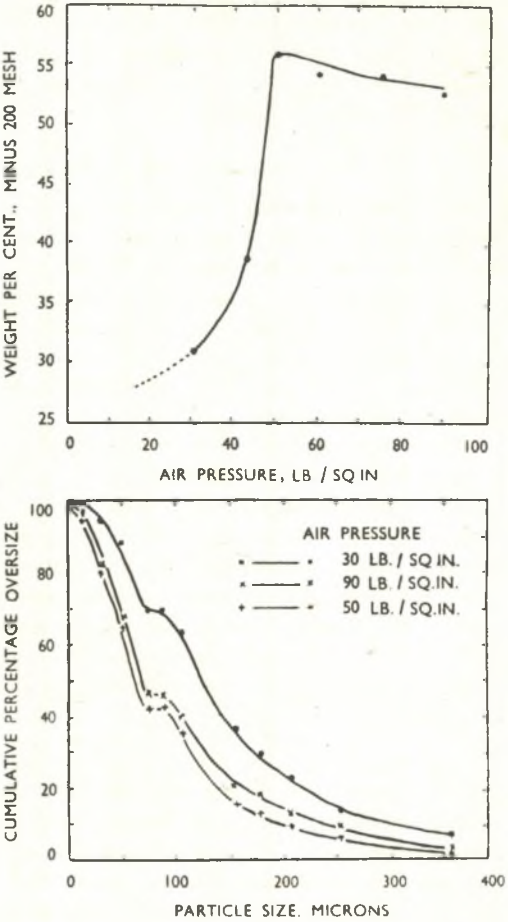

Fig. 10.—Effect of Air Pressure on Size Distribution.

the fineness curve if that curve is the resultant of two opposing curves, one indicating an increase due to the increased air velocity, the other a decrease due to the increased flow of metal. The average oxide content of the powder showed only a slight increase throughout the series, and it is probable that this is merely due to the increased quantity of fines, and therefore increased surface area. The difference in combined aluminium contents between the 30 and 90 lb./in.^{2} products was of the order of 0·75%.

3. *Protrusion of Inner Refractory Nozzle.*

(a) *Constant Factors:* metal orifice, $\frac{5}{32}$ in.; air annulus, $\frac{1}{16}$ in.; inclination of external sheath, zero; air pressure, 75 lb./in.^{2}; metal head, 9½ in.; metal temperature, 775° C.

Reference to Figs. 3 and 7 will make clear the implied meaning of the term "protrusion". It is an actual measurement of the length of the refractory nozzle which is not encased by the outer sheath, and obviously controls the point at which the compressed air impinges upon the metal stream.

The results obtained in the water spraying were considered originally to be rather anomalous, the minimal trough being particularly difficult to interpret. However, the results obtained in the aluminium atomization are similar in nature; the absence of the minimal trough might be due to some difference in nozzle design, or, more probably, either the position of the trough or its magnitude is sufficiently different from that of water for it not to be shown on the curve within the experimental range. In general, the fact that there is a definite maximum on the curve is not surprising if it is considered that protrusion has a two-fold effect:

> (i) As protrusion is increased, the direction of flow of the effluent air becomes more nearly collinear with that of the metal jet, and therefore the tractive component of the force acting on the metal becomes greater. (This is accompanied by an increase in the "focal length" of the metal cone.)
>
> (ii) As protrusion increases, the point of application of the compressed air becomes further removed from the point of initial emergence, and therefore the energy available for atomization must be reduced by a purely dissipative effect, which would mean a decrease in the force applied to the metal.

Unfortunately, the subject does not lend itself to more rigorous treatment, but it is quite conceivable that, at a certain value for protrusion, the loss due to dissipation more than compensates for the

PLATE XVII.

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FIG. 22.—Aluminium Powder, 60/72 Mesh. × 27.
FIG. 23.—Aluminium Powder, 170/200 Mesh. × 27.
FIG. 24.—Aluminium Powder. Elutriator fraction for tube 1 after 2 min. separation. × 75.
FIG. 25.—Aluminium Powder. Elutriator fraction for tube 1 after 40 min. separation. × 75.

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increased value of the component force, and if protrusion is increased further there must be a steady reduction in the magnitude of the tractive force and corresponding reduction in the rate of flow.

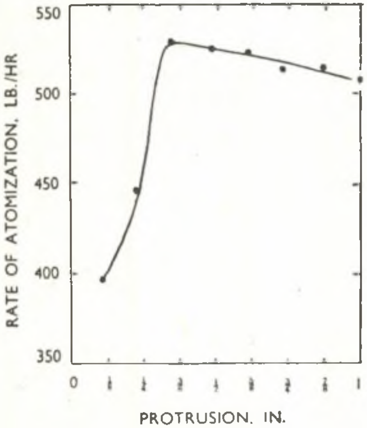

Fig. 11.

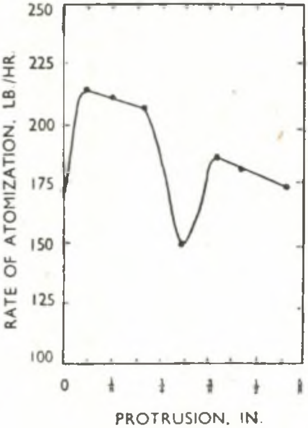

Fig. 12.

Fig. 11.—Effect of Protrusion on Rate of Atomization of Aluminium.
Fig. 12.—Effect of Protrusion on Rate of Atomization of Water.

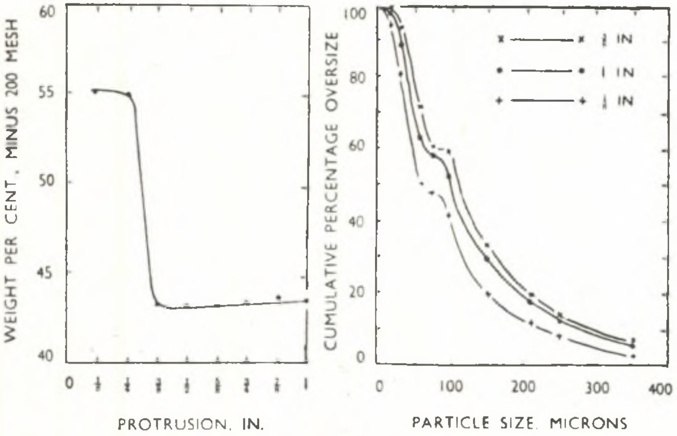

Fig. 13.—Effect of Protrusion on Size Distribution.

The curve shown in Fig. 13, relating protrusion and percentage of "fines", is interesting in that it is the direct reverse of that for protrusion and rate of production (Fig. 11). Thus the fines are at a maximum at low protrusions, fall rapidly to a minimum, and then rise gradually, as the protrusion increases, to a relatively high value. It is justifiable to assume that, except at high protrusions, where the dissipative effect will be marked, alteration in protrusion will have no great effect upon the actual atomization, and therefore changes in atomization efficiency will be conditioned almost solely by changes in rate of flow. (This, of course, is in agreement with the earlier statement on inter-relation of flow rate and efficiency of atomization.)

Difficulty of operation imposed a lower limit to the series, for, while zero protrusion was quite feasible when atomizing water, with aluminium it was found that even at $\frac{1}{8}$-in. protrusion operating conditions became difficult, owing to the effluent metal fouling the air annulus; and at zero protrusion atomization was quite impracticable. At the other end of the scale, operation was quite satisfactory even at the high protrusion of 1 in.

4. *Orifice Area.*

(a) *Constant Factors:* air annulus, $\frac{1}{16}$ in.; protrusion, $\frac{1}{4}$ in.; inclination of external sheath, zero; air pressure, 75 lb./in.^{2}; metal temperature, 775° C.

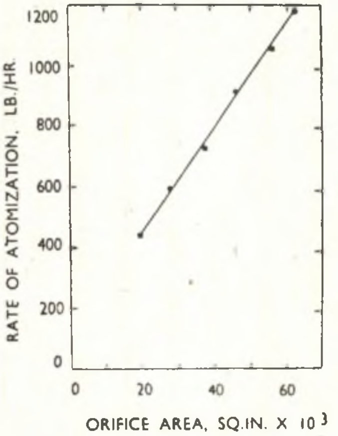

Fig. 14.

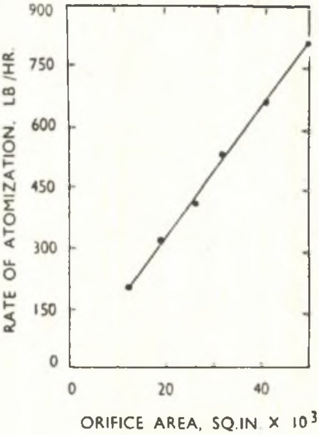

Fig. 15.

Fig. 14.—Effect of Orifice Area on Rate of Atomization of Aluminium.

Fig. 15.—Effect of Orifice Area on Rate of Atomization of Water.

The effect of alteration in area of metal orifice is quite clearly shown in the curves of Figs. 14 and 15, from which it is obvious that a marked linear relationship exists between rate of flow and area of orifice, for both water and aluminium. Only at very low diameters is it possible that any deviation exists, since at such diameters the effects of wall friction might become of sufficient importance to cause an appreciable alteration in the velocity of flow through the orifice. However justifiable this may be theoretically, in practice its effect is negligible. Since alteration in the orifice area does not in itself change the conditions of atomization, any variation in size distribution can only be considered as a secondary effect, i.e. as a consequence of the altered metal flow. Therefore, since there is a definite quantity of energy available for atomization, it is probable that the fineness of the product will decrease in a regular manner. Fig. 16 shows this to be true, and also that fineness actually changes linearly with orifice area.

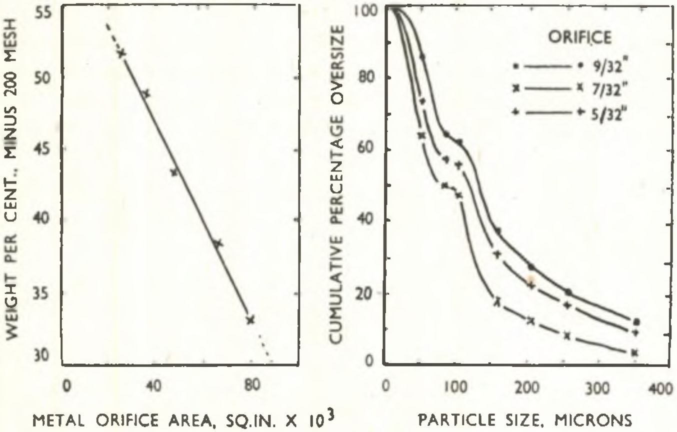

Fig. 16.—Effect of Metal Orifice on Size Distribution.

One operational characteristic which had not been noted previously was observed during this series, particularly at the higher end of the scale where rates of atomization were of the order of 1000 lb./hr. It is well known that metal particles will bond together quite strongly if pressure is applied to them, even at atmospheric temperature. It is, perhaps, not so fully appreciated that metal powders will sinter, or adhere together strongly, at elevated temperatures below their melting points, in the absence of any external applied pressure. An example of this particle cohesion under the influence of temperature was observed during the blowing tests conducted in this series. At high rates of atomization, large " growths " occurred in the pipe-line into which the powder was initially blown. These growths commenced some 6 ft. from the mouth and on the floor of the pipe-line, grew to the central axis of the pipe, and then increased in length towards the nozzle, frequently attaining a length of about 5 ft., with a diameter of 2 ft. at the base. In the earlier stages of formation, it is quite definite that the individual particles were not molten when they joined the mass, since the typically atomized form of each particle was retained in the final, coherent body, and yet the strength of the deposit was frequently great enough to resist manual disintegration. Such growths naturally had a serious effect on the accuracy of the results, and for this reason short running periods and frequent cleaning had to be resorted to during the tests at large orifice areas.

5. *Angular Inclination of External Sheath.*

(a) *Constant Factors :* metal orifice, $\frac{7}{32}$ in.; air annulus $\frac{1}{16}$ in.; protrusion, $\frac{1}{4}$ in.; air pressure, 75 lb./in.^{2}; metal temperature, 775° C.

This factor, which is purely one of nozzle design, has effects similar to, and is comparable with, one previously discussed, namely protrusion of the inner refractory nozzle. Obviously, any increase in the angular inclination of the external sheath inevitably means that the air stream is made to converge more rapidly, whereas increase in protrusion has a reverse effect, giving a greater degree of divergence. Owing to the turbulence existing in the region adjacent to the nozzle tip, it is not feasible to make any strict geometrical comparison between the two factors, but examination of Figs. 11 and 17 shows that the general

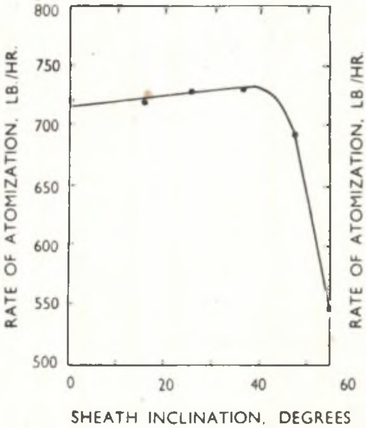

Fig. 17.

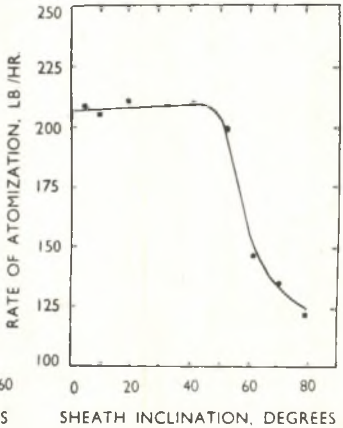

Fig. 18.

Fig. 17.—Effect of Sheath Inclination on Rate of Atomization of Aluminium.

Fig. 18.—Effect of Sheath Inclination on Rate of Atomization of Water.

relationship outlined above does exist, i.e. the graph relating rate of atomization and decreasing inclination of external sheath could almost be superimposed on that of rate of atomization and protrusion.

It is a rather surprising fact that the maximum point on both the curves (i.e. for aluminium and for water) occurs at approximately 45° sheath inclination; indeed, on consideration, it is strange that any maximum should occur at all. On purely theoretical grounds, it would be expected that the productive rate would show a continuous reduction in magnitude as the convergence of the air stream became more pronounced, since the horizontal, tractive component of the force exerted by the air on the metal would steadily decrease. The effect of altered sheath inclination upon size distribution was also rather unaccountable, for the only tendency which was observed, and that only to a very small degree, was towards a slight increase in fineness as inclination increased; but the differences were so small as to be almost within the limits of experimental error. It is feasible, however, that increase in the angle of impact of the air and metal streams will alter the actual atomization and probably render it less efficient. Such an effect would be offset by the decreased production, so that a balance might be effected between the two, giving very little change in the resultant size distribution. Operationally, high angles of inclination were found to be unsatisfactory, giving a much more divergent spray and aggravated " side-splashing ".

6. *Metal Temperature.*

(a) *Constant Factors:* metal orifice, $\frac{5}{32}$ in.; air annulus, $\frac{1}{16}$ in.; protrusion, $\frac{1}{4}$ in.; sheath inclination, $\frac{1}{4}$ in.; air pressure, 75 lb./in.^{2}.

The variable factors investigated previously have exerted what might be termed an external effect on the process, but this represents something quite different, in that the resistance of the metal to atomization must inevitably be altered by any changes in temperature. The metal property which exerts most control over the process will obviously be surface tension, with viscosity as a factor of secondary importance. By comparison with normal liquids, it may be assumed that, for liquid metals over short ranges of temperature, both surface tension and viscosity are inversely proportional to temperature, and therefore the resistance to disruption must also decrease with increased temperature. Fig. 19 shows, however, that the exact reverse of this occurs, and that there is a steady reduction in rate of production as the temperature of the metal is increased. The explanation of this apparent anomaly is not difficult to find. The process of atomization, as carried out with this type of nozzle, is not characterized by the weight of metal flowing through the orifice, but by the volume, a characteristic which is readily affected by alterations in temperature. From this, it will be appreciated that, as the temperature of the metal is increased, the actual volume of metal passing the orifice will not be changed (this ignores viscosity fluctuations), but the resultant mass will be considerably less than that obtained at lower temperatures. Since all rates of atomization are reported in units of mass, it is obvious that there will be a decrease in mass rate of atomization with temperature, a decrease which will be slightly modified by the simultaneous effect of temperature changes upon viscosity, but which should, nevertheless, be linear, since cubical expansion of the metal and viscosity are, respectively, direct and inverse linear functions of temperature. In the case of degree of atomization, the effects of temperature on surface tension become of considerable importance, since it is the magnitude of the forces of surface tension which primarily governs the size of the original liquid droplets, into which the mass of metal is disintegrated. Therefore, if the temperature of the metal is increased, the surface tension is decreased and the available energy can effect more complete breakdown of the stream, giving liquid droplets smaller in size than those obtained at lower temperatures. Further, the droplets are initially at a higher temperature and therefore pass through a greater thermal range before reaching room temperature; they consequently suffer a greater reduction in volume than corresponding " low-temperature "

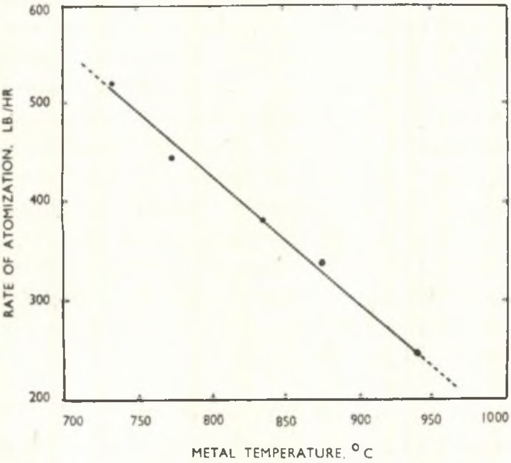

FIG. 19.—Effect of Metal Temperature on Rate of Atomization.

particles. As a result of these two factors, it is to be expected that the general fineness of the powder will increase throughout the series in a regular, probably linear, manner. The two factors which exert the most influence upon particle shape will be temperature at time of formation and time interval between formation and solidification. If the temperature of the metal is increased, the magnitude of the forces of surface tension will be less at the actual moment of drop formation, which would give a tendency to reduced sphericity. To compensate for this, however, there is the increased period during which the particles remain liquid, so that the slightly reduced forces have a longer time in which to affect particle shape. Examination of the powders produced throughout this series revealed no appreciable change in particle shape; the 2 : 1 major- to minor-axis ratio was maintained, even at the highest temperature.

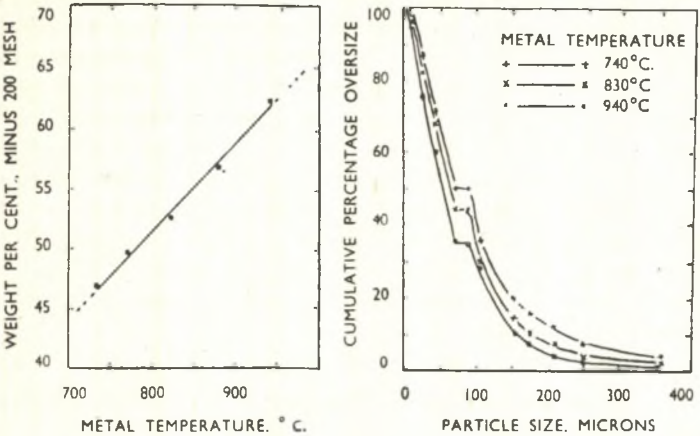

Fig. 20.—Effect of Metal Temperature on Size Distribution.

VI.—Discussion of Results.

Castleman [8] has attempted to give an analysis of the process of atomization (particularly as applied in internal-combustion engines), based on Rayleigh's work relating to the instability of liquid columns.[9] Although Castleman's derivations cannot be directly applied to this work, the general theory certainly can, since conditions are quite comparable in both cases. His major assumption, that, unless the air velocity is exceedingly high, atomization proceeds by a process of ligament formation, appears quite sound, and is in accordance with known facts. Thus the ultimate particles are not produced directly from the main body of liquid, but are formed as a result of the collapse of elongated ligaments torn from the main mass by the external air stream. The size of the ultimate particles is determined by the initial diameters of the ligaments, which for any given liquid are simply a function of the velocity of the surrounding atomizing medium, the diameter and life of any ligament decreasing with increased air speed.

In the atomization of aluminium, the rate of atomization is completely determined by the rate of flow of metal through the orifice. Since exhaustive mathematical treatment would be impracticable, the only operative forces will be considered to be the pressure of metal head in the crucible and the tractive force applied to the metal by the emergent compressed air. (Whether this tractive force is a resultant of several forces due to the compressed air or not has no material effect upon the analysis.) Superficially, it would appear that these two forces are distinct and in no way related, but this is not true. The curves shown in Fig. 5 indicate that, at any given pressure, the relationship between head and rate of atomization can be expressed by an equation of the type :

$$R = a\sqrt{H} + b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where R is the rate of atomization in lb./hr. ; H is the head, in inches ; and a and b are constants.

Similarly, at any given head, the rate of production is proportional to the square root of the air pressure, and the two factors are related by the general equation :

$$R = c\sqrt{P} + d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Thus, assuming the variables to be completely independent, combination of equations (1) and (2), to render them more broadly applicable, would yield an equation of the form :

$$R^2 = K.H.P + K_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This equation cannot be correct, however, since it demands that dR/dP increases with H, when actually the reverse is required (see Fig. 9). This is perhaps obvious when it is considered that the variables cannot be independent, since the magnitude of the tractive force due to the compressed air is determined by the velocity of the air relative to that of the metal and not by the simple air velocity.

Thus, the true equation must be of the type :

$$R = f\{H\} + (f\{P\} - f_1\{H\}) \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where (i) $f\{H\}$ is some function of head which accounts for the increase of R with H at fixed values of P (probably $f\{H\} = K\sqrt{H}$) ; (ii) $(f\{P\} - f_1\{H\})$ is a composite term involving functions of P and H so that the whole term allows for the decrease in magnitude of dR/dP as H increases, i.e. the whole term is essentially a function of the relative velocity of air to metal in the immediate vicinity of the nozzle tip.

Obviously it is possible to visualize a state where velocities are equal and the metal stream moves inside a cylindrical shell of air without any actual atomization occurring. Further, if the effluent velocity of the liquid is very high compared with that of the air, conditions are altered so that they become comparable with those which obtain during pressure atomization or the so-called " airless " injection.

It was appreciated at the outset that graphic presentation of size data offered several difficulties which would not be solved by the use of curves showing the effect of variation of a factor of process control upon the weight percentage of powder passing a 200-mesh sieve, but, nevertheless, its general value was considered to be sufficient to justify its use. In the case of increasing metal head at constant air pressure, it has been shown that the most important consequences are that the rate of metal flow is increased, and because of this the velocity of the air relative to the metal is decreased, both of which factors lead to increased particle size. This is shown in Fig. 6, and with reference to the cumulative oversize plot it is interesting to note that the characteristic distribution curve is not that of the usual skew-probability type, but exhibits two peaks, the major one occurring at approximately 30 microns and the other at approximately 120 microns (see Fig. 21). It is felt that this is an essential characteristic of the process and is due

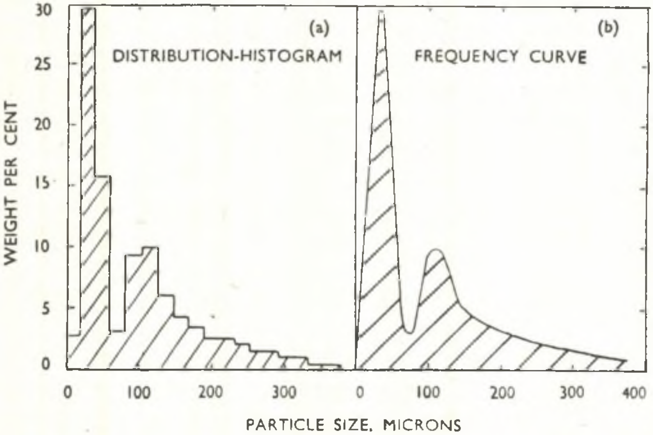

FIG. 21.—Nature of Size Distribution of Atomized Aluminium.

to the fact that the material distribution within the spray is not uniform, but is affected by the gravitational force exerted on the metal as it leaves the orifice. Thus, the metal stream is not truly concentric with the effluent compressed air, but is inclined towards the lower part of the surrounding cone, with the result that two separate sets of conditions operate simultaneously, and that the distribution curve shown in Fig. 21 (*b*) is actually the resultant of two curves. This is substantiated by the fact that powder resulting from atomization in a vertical plane (i.e. either upwards or downwards) where there is complete symmetry, usually exhibits a simple asymmetric or skew-probability distribution in the " as-blown " condition.

When considering the effects of alteration in air pressure upon the size grading of the product, it is necessary to remember that several processes operate simultaneously. When the air pressure is increased, there is an automatic increase in atomization efficiency, but there is also an increase in the quantity of material available for atomization; and these two factors, to a certain extent, oppose each other, the resultant effect depending upon their relative magnitudes and relative rates of change. It is conceivable that, above a certain pressure, the increased coarseness due to an increase in the quantity of metal flowing becomes greater than the refinement due to the increased air velocity. Such an explanation accounts for the maximum which occurs in Fig. 10 and the subsequent slight decrease in fineness at air pressures above 50 lb./in.^{2}.

The two factors, protrusion of inner nozzle and angular inclination of external sheath, investigated in Part V (sections 3 and 5), are rather similar in nature, as has been indicated earlier, and it is considered that the explanations developed in section 3 adequately account for what at first sight may appear to be anomalous results. Thus, as the protrusion is increased, the point of application of the compressed air to the metal stream is moved further from the point of emergence of the compressed air, so that its velocity, which has been shown to be the important factor, is considerably less than the original effluent velocity. The immediate result of such conditions would be a steady decrease in the rate of flow through the nozzle, but initially there is a strong compensatory factor, a consequence of nozzle design, in that a slight protrusion prevents the highly undesirable buffering action of the compressed air in the immediate vicinity of the nozzle tip, and aligns the flow of the air more completely with that of the metal stream. At a particular value for protrusion, the decrease due to the reduction in velocity becomes greater than the preventive action of the increased protrusion, and as the protrusion is increased beyond this figure so the rate of flow suffers a corresponding decrease. Since the effects of increased protrusion upon fineness are directly opposite to those relating to rate of atomization, it appears that, within the experimental limits, fineness of product is conditioned to a very considerable extent by changes in rate of flow brought about by increased protrusions (cf. Figs. 11 and 13). The results obtained for the series concerned with the inclination of the external sheath (this in effect means the inclination of the effluent air) do not lend themselves readily to interpretation, since there would not appear to be any factor capable of causing a sudden change in the rate of production as the value for sheath inclination reaches approximately 45°.

It was appreciated that the size of the orifice would exert considerable influence on the process, and it can be said that it is the most important controlling factor in the whole process, mainly because of the magnitude of the changes in rate of production and quality of powder brought about by any alteration in the diameter of the nozzle orifice. The flow of metal through the orifice is governed by two factors, the velocity of the metal and the cross-sectional area of the orifice, and although alteration in area must have some effect upon the frictional losses throughout the system, it is probably safe to assume that, within the limits of the working range, alterations in the area of the orifice have but little effect upon the mean velocity through the orifice. Theoretically, therefore, changes in area mean a corresponding and predictable change in the rate of flow or atomization. That such conditions are not completely attained in practice is indicated by the fact that the theoretical curve cannot be superimposed completely upon the curve obtained experimentally, but the discrepancies are only relatively slight. Further, since the conditions of atomization are not affected directly, apparent changes in efficiency of atomization will be due solely to variations in the quantity of metal available for atomization.

In addition to this obvious effect, there is an important connection between orifice area and efficiency of operation. It was stated earlier that throughout the tests air at atmospheric temperature was to be employed, and this proved quite satisfactory until attempts were made to operate with relatively small orifices of the order of $\frac{1}{8}$-in. diameter. At such low values, it was found that the rate of flow of metal was too small to counteract the abstraction of heat from the body of the nozzle by the air passing through the annulus, with the inevitable consequence that freezing at the nozzle tip became so frequent as to render continuous operation impracticable. This difficulty was solved by preheating the air prior to its entry into the nozzle, thus permitting smaller orifices to be employed, giving a considerable improvement in fineness. Isolated tests, combining the use of preheated air and small bores, have been performed, and powder passing more than 90% by weight through a 240-mesh sieve has been readily produced at a rate of approximately 1 cwt./hr.

In magnitude of effect, metal temperature is the variable next in importance to orifice area, and, like that factor, its effects are relatively straightforward and applicable over wide ranges of conditions. That is, no matter what combinations of nozzle design, metal head, air pressure, and metal orifice are used, it is highly probable that linear relationships will exist between temperature and rate of flow and quality of product because of the fundamental character of the relationships. With respect to rate of production, such conditions will also prevail for metal head, air pressure, and metal orifice, but the nature of the results of variation in the other factors (i.e. sheath inclination and protrusion) will be much more affected by alteration in the remaining controlling factors. Reverting to considerations of metal temperature, there must obviously be a lower limit of temperature for satisfactory operation, but this limit varies considerably with other conditions, particularly temperature and pressure of the atomizing medium. These conditions govern the rate of heat abstraction, and the area of the orifice, in conjunction with metal temperature, control the amount of heat given up to the body of the nozzle. With an orifice of $\frac{5}{32}$ in. dia. and air at 75 lb./in.^{2} at atmospheric temperature, the lower limit of operation was found to be about 720° C., at which temperature periodic freezing occurred, rendering the process intermittent in operation.

Although the data available are insufficient to allow the rate of atomization to be expressed as a specific function of the primary control variables (i.e. metal head, air pressure, metal orifice, and metal temperature), adequate information has been derived to allow a general relationship to be established. Thus, the relationship between rate of production and air pressure and metal head has been considered to be covered by equation (4) :

$$R = f\{H\} + (f\{P\} - f_1\{H\}) \quad . \quad . \quad . \quad . \quad (4)$$

Introducing the variables, area of metal orifice and metal temperature, into equation (4) gives the general equation :

$$R = \frac{K.A}{T}[f\{H\} + (f\{P\} - f_1\{H\})] \quad . \quad . \quad . \quad (5)$$

where R is the rate of metal flow; A is the cross-sectional area of metal orifice; T is the metal temperature, and is a variable of limited applicability (i.e becoming invalid at the minimum temperature for satisfactory atomization, and also at the boiling point of the metal); H is the metal head; and $(f\{P\} - f_1\{H\})$ is a composite term covering relative velocity of air to metal (see p. 124).

Although certain of the results lend themselves to more definite mathematical treatment (e.g. metal temperature and orifice), it would not be of any advantage to make equation (5) any more specific in application for these particular variables while factors such as protrusion and sheath inclination can be discussed only in very general terms.

VII.—CONCLUSIONS.

The process of atomization which has been described is highly suitable for the production of good-quality aluminium powder of either a coarse grade, such as 36/dust, or a relatively fine grade, such as 200/dust. The rate of atomization is not constant, but is governed by the size distribution required in the final product, and in this connection it has been found that, as a general rule, any increase in rate of flow is inevitably accompanied by a decrease in the fineness of the resultant powder. Nevertheless, the productive rate is high when compared with other processes, and although it is difficult to produce 200/dust powder at a rate of more than 1 cwt./hr., a rate of 6–7 cwt./hr. can readily be maintained on standard 36/dust powder. Operation can be brought to a high pitch of efficiency, ultimate losses being approximately 3% during the production of material passing 50–60% through a 200-mesh screen.

The powder produced by this process is of high quality. Oxidation of the powder is in no degree excessive, and for metallurgical (i.e. pressing and sintering) and explosive uses the powder has been found to be eminently satisfactory. Contamination by other materials during production is very limited; slight dissolution of iron is caused by using steel ladles for transmission to the blowing crucible, but this factor, were it to become serious, could be readily overcome. Particle shape is surprisingly uniform, the length of each particle being approximately twice as great as the other dimensions, and this " shape factor " is probably a general constant, typical of any specific metal powder produced by this process.

Control of the size characteristics of the product is achieved by alteration of several process variables, the most important of which are metal head, air pressure, metal temperature, and metal orifice. In summary, the effects of increasing these variables are :

(i) *Metal Head :* Slight increase in rate of atomization. Corresponding decrease in fineness of product.

(ii) *Air Pressure :* Steady increase in rate of production. Increase in fineness up to 50 lb./in.^{2}, thereafter a slight decrease.

(iii) *Metal Temperature :* Strongly marked linear decrease in rate of production (about 1 lb./hr./° C.). Corresponding linear increase in fineness.

(iv) *Area of Metal Orifice :* Linear increase in rate of production up to very high values (1200 lb./hr. at 0·079 in.^{2} area). Corresponding linear decrease in fineness.

In magnitude, the effects of none of the variables compare with those deriving from alteration in the area of the metal orifice. In practice, alteration in this factor is employed to effect the major adjustments in size distribution which are required, and other variables are only altered to bring about further slight modifications necessary to bring the material within specification. Subsidiary variables, such as protrusion of inner nozzle and inclination of external sheath, effect such relatively small changes that they are unsatisfactory as means of process control, but may conveniently be employed in certain particular circumstances.

ACKNOWLEDGEMENTS.

The investigation was carried out at the works of Durham Chemicals, Ltd., Birtley, and the Department of Metallurgy, King's College, Newcastle-upon-Tyne. The author is indebted to Professor C. E. Pearson of King's College for many valuable suggestions during the course of the study, and to the directors of Durham Chemicals, Ltd., for permission to publish the results.

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APPENDIX.

SIZE GRADING OF SUB-SIEVE-SIZE POWDER BY AIR ELUTRIATION.

The accurate classification of powders of sub-sieve sizes is a problem which has received attention from investigators in all the fields concerned with the handling and treatment of finely particulate matter. Although all the methods which can be applied must ultimately be dependent upon microscopic calibration, certain of the standard methods suffer through lack of reproducibility in results, which renders them unsuitable for either routine sizing tests or for more accurate research work. Most of the methods which can be applied to particles in the 1–100 micron range have been tried in connection with this work, and, of these, only air elutriation, which is not strictly dependent upon any fundamental law, was found to give satisfactorily reproducible results in a relatively short time.

The majority of the earlier methods employed for size determination belonged to that class now commonly referred to as "sedimentation methods", and are typically dependent upon Stokes' Law relating to the unhindered fall of solid particles in homogeneous fluids. The technique of elutriation is essentially the reverse of sedimentation, in that it depends upon the provision, in a fluid medium, of velocities greater than the ultimate free falling velocity of certain of the particles under the given conditions of test. Further, in elutriation, conditions are such that the fluid medium is in a state of considerable turbulence, which renders Stokes' Law inapplicable except as a very approximate basis for calculation.

The most interesting apparatus which have been developed of recent years are those due to Haultain [10] and Roller,[11] similar in both principle and design, and apparently efficient and accurate in operation. For the sizing of aluminium powder, preliminary tests indicated that air elutriation afforded a satisfactory method, and an apparatus was devised which, although similar to both the Haultain Infra-Sizer and the Roller Air-Analyser in design, differed from them in certain respects, and was, in general, simpler in operation. The elutriator consisted of four glass tubes, connected in series to a regulated supply of compressed air. The tubes increased progressively in size, and the effluent from the largest was led to a bag filtration unit. The air inlet, at the base of each tube, was designed so that maximum agitation of the powder was obtained. Extensive calibration tests showed conclusively that, even with this relatively simple apparatus, results reproducible to within ± 2% could be obtained within 40 min., with the additional advantage that the grades of powder are available, if required, for further physical or chemical examination. The efficiency of separation obtainable with the instrument can readily be appreciated from Figs. 24 and 25 (Plate XVII), which are comparative photomicrographs of fractions produced after different times of elutriation.

1115

THE SURFACE TENSION AND DENSITY OF LEAD–ANTIMONY AND CADMIUM–ANTIMONY ALLOYS.*

By H. T. GREENAWAY,† B.Met.E.

SYNOPSIS.

This paper describes the first part of a programme of research on several aspects of the surface tension of liquid metals and alloys, including the significance of this property in casting and soldering. The work of earlier investigators is briefly reviewed, and a description is given of the construction and checking of the maximum-bubble-pressure apparatus which was selected for use.

Using vacuum-distilled mercury and water as standard liquids, and values obtained by previous workers as a basis for comparison, the equipment and technique have been proved to give consistent and reliable results.

The surface tensions of molten cadmium–antimony and lead–antimony alloys have been determined; the curves of surface tension plotted against composition show a large fall for the cadmium–antimony system, which contains a solid intermetallic compound, but only a small fall for the lead–antimony system, in which no solid intermetallic compound occurs. This finding is in conformity with those of other investigators.

A simple, accurate method has been developed for measuring the densities of molten alloys, using a variation of the maximum-bubble-pressure method employed for the determination of surface tension.

I.—INTRODUCTION.

A GENERAL investigation of the measurement of the surface tensions of liquid metals and alloys has been undertaken because it is considered that the data obtained will have considerable practical and theoretical significance in certain metallurgical operations involving liquid metals and alloys. For example, surface tension is considered to be important in determining the ability of liquid metals and alloys to be cast into intricate shapes and small sections. Likewise, the spreading of solders is governed by a balance of interfacial tensions. On the theoretical side, the existence of intermetallic compounds in liquid alloys is likely to be revealed by an analysis of the relationship between composition and surface tension.

The work described in this paper was also undertaken to correlate the surface-tension–composition relationship in liquid alloy systems with the presence of intermetallic compounds in the solid systems.

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† An officer of Broken Hill Associated Smelters Pty., Ltd., on loan to the Council for Scientific and Industrial Research, Division of Industrial Chemistry, Melbourne, Australia.

Two metal systems were therefore chosen—one (cadmium–antimony) containing a solid intermetallic compound, and one (lead–antimony) containing no solid intermetallic compound—and their surface-tension–composition relationship established.

A comprehensive survey (up to 1935) of the methods employed by various investigators working on the surface tension of liquid metals and alloys is given by Bircumshaw [1] and will not be repeated in this paper.

Sugden [2] has shown that Macleod's [3] "constant" $\gamma^{\frac{1}{4}}/(D-d)$ (where γ is the surface tension in dynes/cm., D the density of the liquid, and d that of the vapour) is constant over large ranges of temperature for a large number of non-associated organic liquids, but increases with temperature for associated organic liquids. Bircumshaw,[1] assuming that Sugden's findings would apply to liquid metals, has shown that tin, lead, bismuth, cadmium, and antimony are all associated in the liquid state.

Matsuyama [4] observed changes of gradient in the curves of surface tension plotted against composition for the systems cadmium–antimony and zinc–antimony at the compositions of the solid intermetallic compounds known to exist in these alloy systems. The curves also showed a large fall from linearity. On the other hand, the curve for the lead–antimony alloy system (which contains no solid intermetallic compound) showed only a slight fall. From these results he concluded that an intermetallic compound existing in the solid phase does not decompose during melting, and exists as such in the liquid phase.

Sauerwald and Drath [5] obtained similar results in that the systems bismuth–tin and bismuth–lead, which contain no intermetallic compound, showed comparatively small falls in the curves of surface tension plotted against composition, while the systems copper–antimony and copper–tin, containing one or more intermetallic compounds, gave large falls. They found also that copper and cast-iron melts show a positive temperature coefficient of surface tension.

II.—APPARATUS AND GENERAL TECHNIQUE.

1. *Surface-Tension Determinations.*

The differential maximum-bubble-pressure method was chosen for use in the present investigation because of the formation of a fresh surface with each bubble, independence of angle of contact, and easy temperature control.

Fig. 1 shows the concentric tubes, the stand used to hold them vertically, and the means employed to melt the metal or alloy under test. The dimensions of the concentric tubes are given in Table I.

In the preliminary tests, both hydrogen and nitrogen were used. The commercial gases were deoxidized by passing through heated fine copper turnings and dried with calcium chloride and phosphorus pentoxide. The rate of flow of gas was adjusted to approximately 1 bubble per min. Pressures were measured on a 2 mm.-bore water manometer, a cathetometer reading to 0·001 cm. being used to obtain accurate values.

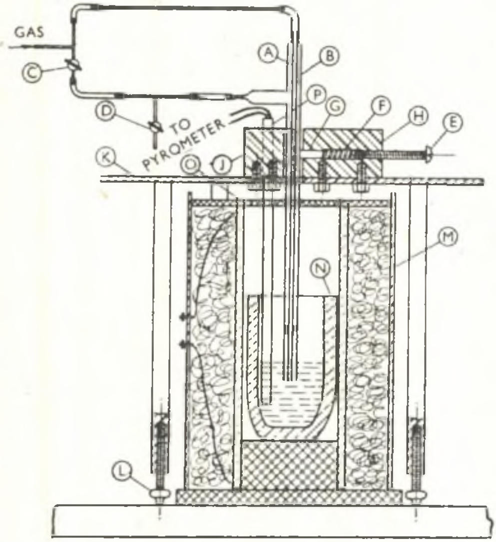

Fig. 1.—Surface-Tension Apparatus.

Key.

A. Inner tube.
B. Outer tube.
C and D. Cocks.
E. Stud.
F. Spring.
G. Plunger.
H. Mild-steel block.
J. Mild-steel block with V-groove to accommodate B.
K. Tripod stand.
L. Levelling screws.
M. Electric resistance furnace.
N. No. 2 Morgan Battersea crucible.
O. Asbestos cover.
P. Chromel–Alumel thermocouple.

The effect of various degrees of polish on the ends of the silica tubes was investigated, the following being used as final polishing media: (1) Oakey's No. 120 carborundum paper, (2) Oakey's No. 400 carborundum paper, and (3) $+5$ to $-15\,\mu$ aloxite abrasive on a wet polishing cloth.

The method employed to calculate surface tension from the observed maximum bubble pressures was the method of successive approximations developed by Sugden.[6] The calculations were based on the assumption that the bubbles blown in mercury leave the outer circumference of the tubes, which is a reasonable assumption since the tube material is not wetted by mercury. Confirmation of the correctness of the assumption is provided by the fact that calculations based on the internal diameters give decidedly low values. On the other hand, when bubbles are blown in a liquid which wets the tube material, the correct value of surface tension is obtained only by calculations based on the inner diameters. The fact that the bubbles form on the inner surfaces of the tubes can be confirmed visually in the case of water, which wets all the tube material used.

TABLE I.—*Diameters of Tubes Used in Surface-Tension Determinations.*

	Silica Tubes.		Glass Tubes.	Stainless-Steel Tubes.
	Set 1.	Set 2.		
	Dia., mm.	Dia., mm.	Dia., mm.	Dia., mm.
Outer tube (external dia.) .	10·93 ±0·05	10·244 ±0·008	7·690 ±0·001	9·597 ±0·015
Outer tube (internal dia.) .	6·73 ±0·01	6·02 ±0·02	5·895 ±0·006	8·084 ±0·070
Inner tube (external dia.) .	2·69 ±0·03	2·702 ±0·007	2·169 ±0·013	2·193 ±0·003
Inner tube (internal dia.) .	1·76 ±0·01	...	1·172 ±0·003	1·479 ±0·001

In order to check the reliability of the apparatus, the surface tensions of distilled water and vacuum-distilled mercury were determined. Table II gives the results obtained.

The accepted value for the surface tension of water at 20° C. is 72·8 dynes/cm., with which the average values obtained (73·4 with silica tubes and 72·8 with glass tubes) agree quite well. The average values for the surface tension of mercury obtained with the three types of tubes agree within 1%, averaging 507 dynes/cm. for both nitrogen and hydrogen. Other investigators who have used the maximum-bubble-pressure method have reported values for mercury ranging from 465 to 502 dynes/cm. The values obtained in the present investigation are higher than this range, but are of the same order. It can therefore be concluded that the apparatus and technique are satisfactory.

The silica tubes ground on No. 120 polishing paper are seen to give irregular high values for the surface tension of mercury, while

TABLE II.—*Surface-Tension Determinations on Mercury and Water at Room Temperature* (20° C.).

Liquid.	Tube Material.	Atmosphere.	Abrasive Used in Final Preparation of Ends of Tubes.	Surface Tension, dynes/cm.
Mercury	Silica (Set 1)	Nitrogen	Oakey's No. 120 paper	562 557 573 Aver. 564
Mercury	Silica (Set 1)	Nitrogen	Oakey's No. 400 paper	510 504 506 512 Aver. 508
Mercury	Silica (Set 2)	Nitrogen	+5 to −15 μ aloxite on wet polishing cloth	510 509 510 511 511 Aver. 510
Mercury	Glass	Nitrogen	Oakey's No. 400 paper	513 505 507 Aver. 508
Mercury	Stainless steel	Nitrogen	Oakey's No. 400 paper	502 503 502 505 508 Aver. 504
Mercury	Stainless steel	Hydrogen	Oakey's No. 400 paper	507 500 504 513 Aver. 506
Water	Silica (Set 1)	Nitrogen	Oakey's No. 400 paper	73·6 73·9 73·5 74·0 72·7 72·2 Aver. 73·4
Water	Glass	Nitrogen	Oakey's No. 400 paper	73·1 73·2 71.9 72·4 73·3 Aver. 72·8

those polished with the two finer abrasives give consistent values of the order expected. These results vary somewhat from those obtained by Bircumshaw,[1] who found that silica tubes, when ground with No. 3 emery, gave values for mercury of the order expected, but when polished with " fine emery ", gave much higher values. Using glass tubes, he found that the fine-emery polish gave only slightly higher values than the No. 3-emery finish.

2. *Density Determinations.*

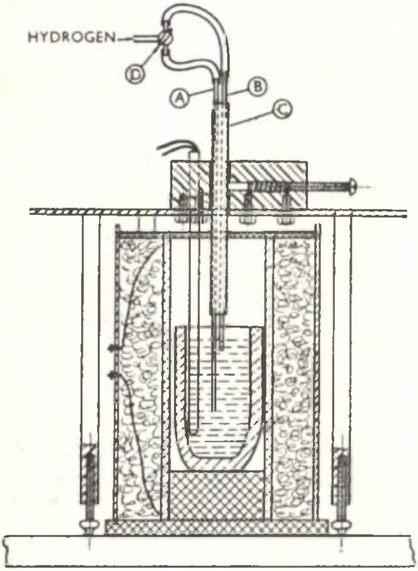

Fig. 2.—Density Apparatus.

Key.

A and B. Silica or stainless-steel tubes sealed into C.
C. Double-core silica rod adaptable to stand used for surface-tension determinations.
D. Two-way cock.

In determining surface tension by the maximum-bubble-pressure method, it is necessary to know the density of the molten metal under investigation. The apparatus shown in Fig. 2 was developed for this purpose. The protruding ends of the two tubes were arranged to be 4·5–5·0 cm. apart vertically, and the precise distance was measured by a travelling microscope. The tubes were obtained with identical lower-end diameters by taking a length of tube of 2·5–3·0 mm. external dia., cutting it in the desired position, and polishing the two mating surfaces flat and perpendicular to their axes.

The difference in the pressures required to detach bubbles from the two tubes in turn (measured as in surface-tension determinations) provides a measure of density, since the surface-tension effects cancel out.

The formula used was:

$$\text{Density of metal} = \frac{\text{Pressure difference (cm. water)} \times \text{Density of water at room temp.}}{\text{Vertical distance between the ends of tubes (cm.).}}$$

A small correction has to be made to the measured distance between the ends of the two tubes to allow for the thermal expansion of the tubes and for the increase in depth of immersion caused by the extra metal displaced from inside the deeper-immersed tube as compared with the second tube.

The apparatus was checked by determining the density of mercury at 20° C. The results obtained are given in Table III.

TABLE III.

Pressure Difference, cm. water.	Corrected Length Between Ends of Tubes, cm.	Density, g./c.c.
64·7	4·779	13·54
64·7	...	13·54
64·6	...	13·53

The accepted value for the density of mercury is 13·546 at 20° C., with which the observed values agree closely, proving the method is sound.

III.—EXPERIMENTAL PROCEDURE FOR CADMIUM–ANTIMONY AND LEAD–ANTIMONY ALLOYS.

1. *Liquidus Measurements.*

Various alloy compositions were chosen to obtain an accurate graph of surface tension plotted against composition, with particular attention to the vicinity of the intermetallic compound in the cadmium–antimony system. Cooling curves were determined on those alloys for which the liquidus temperatures were not accurately known, a portable potentiometer reading to 1° C. being used. Samples of approximately 1000 g. of each alloy were used.

2. *Density Measurements.*

The metal or alloy was melted, and the stand placed over the furnace and levelled. The ends of the tubes were gradually lowered into the metal, and the pressures required to detach bubbles from the two tubes in turn were measured. This was done for temperatures increasing in 10° C. intervals over a range of 100° C. from the liquidus, except for those cadmium–antimony alloys containing more than 50% antimony. These were found to attack stainless steel severely and silica slightly, and only two points were obtained for them near the liquidus, using silica tubes.

The density values thus obtained were plotted against temperature and the average values used in the surface-tension calculations.

3. *Surface-Tension Measurements.*

Surface-tension measurements were carried out over the ranges of temperature investigated in the density determinations. The values of Macleod's "constant" were calculated for each surface-tension determination.

(a) *Cadmium–Antimony System.*—Nitrogen was found to give inconsistent and high results for the surface tension of cadmium. Hydrogen gave consistent results agreeing closely with published figures of other investigators, and was therefore used throughout all tests on this system.

Uncovered cadmium drossed severely, but a thin layer of molten flux on the metal surface was found to prevent this trouble. Satisfactory fluxes were:

(i) 22% KCl, 78% $CdCl_2$, m.p. 383° C.
(ii) 41·5% KBr, 58·5% $CdBr_2$, m.p. 302° C.

These fluxes tended to become viscous and finally solid after a few hours (depending on the temperature). The addition of a small amount of ammonium chloride gave a flux which appeared to stay fluid for a longer time and which could be used satisfactorily for one test. Chemical tests failed to reveal any potassium in the metal.

(b) *Lead–Antimony System.*—This system gave more experimental difficulties in surface-tension determinations than the cadmium–antimony alloys because, when the temperature was within approximately 100° C. of the liquidus, the maximum bubble pressures were inconsistent, and this condition became progressively worse as the temperature decreased in this range. The trouble was particularly evident with the lower-antimony alloys (10 and 20% antimony). Values obtained in this doubtful range gave a marked positive gradient, although little reliance can be placed on these figures. The surface tension of a fresh sample of 10%-antimony alloy gave similar results using nitrogen. It is interesting to note that the parent metals gave much more consistent maximum bubble pressures at temperatures near their melting points than did their alloys. This has not been satisfactorily explained. Grosheim-Krisko[7] has shown that the viscosities of 0–12%-antimonial lead alloys are slightly less than that of lead, from which it would appear that the viscosity of the alloys has nothing to do with the trouble. Bircumshaw[1] reported that he encountered the same trouble with inconsistency of maximum bubble pressures when working with lead–tin alloys in the lower-temperature range (250°–350° C.), although he has been able to obtain results in this range.

The curve of surface tension plotted against composition was constructed, using values of the surface tensions at 140° C. above the liquidus temperature for each alloy. No flux was needed to prevent drossing.

IV.—RESULTS.

The experimental results are given in Tables IV–XI.

TABLE IV.—*Chemical Analysis of the Three Basis Metals.*

Metal.	Impurities, %.
Electrolytic Cadmium.	Zn 0·016, Pb 0·0115, Cu 0·001, Fe 0·002.
Star Antimony.	Pb 0·42, Cu 0·031, Ni 0·005 max., As 0·02 max., Fe 0·005 max.
B.H.A.S. Special Lead.	Ag 0·003, Cu 0·0014, Zn 0·018.

TABLE V.—*Composition–Liquidus Data for the Three Metals and Thirteen Alloys Used.*

Alloy No.	Composition.	Liquidus Temperature, ° C.
	Electrolytic cadmium	321°
	Star antimony	630°
	B.H.A.S. special lead	327°
1	18·8% Sb, 81·1% Cd †	343° *
2	29·5% Sb, 70·3% Cd †	379° *
3	40·4% Sb, 59·4% Cd †	432° *
4	48·7% Sb, 51·1% Cd †	452°
5	53·8% Sb, 45·9% Cd †	456°
6	59·0% Sb, 40·7% Cd †	445°
7	71·2% Sb, 28·5% Cd †	505° *
8	87·3% Sb, 12·3% Cd †	569° *
9	10·1% Sb, 89·9% Pb	260°
10	18·6% Sb, 81·1% Pb	313° *
11	38·5% Sb, 61·1% Pb	430° *
12	64·1% Sb, 35·8% Pb	522° *
13	79·7% Sb, 20·2% Pb	577° *

* Values obtained from cooling curves. The remainder were taken from Hansen, " Der Aufbau der Zweistofflegierungen ", Berlin : **1936**.

† Values obtained by difference.

The surface-tension–composition relationships and the phase diagrams of the two alloy systems, as obtained from the experimental results, are given in Fig. 3.

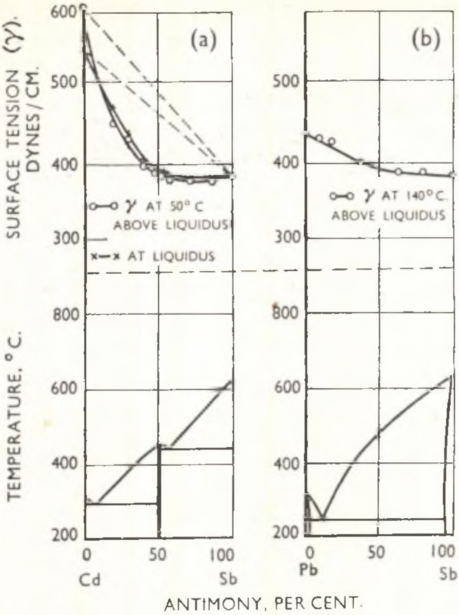

FIG. 3.—Surface-Tension–Composition Relations and Phase Diagrams for:

(*a*) Cadmium – antimony alloys.

(*b*) Lead–antimony alloys.

TABLE VI.—*Surface-Tension Values Obtained for Cadmium, Lead, and Antimony.*

The values obtained by other investigators (using hydrogen) are given for comparison.

Temp., ° C.	Surface Tension, dynes/cm.						Temp., ° C.	Surface Tension, dynes/cm.	
	Cadmium.			Lead.				Antimony.	
	Author.	Bircumshaw.[1]	Hogness.[8]	Author.	Bircumshaw.[1]	Hogness.[8]		Author.	Bircumshaw.[1]
330°	564	570	...	...	...	...	635°	383	...
340°	577	...	606	448	...	...	640°	384	350
350°	584	583	...	449	453	442	650°	384	...
360°	596	...	...	446	...	...	675°	384	...
370°	608	592	616	444	...	...	700°	382	349
380°	606	...	617	443	...	...	725°	383	...
390°	604	...	...	442	...	...	750°	383	...
400°	609	597	...	443	446	438	775°	...	...
410°	600	...	...	442	...	...	800°	380	346
420°	598	...	622	442	...	...	...	...	...
430°	608	...	...	441	...	...	...	...	...
440°	606	...	...	439	...	...	...	...	...
450°	611	...	621	...	...	...	...	...	...
460°	608	...	...	...	...	...	...	...	...
470°	612	...	...	...	...	...	...	...	...
480°	607	...	...	...	...	...	...	...	...
490°	599	...	...	...	...	...	...	...	...
500°	600	591	619	...	...	...	...	...	...

Table VII.—*Density, Surface Tension, and Macleod's "Constant"* versus *Temperature Results for Cadmium and Alloys 1–4 Inclusive.*

Temp., ° C.	Cadmium.			Alloy 1.			Alloy 2.			Alloy 3.			Alloy 4.		
	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.
330°	...	564	0·608	...	...	...	...	...	...	...	...	...	...	...	...
340°	8·009	577	0·612	...	...	...	...	...	...	...	...	...	...	...	...
350°	...	584	0·614	7·677	471	0·607	...	...	...	...	...	...	...	...	...
360°	7·986	596	0·616	7·637	466	0·608	...	...	...	...	...	...	...	...	...
370°	...	608	0·623	7·592	463	0·612	...	...	...	...	...	...	...	...	...
380°	7·956	606	0·624	7·571	460	0·612	...	...	...	...	...	...	...	...	...
390°	...	604	0·624	7·529	458	0·616	7·387	440	0·619	...	...	...	...	...	...
400°	7·942	609	0·624	7·486	455	0·617	7·365	437	0·620	...	...	...	...	...	...
410°	...	600	0·625	7·443	450	0·619	7·345	436	0·622	...	...	...	...	...	...
420°	7·916	598	0·626	7·423	446	0·619	7·328	434	0·622	...	...	...	...	...	...
430°	...	608	0·627	7·417	442	0·620	7·305	433	0·624	...	...	...	...	...	...
440°	7·884	606	0·628	7·390	440	0·622	7·283	430	0·624	7·198	399	0·620	...	...	...
450°	...	611	0·630	...	...	...	7·271	428	0·625	7·180	398	0·622	...	...	...
460°	7·858	608	0·631	...	...	...	7·249	425	0·627	7·158	398	0·624	...	394	0·632
470°	...	612	0·632	...	...	...	7·223	...	...	7·133	397	0·625	...	391	0·633
480°	7·830	607	0·633	...	...	...	7·201	...	...	7·109	397	0·627	...	388	0·633
490°	...	599	0·633	...	...	...	7·180	...	...	7·074	395	0·630	6·987	386	0·635
500°	7·821	600	0·634	...	...	...	...	...	...	7·043	394	0·633	6·960	385	0·636
510°	...	...	...	...	...	...	...	...	...	7·010	394	0·635	6·944	385	0·638
520°	...	...	...	...	...	...	...	...	...	6·978	393	0·637	6·926	384	0·639
530°	...	...	...	...	...	...	...	...	...	6·946	393	0·640	6·911	383	0·642
540°	...	...	...	...	...	...	...	...	...	6·913	392	0·644	6·895	383	0·643
550°	...	...	...	...	...	...	...	...	...	...	...	...	6·863	382	0·645
560°	...	...	...	...	...	...	...	...	...	...	...	...	...	381	0·646

TABLE VIII.—*Density, Surface Tension, and Macleod's "Constant"* versus *Temperature Results for Alloys* 5–8 *Inclusive and Antimony.*

Temp., ° C.	Alloy 5.			Alloy 6.			Alloy 7.			Alloy 8.			Antimony.		
	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.
450°	...	...	...	6·806	383	0·651	...	...	...	...	...	...	...	...	...
460°	6·923	388	0·641	6·782	381	0·653	...	...	...	...	...	...	...	...	...
470°	6·901	386	0·642	6·756	380	0·655	...	...	...	...	...	...	...	...	...
480°	6·890	384	0·643	6·730	...	...	...	...	...	...	...	...	...	...	...
490°	6·866	383	0·645	6·713	...	...	...	...	...	...	...	...	...	...	...
500°	6·861	381	0·645	6·695	...	...	...	...	...	...	...	...	...	...	...
510°	6·850	...	...	...	...	...	6·694	381	0·662	...	...	...	...	...	...
520°	6·839	...	...	...	...	...	6·670	380	0·664	...	...	...	...	...	...
530°	...	...	...	...	...	...	6·653	...	...	...	...	...	...	...	...
570°	...	...	...	...	...	...	...	...	...	6·667	379	0·662	...	...	...
580°	...	...	...	...	...	...	...	...	...	6·661	378	0·662	...	...	...
635°	...	...	...	...	...	...	...	...	...	...	...	...	...	383	0·678
640°	...	...	...	...	...	...	...	...	...	...	...	...	...	384	0·678
650°	...	...	...	...	...	...	...	...	...	...	...	...	6·530	384	0·676
675°	...	...	...	...	...	...	...	...	...	...	...	...	6·518	384	0·679
700°	...	...	...	...	...	...	...	...	...	...	...	...	6·509	382	0·679
725°	...	...	...	...	...	...	...	...	...	...	...	...	6·498	383	0·681
750°	...	...	...	...	...	...	...	...	...	...	...	...	6·468	383	0·683
775°	...	...	...	...	...	...	...	...	...	...	...	...	6·458	...	...
800°	...	...	...	...	...	...	...	...	...	...	...	...	6·424	380	0·687

TABLE IX.—*Density, Surface Tension, and Macleod's "Constant"* versus *Temperature Results for Lead and Alloys* 9–11 *Inclusive.*

Temp., ° C.	Lead.			Alloy 9.				Alloy 10.			Alloy 11.		
	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.		Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.
					Nitrogen.	Hydrogen.							
320°	...	...	...	10·18	...	427 ?	...	...	...	...	...	...	...
330°	...	...	...	10·17	416 ?	427 ?	...	...	...	...	...	...	...
340°	10·57	448	0·436	10·16	417 ?	428 ?	...	...	...	...	...	...	...
350°	10·55	449	0·436	10·16	420 ?	429 ?	...	9·479	...	...	...	...	...
360°	10·54	446	0·437	10·15	430 ?	429 ?	...	9·464	...	...	...	...	...
370°	10·52	444	0·437	10·14	429 ?	432 ?	...	9·441	436	0·483	...	...	...
380°	10·52	443	0·437	10·12	430	432 ?	...	9·423	434	0·484	...	...	...
390°	10·51	442	0·437	10·11	430	437	0·452	9·406	433	0·485	...	...	...
400°	10·49	443	0·438	10·09	429	436	0·453	9·385	433	0·485	...	...	...
410°	10·46	442	0·438	10·07	429	435	0·453	9·365	432	0·486	...	...	...
420°	10·46	442	0·439	10·06	428	434	0·454	9·342	431	0·487	...	...	...
430°	10·43	441	0·439	10·05	427	433	0·454	9·324	430	0·487	...	...	...
440°	10·43	439	0·439	10·04	429	432	0·455	9·311	428	0·488	8·510	...	...
450°	...	...	...	10·02	427	431	...	9·287	427	0·489	8·504	...	...
460°	...	...	...	...	424	431	0·455	...	...	...	8·498	410	0·529
470°	...	...	...	...	424	430	0·455	...	...	...	8·493	409	0·530
480°	...	...	...	...	423	430	0·456	...	...	...	8·486	409	0·530
490°	...	...	...	...	421	429	0·456	...	...	...	8·480	408	0·531
500°	...	...	...	...	420	429	0·457	...	...	...	8·470	407	0·531
510°	...	...	...	...	...	...	...	...	...	...	8·467	405	0·531
520°	...	...	...	...	...	...	...	...	...	...	8·462	...	...

TABLE X.—*Density, Surface Tension, and Macleod's "Constant"* versus *Temperature Results for Alloys* 12–13 *Inclusive and Antimony.*

	Alloy 12.			Alloy 13.			Antimony.		
Temp., ° C.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.	Density (D), g./c.c.	Surface Tension (γ), dynes/cm.	Macleod's "Constant", $\gamma^{\frac{1}{4}}/D$.
540°	7·729	...	...	...	...	...	...	...	...
550°	7·721	...	...	...	...	...	...	...	...
560°	7·700	...	...	...	...	...	...	...	...
570°	7·670	392	0·580	...	...	...	...	...	...
580°	7·660	392	0·580	...	...	...	...	...	...
590°	7·643	392	0·581	...	395	0·647	...	...	...
600°	7·628	391	0·582	6·880	394	0·647	...	...	...
610°	...	389	0·583	6·875	393	0·647	...	...	...
620°	...	388	0·584	6·858	394	0·647	...	...	...
630°	...	386	0·584	6·851	391	0·647	...	...	...
640°	...	...	...	6·839	391	0·649	...	384	0·678
650°	...	...	...	6·825	389	0·650	6·530	384	0·678
660°	...	...	...	6·820	389	0·651	...	...	...
670°	...	...	...	6·820	389	0·651	6·518	384	0·679
680°	...	...	...	6·815	...	...	...	...	...
690°	...	...	...	6·813	...	...	...	...	...
700°	...	...	...	...	...	...	6·509	382	0·679
725°	...	...	...	...	...	...	6·498	383	0·681
750°	...	...	...	...	...	...	6·468	383	0·683
775°	...	...	...	...	...	...	6·458	...	...
800°	...	...	...	...	...	...	6·424	380	0·687

TABLE XI.—*Average Increase in Macleod's "Constant" for the Various Metals and Alloys Investigated.*

Metal or Alloy.	Temperature Range, ° C.	Average Increase in Macleod's "Constant" per ° C.
Cadmium	330°–390°	0·00040
Cadmium	390°–500°	0·000085
Alloy 1	350°–440°	0·00017
Alloy 2	390°–460°	0·00011
Alloy 3	440°–540°	0·00024
Alloy 4	460°–560°	0·00014
Antimony . . .	635°–800°	0·00006
Lead	340°–440°	0·00003
Alloy 9	390°–500°	0·000045
Alloy 10	370°–450°	0·000075
Alloy 11	460°–510°	0·00004
Alloy 12	570°–630°	0·000075
Alloy 13	590°–670°	0·00005

V.—DISCUSSION OF RESULTS AND CONCLUSIONS.

The surface tension of cadmium has been found to have a large positive temperature coefficient from its melting point upwards for 40° C., after which it becomes slightly negative. This is in agreement with other workers, including Bircumshaw[1] and Hogness.[8] The variation of values obtained by different investigators for cadmium and antimony is of the same order as that obtained for mercury.

Macleod's " constant " has been found to increase for all the liquids investigated. If the constancy of this relation is accepted as a criterion of an unassociated liquid, then it appears that all the metals and alloys investigated are associated to some extent in the liquid state for the temperature ranges investigated. It has also been shown that the increase in Macleod's " constant " is much larger for cadmium (330°–370° C.) and the cadmium–antimony alloys Nos. 1–4, than it is for lead, antimony, cadmium (370°–500° C.), and the lead–antimony alloys. The ranges of temperature investigated for the cadmium–antimony alloys Nos. 5–8 were not sufficiently large to obtain an accurate average increase in Macleod's " constant ", but the values which have been obtained indicate that these alloys give similar results to alloys Nos. 1–4. These results suggest that cadmium (350°–370° C.) and cadmium–antimony alloys are more highly associated than lead, antimony, cadmium (370°–500° C.), and lead–antimony alloys. The higher association of cadmium–antimony alloys could be due to the persistence of the intermetallic compound CdSb in the liquid state.

The curves of surface tension plotted against composition show a large fall for the cadmium–antimony system, which contains a solid intermetallic compound, but only a small fall for the lead–antimony system, in which no solid intermetallic compound occurs. From these results it may be concluded that the intermetallic compound (CdSb) existing in solid cadmium–antimony alloys up to the liquidus temperature does not decompose during melting.

The method developed for measuring the densities of molten metals and alloys was found to give reproducible results, the values obtained for mercury, lead, antimony, and cadmium being in close agreement with accepted values.

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AUTUMN LECTURE, 1947.

THE METALLURGICAL RESOURCES OF SCOTLAND.

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EIGHTEENTH AUTUMN LECTURE TO THE INSTITUTE OF METALS, DELIVERED 23 SEPTEMBER 1947.

Synopsis.

A survey is made of the ores, fluxes, fuels, and hydro-electric energy available, the favourable geographical location, climate, and existing plants. Also, and particularly, the technical and scientific heritage in metallurgy, as exemplified by the invention of the hot blast by Neilson, the steam hammer by Nasmyth, and the varied contributions to the problem of steel quality by McCance, prove great latent capacity.

The material resources, together with the metallurgical inheritance, and latent capacity can assure an interesting future, even during, and after, a possible transition from conventional heavy metallic construction with massive parts, to lighter, often fast-moving apparatus, of greater precision. But design, research, and development, and training in these, should be carried out on a very large scale, hitherto unapproached, to ensure progress, to discover talent, and to distribute and buffer employment. Such design and research and development establishments scattered over Scotland, with full-scale operated pilot plants, could absorb some of the power resources available, and perhaps be more in line with traditional Scottish methods and future requirements than the erection of a few standardized, gigantic metallurgical plants in or near the present industrial zone.

May I say at once how greatly I appreciate the honour you have conferred on me by inviting me to deliver the Autumn Lecture. It was not easy to select a suitable subject, and I trust the present title and subject matter are appropriate to this meeting. Perhaps you will decide during and after the lecture that I have not been strictly fair in my treatment of the subject: I felt the word " resources " gave me a chance to develop several themes to which I am particularly attached. For not only do I propose to discuss " resources " in the sense of " supplies "—prolific, as those described by Captain Cook in his first voyage when he opened up the Bay of Plenty, where " the anchor was let go in eleven fathoms, the seine nets were got out and marvellous hauls of fish were made, while the shore parties bought oysters, wild celery, lobsters, wood, and plenty of good water ", or scanty, perhaps,

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as in the passage of Victor Hugo's "Toilers of the Sea" in which the hero, supposedly entirely without resources, had wreckage for fire, water for power, wind for blast, a stone for an anvil, and his will alone for energy, yet successfully completed his task—but I propose to describe also the resource of some Scotsmen, particularly metallurgists, in their capability of meeting a situation or problem, rising to the occasion, and finding a solution. So, perhaps by considering the resources of this country, and the resource of its people, a picture may be obtained of the possibilities of the future.

I should like at this stage to acknowledge the help I have received from many friends, books, and periodicals; to list them all would almost double the length of this lecture.

The mineral deposits of Scotland were dealt with by Dr. Robertson in his lecture to the Scottish Local Section of the Institute in 1945. Most of my comments are taken from Dr. Robertson's paper. He concluded that, on the whole, the Scottish output and resources of most of the common economic minerals are low. Lead and zinc ores have been worked profitably, and although not worked at present, there is a possibility of profitable deposits at greater depths. Copper and nickel occur in small amounts, but it seems doubtful whether exploitation will occur. The principal iron ore is a Scottish black-band. Clay-band has also been worked. The estimated resources of the black-band ores of Scotland are:

Proved	7,772,000 tons.
Probable	76,652,600 tons.
Possible	423,230,500 tons.

Mushet discovered this stone in 1801 when crossing the Calder in the parish of Old Monkeland. He quickly satisfied himself of its nature, iron content, and value. It was smelted at once at the Calder Iron Works and the Clyde Iron Works. But it was not extensively used until 1825 when, in addition, raw pit coal and hot blast were employed. Mushet considered the hot blast admirably adapted for smelting black-band iron-stone. The output per furnace increased from 60 to 90 tons per week, of which 10 tons were attributed to the use of pit coal and 20 tons to hot blast. There were then some 33 furnaces in the neighbourhood of Glasgow smelting black-band. The bed of oolitic iron-stone in the south of the Isle of Rasay should also be mentioned.

Fluxes and refractory materials are more plentiful. Limestones have been extensively worked; there are immense quantities of high-grade dolomite in the North-West Highlands. There are also large and very valuable resources of fire-clays. Silica in various forms and purities is available and may be potentially very valuable. The fineness of the sea sand is remarkable; consider the sands of Iona trodden by St. Columba.

Turning next to sources of energy, Scotland possesses immense coal reserves, estimated at 21,000 million tons. The majority of the coals are bituminous: but there are first-class steam coals, bunker coals, house coals, gas and cooking coals, and anthracitic types. Quantity, quality, and variety are thus available for metallurgical purposes.

Dr. James Young of Glasgow obtained a patent in 1850 for the distillation of bituminous coals to obtain paraffin wax and oils. But Young turned from the coals to bituminous shales, and the successful results of his investigations led to the Scottish shale-oil industry. The Scottish shale-oil industry is the only one which has been developed on a large scale. The production of oil from shale is about 21 gal. per ton. Ordinarily, oil from an oil-field is cheaper, but the plants developed in Scotland for refining shale oil became examples for the oil-fields of the rest of the world.

The water-power resources of Scotland are now being developed by the North of Scotland Hydro-Electric Board. It is expected that the production of electricity will reach 400,000 kW. within the next three years and that this will increase as time goes on. This is a large output of power. Some 3000 million units per annum will be available for new industrial or agricultural purposes.

The foregoing brief review has indicated a country rich in fuels, electrical energy, and refractory materials, but poor in ores, except black-band iron-stone. The excellent geographical location, with its indented coast-line, on the fringe of the great western land mass, suggests the importation of ores, bringing them to the fuels and energy. This is, of course, occurring, and exemplary plants for iron and steel production, with manifold products, for aluminium production, and for the forming of many metals and alloys by a wide variety of processes, are in operation. Many of the plants will be visited by members.

Next, let us consider the resource which Scotsmen have applied to typical metallurgical problems. First, that of James Beaumont Neilson, who was born in Shettleston in 1792. He became foreman and then manager of the Glasgow Gas Company. In the course of his employment he made many improvements to the gas-generating plant and to the gas-consuming apparatus. Apparently, a Glasgow iron-master asked his advice whether it were possible to purify the air blown into the blast furnaces in the same way as coal gas is purified. The iron-master thought that the presence of sulphur in the atmospheric air caused the irregular working and poorer iron obtained during the summer months. Neilson, however, thought over the matter, and in a paper read in 1825 stated, correctly, that the cause was a want of oxygen during the summer months on account of the lower density of the air and also because of the greater moisture content in the air in the summer. His idea to deal with the latter was to pass the air through two long tunnels containing calcined lime and so dry the air. He did not actually test this idea. He was also asked advice from a friend about an iron furnace situated half a mile from the blowing engine, and which did not make as much iron as a furnace located nearer. It occurred to Neilson that if the air at the distant furnace were heated, and its volume increased, it might do more duty. Being an experimentalist, he at once tried the effect of heated air on the combustion of illuminating gas, and observed more perfect combustion, and that the illuminating power of the flame had increased. He repeated the experiment in a smith's fire, and noticed that the heat was more intense. He considered that a similar increase in the intensity of combustion, and in temperature, would occur if the same plan were applied on a much larger scale to the blast furnace. The iron-masters were not prepared to listen to his proposals because their own observations led them to believe that the colder the blast the better the quality of the iron made, and the larger the quantity. But as an early writer on the subject very properly stated " . . . this being the state of the practice, and this the state of the science, and known to men of skill in the iron trade, it occurred to Mr. Neilson, who was fortunately out of the trade, and consequently unencumbered with either its practices or its prejudices, that the power of the blast in igniting the materials would be greatly increased if in its passage to the tuyères it were heated to a very considerable temperature ". Neilson, in his experiments, had glimpsed the factor of intensity. He at length obtained permission from Mr. Charles MacIntosh and Mr. Colin Dunlop of the Clyde Iron Works to try out the effect of blowing the heated air into an iron furnace. The results soon showed that the idea was sound, and although the design and development of a successful stove proved difficult, success eventually followed. The difficulties were concerned with the design and operation of apparatus and not with the principle. The total coal consumption eventually fell from about 8 tons per ton of iron made with cold blast to 5 tons per ton of iron made with the blast heated to 150° C.

Neilson's invention thus resulted in a considerable saving of fuel, and in increased output. Both these factors are of great importance to metallurgists at the present time. It is permissible to speculate whether further development along the lines of Neilson's invention are possible to-day. I think so. A similar increase in the intensity of combustion may be obtained by removing the nitrogen ballast from the air supplied to furnaces, notably the blast furnace and the open-hearth steel furnace. The condition is that described by Neilson, namely, input of heat at a high temperature level. The application of such enriched airs, or oxygen, could prove very successful. Examples might be the production of ferro-alloys in small blast furnaces, and much more rapid melting in the steel furnaces. The application might also give rise to increased output from a given apparatus, and lower fuel consumption. The field of fuel economy in metallurgical works is to-day most important.

I would refer next to the invention of the steam hammer by Nasmyth. Time is inadequate to deal with the fascinating history of the family, whose coat of arms was a sword between two hammers with broken shafts and the motto " Non arte sed Marte ". James Nasmyth eventually proved himself a true smith despite the family coat of arms and motto. He was born in Edinburgh in 1808, and from the age of 15 onwards made excellent working models of steam engines which he sold, and used the proceeds to pay for admission to the lectures on Natural Philosophy and Chemistry delivered at the University of Edinburgh. He also made an engine for a steam coach, which worked successfully and was eventually employed to drive a small factory. He determined to work in a large engineering works, and decided that the factory of Henry Maudslay of London was the most desirable. He made, including the castings and forgings, a small steam engine which he took and showed Maudslay, who at once appointed him as his private mechanic. We obtain a glimpse of a true mechanical engineer, capable of using tools and of producing sound designs. He founded the Bridgwater Foundry in Manchester, where he invented the steam hammer.

The tools for working iron had not kept pace with the production of the metal, and although improvements had been made to tilt hammers, they were capable of working only small sections. Machine tools were being made in Nasmyth's factory to machine the engines of a large paddle steamer, and the problem arose of forging the large 30-in. dia. paddle shaft for the vessel. No forge-master was prepared to undertake this work, and the designer asked Nasmyth if he might dare to use cast iron. Nasmyth immediately considered the mechanics of the existing hammers, and then stated the problem to himself, which was that of lifting a block of iron sufficiently high, letting it fall on to the forging, and guiding it while it fell. He made a sketch immediately of a steam-lifted block to carry out the programme of operations he had conceived, and the steam hammer was invented. The paddle shaft, however, was not forged because screw propulsion was substituted in the vessel. No forge-master was prepared to order a hammer, particularly in view of the then prevailing depression, perhaps not realizing that a new tool, enabling new products to be made, might conceivably help to break the depression. The French iron-master, Schneider, of le Creusot, when on a visit to Nasmyth's works, in Nasmyth's absence was shown the sketches of the hammer, and on his return to France built a hammer on these principles. Nasmyth later, when on a visit to le Creusot, saw his invention at work there. On his return to England, a hammer was soon built. It worked successfully, as was expected, and full development followed.

The steam hammer was invented to meet a particular technical problem, the forming of a mass of metal into a desired shape. It involved a considerable knowledge of mechanics and an unusual capacity in mechanical design. Nasmyth's father was an exceptionally gifted artist and had a good knowledge of architecture and civil engineering. These factors may have led to the son's interest, and success, in design.

The design and manufacture of plant for forming metals and alloys is of the greatest importance in metallurgy. The behaviour of metals subjected to deformation, cold and hot, is a subject now fairly well understood; but much remains to be done to design the most efficient machines for carrying out forming operations on all sizes of material. Surely the mechanical skill employed in the design of ships, their parts, and their power plants can be applied to this problem? The hammer, the press, and the mill still offer many problems which await inspired and detailed design. Other forming processes, casting, welding, and compacting, present their problems, but these are preponderantly of a scientific nature.

May I now be permitted to pass to a problem of a very different type? I refer to the "quality" of steel. The question, as it then appeared, was stated in Glasgow on several occasions by Mushet over a century ago. May I quote his words? "At this day, assisted by a variety of facts, mechanical and philosophic, we yet remain in comparative ignorance of what constitutes the real difference in point of quality betwixt home-made iron and that imported from foreign markets" . . . "but if the matter is impartially investigated, there will be sufficient reason to comprehend that our knowledge and general progress in the iron trade are more applicable to quantity than quality. The successful exertions of individuals have increased the manufacture of cast and malleable iron beyond all precedent in this country."

Although the question has become modified during the century, it was constantly asked wherein lay the real difference between steels of the same general composition, made by different processes, at different works? These differences were revealed by their relative ductility, toughness, ability to case-harden, hardenability, &c.

Dissolved gases were considered a possible cause, and the gases evolved on heating steels were investigated for quantity and composition by very many workers, the late Dr. J. W. Donaldson among them. It was found that with increasing temperature of extraction the proportion of carbon monoxide increased. New techniques, such as adding tin and antimony, and the use of high-frequency heating permitted fusion, and a further increase in carbon monoxide was observed. The conclusion was then slowly reached that the carbon monoxide was a reaction gas, not a gas held in solution, and that it was generated by the reduction of iron and other oxides in the steel by the carbon present. These hot-extraction methods were thus not really methods for the determination of dissolved gas, but for the determination of oxide in steel. Progress was also made with wet-extraction methods, and a clearer picture was obtained of the quantity and composition of the solid oxides present. Inclusions in steel were also investigated by various methods, particularly metallographic, and the paper by McCance on " Inclusions in Steel " in 1918 focused attention on this aspect of the subject.

A further very important development was the attempt made by McCance shortly afterwards to apply the laws of physical chemistry to steel and steel-making processes. His theoretical treatment of the solubility of oxygen in molten iron broke new ground and was one of the starting points for a series of very fruitful researches and one can say a whole literature on this very important subject, which, while of absorbing theoretical interest, is now able to deal quantitatively with many of the actual operating aspects of steel production. The origin, type, and composition of inclusions or slags—" every impurity which enters into a metal from the melting vessel "—were now becoming more clear.

But, further, the original pattern of the inclusions in the ingot of steel as cast, its skeletal form, was also being brought out, together with the features of ingot segregation, by groups of investigators. Service has made important contributions in this field. It was demonstrated clearly that the dendrites growing inwardly into the mother liquor both push forward some slag inclusions and enmesh or " land-lock " others, so mapping out both a major ingot pattern and a minor interdendritic one in which a skin of inclusions surrounds the dendritic forms. The grosser heterogeneities of pipe, A- and V-segregates, and the sedimentary cone were also explained. These gross macro- and finer micro-patterns persist throughout the normal life of the steel. They are deformed and perhaps broken up by the working processes, but nevertheless they finally give rise to the texture or fibre of the finished product. The bold relief, or fineness, of this pattern has a great effect on the quality of the steel, particularly as measured by tests " with " or " across " the grain; in fact, many of the old differences of quality can now be adequately explained. The theory also indicates directions in which quality may be improved, and sets limits to the quality which may be expected from large masses of metal produced by present-day processes.

What lines of development may be expected in this field? Certainly a great improvement in the quality and uniformity of our products as knowledge now available is persistently applied to practice. Research work in progress on the effect of gases on quality has already given very important results and will doubtless give more. It may prove, however, that avoidance altogether of the ingot stage of metal making is the only method of avoiding grosser heterogeneities. The continuous solidification of a jet of molten metal may be the answer.

Light has thus been thrown on the old question of the quality of steel, mainly by groups of workers, investigators in quite different fields, although definite moves forward and indications of promising lines have been made by particularly gifted workers here and elsewhere. Rather than the individual inspiration to " heat the blast " or " lift the hammer by steam ", the teams, inspired by intellectual curiosity or pressure of urgent works problems, have together solved the problem. Here, as elsewhere, if the problem be compared with a forest, the greater the area cleared, the more numerous are the contacts with the remaining trees. This is perhaps in accordance with the nature of a complex problem, and to-day such problems seem to be the principal ones.

Trained scientists and technologists are more than ever necessary for the solution of such problems. Scotland's share in the training of metallurgists is large, and its graduates have proved successful in all fields. If I might be permitted, I would suggest that somewhere instruction, and facilities for research, in technical electrometallurgical processes and metallurgical engineering be provided, particularly in view of the hydro-electric developments to which I have referred. It would be particularly appropriate there, for the students would see at first hand the importance of electrometallurgical processes.

Do these sketches I have attempted to make of the material resources, location, heritage, emergence of gifted men, and flow of metallurgists enable us to suggest a line, or lines, or development? I think they do. It is possible that a gradual transition is occurring in our large-scale employment of metals and alloys as constructional materials. Reasons of economy alone compel us to construct as lightly as possible;

with lighter and smaller power units the majority of transport will tend to decrease in size and become faster in movement. Perhaps the day of the great ship and the heavy train is passing. During such a period, design, research, and development should be extremely active if a position in the van of progress is to be maintained. The numbers engaged on these problems should be increased. With every increase in numbers, there is a greater possibility of discovering first-class talent.

Several problems awaiting solution have already been indicated, and there remains the great problem of the gasification of coal underground. This surely is one requiring knowledge of many branches of physics, chemistry, and engineering. Much of the data required for the solution is already known. Much more could be obtained by team work. The large-scale experimental work would demand first-class engineers and chemists. With the will and the investigators, the problem cannot be regarded as without prospects of solution.

The trend seems, therefore, towards a very large-scale expansion of research and development, directed towards the main problems of fuel supply and economy, metal extraction, forming processes, and the application of metals and alloys.

Superb locations are available in Scotland for such establishments, and ample power to operate large trial plants is becoming available. Some of the establishments could be located in development areas, and others in the Highland centres. They would absorb man-power, act as foci for instruction, and complement other schemes for a wider dispersal of flexible activities throughout Scotland. Such schemes, or modifications of them, might be more capable of rapid realization, and of greater value to our economy, than the erection of a few giant metallurgical plants in or near the present industrial zone.

METALLURGICAL ABSTRACTS

AUTHOR INDEX TO ABSTRACTS

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 15 NOVEMBER 1947 Part 3

I.—PROPERTIES OF METALS

[**Discussion on E. V. Potter and H. C. Lukens's Paper :**] **"Solubility of Hydrogen in Electrolytic Manganese and Transition Points in Electrolytic Manganese."** —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 37–40).—Cf. *Met. Abs.*, 1947, **14**, 1. *W. R. Ham* and *C. H. Samans* discuss the transition points in manganese. They point out that iron, nickel, and cobalt when present as oxides in glasses undergo transitions, the temp. of which follow series laws of the type $T_n = c(1/3^2 - 1/n^2)$. Measurements of hydrogen diffusion indicate transition temp. of the same type. These may be due to electronic shifts in the atoms, and H. and S. suggest that series transitions of this type may be present in solid manganese, and may be responsible for the discrepancies between the results of different investigators for some of the transition temp. Changes of this kind may be distinct from phase changes. In reply to *M. B. Bever*, P. and L. state that they found fused quartz preferable to alundum crucibles for melting manganese. *F. T. Worrell* shows a photograph of twins in a copper–manganese alloy, and suggests that γ-manganese may be face-centred cubic and not face-centred tetragonal; the latter may be due to strains in quenching.—W. H.-R.

Discussion on [**R. M. Parke and J. L. Ham's Paper :**] **"The Melting of Molybdenum in the Vacuum Arc."** —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 11–14).—Cf. *Met. Abs.*, 1947, **14**, 2. *W. J. Kroll* and *A. W. Schlechten* refer to earlier papers on melting in the vacuum arc. They emphasize the difficulties likely to arise from vaporization of metal, and from gas discharge from residual gas in the metal. They found difficulty in maintaining a steady A.C. arc, and were forced to use D.C.; it might be possible to superimpose D.C. on A.C. P. and H. in reply state that vaporization difficulties were not encountered with molybdenum, but might be expected with relatively volatile metals such as chromium or manganese. So long as a sufficient c.d. was maintained, they found the A.C. arc very steady. In reply to *G. F. Comstock* and *R. S. Dean*, P. and H. state that with new types of vacuum pumps, the required degree of evacuation could be obtained.
—W. H.-R.

Viscosity of Molten Aluminium and Its Alloys. (Akimow). See p. 99.

***Copper Oxidation Study Using Radio-Active Cu Tracer.** J. Bardeen, W. H. Brattain, and W. Shockley (*Bell Teleph. System, Tech. Publ.*, 1946, Monograph **B-1425**).—Reprinted from *J. Chem. Physics*, 1946, **14**, (12), 714–721; see *Met. Abs.*, 1947, **14**, 305.—J. L. T.

***Linear Casting Shrinkage of Gold and Its Alloys.** (Hollenback). See p. 104.

[**Discussion on E. A. Gulbransen and J. W. Hickman's Papers :**] **"Electron-Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Chromium, and Copper and Alloys at High Temperatures."** (——) See p. 102.

Recent Developments and Prospects for the Future Regarding the Resistance of Materials. Ch. Massonnet (*Rev. Univ. Mines*, 1947, [ix], **3**, (4), 118–126). —A review.—M. E.

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* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

The Failure of Metals by Fatigue. J. Neill Greenwood (*Metallurgia,* 1947, **35,** (210), 289–290).—A general introduction to a symposium on the " Failure of Metals by Fatigue " held under the auspices of the Faculty of Engineering, University of Melbourne.—J. L. T.

Theories of the Mechanism of Fatigue Failure. W. Boas (*Metallurgia,* 1947, **35,** (210), 290–291).—A summary of a paper presented at the symposium on the " Failure of Metals by Fatigue " held under the auspices of the Faculty of Engineering, University of Melbourne.—J. L. T.

Fatigue Problems Associated with Aircraft Materials. H. Sutton (*Metallurgia,* 1947, **35,** (210), 291–292).—A summary of a paper presented at the symposium on the " Failure of Metals by Fatigue " held under the auspices of the Faculty of Engineering, University of Melbourne.—J. L. T.

[Discussion on J. H. Hollomon's Paper :] The Mechanical Equation of State. —— (*Metals Technol.*, 1947, **14,** (4) ; *A.I.M.M.E. Tech. Publ.* No. **2187,** 9–11).—Cf. *Met. Abs.*, 1947, **14,** 4. *J. H. Palm* and *A. V. Wijngaarden* summarize their work (*Metalen,* 1946, (Dec.)) which leads to H.'s equation. *D. J. McAdam* emphasizes that softening of a metal after cold work can take place at temp. well below that of recrystallization. H. agrees, and considers that the concept of a mechanical equation of state does not preclude the possibility that the stress may be differently dependent on strain at different temp. or rates of strain.—W. H.-R.

***Surface States and Rectification at a Metal–Semi-Conductor Contact.** John Bardeen (*Phys. Rev.*, 1947, [ii], **71,** (10), 717–727).—Theoretical. The condition of affairs at the interface between a metal and a semi-conductor is discussed. The previous theory regarded impurity atoms as giving rise to new energy levels in the forbidden region between the filled and conduction bands of a semi-conductor. This view is extended to take into account localized states on the surface with energies in the forbidden region. A condition of no net charge on the surface may correspond to a partial filling of these states. If the density of surface levels is sufficiently high, there will be an appreciable double layer at the free surface of a semi-conductor formed from a net charge from electrons in surface states and a space charge of opposite sign, similar to that of a rectifying junction, extending into the semi-conductor. This double layer tends to make the work function independent of the height of the Fermi level in the interior which in turn depends on the impurity content. If contact is made with a metal, the difference in work function between metal and semi-conductor is compensated by surface-states charge rather than by a space charge as is ordinarily assumed, so that the space-charge layer is independent of the metal. Rectification characteristics are then independent of the metal. These ideas are used to discuss conflicting experimental data.
—W. H.-R.

***Contact Potential Difference in Silicon Crystal Rectifiers.** Walter E. Meyerhof (*Phys. Rev.*, 1947, [ii], **71,** (10), 727–735).—Cf. preceding abstract. The rectifying portion of a crystal rectifier is the contact between a small point of metal such as tungsten, and a semi-conductor such as silicon containing suitable impurities. The potential energy characteristics of such contacts are reviewed, and the usual theory described. The contact p.d. between *n* and *p* types of silicon and different metals were measured experimentally by a method (Stephens, Serin, and Meyerhof, *Phys. Rev.*, 1946, [ii], **69,** 42, 244 ; see *Met. Abs.*, 1946, **13,** 158) in which the zero voltage resistance of the contact is measured as a function of the temp. The contact p.d. values were practically independent of the kind of metal used, and of the structure of the silicon surface. The work-function differences between the same substances were obtained independently by a parallel-plate condenser (Kelvin) method, using surfaces prepared under various conditions as regards exposure to the atmosphere. The results showed no correlation between the contact p.d. and work-function-difference values. This is in contrast to accepted theory, and the reasons for this are discussed.—W. H.-R.

***The *K* X-Ray Absorption Edge of Silicon.** Vola P. Barton and George A. Lindsay (*Phys. Rev.*, 1947, [ii], **71**, (7), 406–408).

Erratum : The *K* X-Ray Absorption Edge of Silicon. Vola P. Barton and George A. Lindsay (*Phys. Rev.*, 1947, [ii], **71**, (10), 736–737).—A note making corrections to the authors' paper (see preceding reference).—W. H.-R.

***The Magnetic Quenching of Supraconductivity.** J. W. Stout (*Phys. Rev.*, 1947, [ii], **71**, (10), 741).—A note. Sienko and Ogg (*Phys. Rev.*, 1947, [ii], **71**, 319; see *Met. Abs.*, 1947, **14**, 310) suggested that for the " soft " supraconductors lead, mercury, tin, indium, thallium, CuS, Au_2Bi, zinc, and cadmium, the threshold magnetic field H_T for the destruction of supraconductivity is better represented by the expression $H_T = A(T_c^{3/2} - T^{3/2})$ than by the parabolic relation $H_T = B(T_c^2 - T^2)$. T_c is the temp. at which the metal becomes supraconducting in zero field. Systematic examination of the most accurate data shows that neither relation exactly fits the data, and that the parabolic relation is in all cases the better approximation.—W. H.-R.

For *A.S.T.M. Standards*, see pp. 124–129.

II.—PROPERTIES OF ALLOYS

Viscosity of Molten Aluminium and Its Alloys. G. Akimow (*Metal Progress*, 1946, **49**, (1), 99–100).—The viscosity of molten aluminium and of certain aluminium–silicon and aluminium–copper alloys has been investigated by Sergeiev and Polack by observations of the damping effects of the molten materials on the torsional oscillation of a steel ball suspended in the melt. The ball and pivot were protected by a refractory coating. Data obtained at 1290° F. (699° C.) for aluminium–silicon alloys and at 1255° F. (680° C.) for aluminium–copper alloys are summarized graphically, portions of the respective constitutional diagrams being reproduced for comparison. The viscosity in both cases increases sharply as the second component in the alloy first appears, and decreases considerably at eutectic composition. The discrepancy between these results and those of Sauerwald may be explained by the fact that S. measured the viscosity at temp. well above the liquidus. —P. R.

***Room-Temperature Tensile Properties of Aluminium Alloy Sheet Following Brief Elevated-Temperature Exposure.** J. T. Lapsley, A. E. Flanigan, W. F. Harper, and J. E. Dorn (*J. Aeronaut. Sci.*, 1947, **14**, (3), 148–154).—Naturally aged materials 24S-T, 24S-RT, and 61S-W may be exposed (without deformation) for 20 min. at temp. up to 500° F. (260 C.) with little or no loss in yield stress. The artificially aged materials 24S-T81, 24S-T84, 24S-T86, 61S-T, R301-T, and XB75S-T may be similarly exposed without loss in yield stress at temp. up to 400° F. (205° C.), but above 450° F. (233° C.) the loss becomes great. Deformations involved in hot forming may induce an acceleration of the elevated-temp. ageing process.—H. Pl.

[Discussion on A. E. Flanigan, L. F. Tedsen, and J. E. Dorn's Paper :] " Stress-Rupture and Creep Tests on [Alclad] Aluminium Alloy Sheet at Elevated Temperatures." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 7–8).—Cf. *Met. Abs.*, 1947, **14**, 5. In reply to *J. C. McDonald*, the authors state that elongations at fracture in short-time tensile tests tended to be greater than elongations at fracture in stress-to-rupture tests. In reply to *K. R. van Horn*, they say that extrapolation of short-time creep data would seem hazardous.—W. H.-R.

***Brittle Failure of Hogged-Out Fittings from 14S-T Billets.** Given Brewer and Herman C. Ihsen (*Metal Progress*, 1946, **49**, (3), 566–571).—An account is given of failure in a large aircraft fitting hogged-out from 14S-T billet for experimental purposes, parts actually put into service being normally drop forged. Failure at a very low tensile stress occurred in one of the lugs, and observations of stress distribution on a photo-elastic model showed a marked difference between the actual distribution and that assumed for ductile material. Tests of pieces of the same shape as the lug again showed an unexpectedly low breaking stress, while similar pieces in 24S-T showed satisfactory properties in tension and a higher shear strength than was predicted. Measurements of stress distribution by means of photo-grids suggested that standard testing methods did not satisfactorily discriminate between satisfactory and poor material. Tests were then carried out on tensile pieces with a central round hole, the results corresponding fairly with those suggested by the stress distribution. Similar tests on billets which were upset before drawing showed a considerable improvement in properties. It is concluded that (*a*) notch-sensitiveness can be satisfactorily detected by using holed test-pieces, (*b*) billets for hogging-out should be upset and drawn at forging temp. before being machined. It is noted that 14S-T in extruded or plate form does not show similar notch-sensitiveness.—P. R.

[Discussion on A. H. Geisler and F. Keller's Paper :] "Precipitation in Age-Hardened Aluminium Alloys." (——) See p. 102.

[Discussion on A. D. Smigelskas and E. O. Kirkendall's Paper :] "Zinc Diffusion in Alpha Brass." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 15–22).—Cf. *Met. Abs.*, 1947, **14**, 94. *R. Smoluchowski* regards S. and K.'s results as evidence for the existence of lattice defects and vacancies, and is surprised that the influence of vacancies is so large. *R. F. Mehl* discusses the bearing of the results on the general theory of diffusion. *C. S. Smith* suggests that the changes in composition resulting from diffusion set up strains on account of changes in lattice spacing. These strains may be relieved by the formation of cracks or fissures through which zinc may pass by vaporization, and this may account for an apparent diffusion of zinc greater than that of copper. *L. S. Darken* points out that in the formation of oxide scales, it has already been recognized that the mobilities of anion and cation are not equal. He also develops the activity theory of diffusion. *E. W. Palmer* raises the possibility of the results being affected by oxidation, and *M. R. Herman* states that results similar to those of S. and K. have been observed in the study of diffusion in α aluminium bronzes. E. O. K. replies to the discussion, and thinks it improbable that the results were affected by oxidation.—W. H.-R.

***Constitution of the System Indium–Tin.** F. N. Rhines, W. M. Urquhart, and H. R. Hoge (*Trans. Amer. Soc. Metals*, 1947, **39**, 694–711; discussion, 711–712).—The liquidus was determined from cooling curves and the solidus by observing the temp. at which a lightly loaded test specimen ruptured during slow heating. Metallographic observations were made on specimens cut with a razor blade, ground with 600 carborundum in soap solution on broadcloth, polished with alumina in soap solution on silk nap cloth, and etched in a solution of 6 g. K_2CrO_7 in H_2SO_4 20, saturated NaCl solution 12, HF 80, HNO_3 40, and water 300 c.c. In general, the diagram of Fink, Jette, Katz, and Schnettler (*Trans. Electrochem. Soc.*, 1939, **75**, 463; see *Met. Abs.*, 1939, **6**, 403) is confirmed, but it is considered that the γ-phase undergoes peritectoid decomposition below 80° C. and not peritectic decomposition at 124° C. The limits of the α- and δ-phase fields are relocated. Resistance to compression is a well defined maximum near the limit of solid solubility of indium in tin. —J. C. C.

[Discussion on E. A. Gulbransen and J. W. Hickman's Papers :] "Electron-Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Chromium, and Copper and Alloys at High Temperatures." (——) See p. 102.

[Discussion on R. S. Busk and E. G. Bobalek's Paper:] "Hydrogen in Magnesium Alloys." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 22–24).—Cf. *Met. Abs.*, 1947, **14**, 95. *L. A. Carapella* states that hydrogen could be removed more rapidly by vigorous mechanical stirring, or by vibration during high-frequency melting. In reply to questions, R. S. B. states that the role of hydrogen in magnesium alloys is that of aggravation of micro-shrinkage. As a void is formed on contraction of the solidifying liquid, hydrogen gas diffuses into the space, and so prevents more liquid from feeding the void. In reply to *L. C. Chang*, R. S. B. says that the solid solubility of hydrogen in magnesium is markedly affected by the presence of alloying elements, but no correlation with the Periodic Table could be found. *J. J. Naughton* raises the question of hydrogen embrittlement, and R. S. B. says that there was no evidence of hydrogen embrittlement of magnesium alloys.—W. H.-R.

[Discussion on J. P. Doan and G. Ansel's Paper :] "Some Effects of Zirconium on Extrusion Properties [and Constitution] of Magnesium-Base Alloys Containing Zinc." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 24–25).—Cf. *Met. Abs.*, 1947, **15**, 199. In reply to *P. Gordon*, A. states that little is known about the characteristics of the zirconium phase present in the magnesium-rich alloys. The improvement in properties is due chiefly to grain refinement. *A. R. Kaufmann* raises the question of extrusion speed, and A. states that the effect of variations in this factor could be ascribed largely to the temp. developed. In reply to *A. V. Lorch*, A. says that there was no apparent effect of zirconium on the corrosion of magnesium–zirconium, or magnesium–zinc–zirconium alloys.—W. H.-R.

Nickel and High-Nickel Alloys. Norman E. Woldman (*Materials and Methods*, 1946, **24**, (6), 1475–1490).—A " materials and methods manual ". A comprehensive summary is given of the properties of the commercially available forms of nickel and nickel alloys, with an account of preferred practices for heat-treating, welding, cleaning, finishing, and machining these materials.
—J. C. C.

Physical Metallurgy of Precious-Metal Alloys. (Wise). See p. 105.

Development of Silver Alloys with Specialized Physical Characteristics. (Shell). See p. 105.

Super Alloys for High-Temperature Service. H. A. Knight (*Mécanique*, 1946, **30**, (337), 218–220).—From *Materials and Methods*, 1946, **23**, (6); see *Met. Abs.*, 1947, **14**, 200.—W. G. A.

Magnetic and Electrical Materials. Robert S. Burpo, Jr. (*Materials and Methods*, 1947, **26**, (2), 115, 117).—Engineering File Facts No. 146.—J. L. T.

A Periodic Chart for Metallurgists. Carl A. Zapffe (*Trans. Amer. Soc. Metals*, 1947, **38**, 239–265; discussion, 265–270).—The elements are arranged on a schematic representation of the electron shells of the heaviest element. The elements of atomic weight 89 and upwards (including the four newly discovered elements 93–96) are arranged as a second series of rare earths. The use of the chart to illustrate certain principles of alloy formation is discussed. —J. C. C.

For *A.S.T.M. Standards*, see pp. 124–129.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

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

[Discussion on A. H. Geisler and F. Keller's Paper:] "Precipitation in Age-Hardened Aluminium Alloys." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 8–9).—Cf. *Met. Abs.*, 1947, **14**, 97. In reply to *J. H. Hollomon*, G. and K. state that quenching of alloys produces plastic deformation, so that slip bands are visible on a polished surface, and these may act as sites for localized precipitation in the early stages of ageing. The effect is not observed with slower rates of cooling. *A. S. Coffinberry* questions the use of the electron microscope for detecting localized precipitation, and G. replies that the ordinary light microscope will supply evidence of localized precipitation more readily than the electron microscope because a large area must be scanned. The electron microscope will resolve particles which are too small for the ordinary microscope.—W. H.-R.

[Discussion on E. A. Gulbransen and J. W. Hickman's Papers:] "Electron-Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Chromium, and Copper and Alloys at High Temperatures." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 25–37).—Cf. *Met. Abs.*, 1947, **14**, 98. *P. K. Koh* refers to the effect of thermal expansion on the measured lattice spacings, and, after replying, G. reproduces a graph showing the reduced lattice constants of the oxides in iron scale as a function of the oxygen content. *R. F. Mehl* discusses the orientation and rate of growth of films. In reply to *C. G. Goetzel*, G. describes and illustrates the electron-diffraction camera high-temp. furnace. *C. H. Samans* states that results for the oxidation of stellite in air at 900°–1100° C. did not agree with those obtained under the conditions used by G. and H., and reasons for this are discussed. *A. R. Bobrowsky* questions the sensitivity of the electron-diffraction methods for detecting small percentages of one oxide in the presence of another. In reply to *Roger Sutton*, G. states that most of the oxides used would not be expected to decompose at the temp. and pressures concerned. *H. S. Avery* refers to Fe_3O_4 and the spinels, and emphasizes that many spinel compositions are possible. G. and H. discuss this, and describe electron-microscopic observations of the growth of films. *M. L. Fuller* refers to the possibility of false values being obtained for lattice spacings owing to the accumulation of positive charge on the specimen, with a resulting deflection of the diffracted electron beams. G. and H. agree with this, but show that the effect could not be responsible for the relatively large lattice spacings which they obtained. Variations in the compositions of different specimens might account for the conflicting lattice spacings. *U. R. Evans* agrees that departure from stoichiometrical equivalence often occurs. He then describes experiments on the stripping of films from oxidized surfaces; these films were often wrinkled or curved, suggesting the presence of stresses which would affect the lattice spacings. *A. G. Quarrell* emphasizes that the relatively slight differences between the lattice spacings of different spinels limits the use of electron-diffraction methods for identifying substances in the film. He also discusses the protective mechanism.—W. H.-R.

[Discussion on C. S. Barrett and C. T. Haller's Paper:] "Twinning in Polycrystalline Magnesium [Alloys]." —— (*Metals Technol.*, 1947, **14**, (4); *A.I.M.M.E. Tech. Publ.* No. **2187**, 1–7).—Cf. *Met. Abs.*, 1947, **14**, 202. *R. L. Dietrich* summarizes previous work, and states that the deformation of polycrystalline magnesium alloys is not completely explained by work on single crystals. He agrees with B. and H. that {101} slip is active at room temp., and shows an example of a banded structure. *K. Jetter* illustrates banded structures produced by bending; these are outcrops of regions where localized as a result of re-orientation resulting from {102} twinning. Banded structures and other examples of localized deformation produced in rolling are illustrated and discussed. B. and H. consider that further evidence is needed before twinning is definitely established as responsible for these structures. *G. Ansel* enquires whether the decrease in tensile yield strength occurring in the roller-levelling process is the result of re-twinning of material twinned during roller-levelling, and B. and H. agree that this is probable. G. shows new pole figures for material subjected to compression.—W. H.-R.

***Some Special Metallographic Techniques for Magnesium Alloys.** P. F. George (*Trans. Amer. Soc. Metals,* 1947, **38**, 686–708; discussion, 708; and (summary) *Aluminum and Magnesium,* 1947, **3**, (5), 11–13, 24–25).—Special etching solutions are freshly made up from I, 5 g. of picric acid dissolved in ethanol to make 100 c.c.; II, glacial acetic acid; III, conc. nitric acid; IV, 48% hydrofluoric acid; and V, distilled water. A mixture of I 50, V 20, and II 20 parts by vol., used for exactly 15 sec., forms an amorphous film on the polished surface of magnesium–aluminium–zinc solid-solution alloys within a restricted range of compositions, and a mixture I 50, V 20, and II 16 forms a similar film on alloys within a rather more extended range. The films, when dry, develop cracks parallel to the trace of the basal plane in each grain. These etchants may be used for revealing changes in composition within grains, for showing diffusion during heat-treatment, for distinguishing between micro-shrinkage and fusion voids, and for estimating the temp. at which some alloys have been aged. A mixture of I 100, II 5, and III 3 slows diffusion of aluminium from an aluminium-clad base metal to a manganese-containing cladding metal. A mixture of equal vol. of I and V gives great contrast between Mg_2Si (brilliant blue) and the manganese constituent (dull grey). A mixture of IV 10 and V 90 darkens $Mg_{17}Al_{12}$ compound and leaves $Mg_3Al_2Zn_3$ unetched and white; and if the specimen is then immersed in a mixture of I 10 and V 90, the matrix is stained a golden colour and $Mg_3Al_2Zn_3$ remains white. This procedure ensures that the ternary compound is not overlooked. Grain boundaries in cast alloys and those wrought alloys which are usually hard to etch may be revealed with a mixture of I 100, V 10, and II 5, which also differentiates between grains of various orientations and is very sensitive in revealing distortion. Good contrast between the two types of precipitate found in the magnesium–aluminium and magnesium–aluminium–zinc alloys is given by an etchant containing I 100 and V 10.—J. C. C.

Visual Aids in Teaching Metallography. J. O. Lord (*Machinery Lloyd,* 1946, **18**, (2), 67–69).—The American Society for Testing Materials sponsored a programme of research and experimentation in the development of motion pictures dealing with some of the elementary concepts of physical metallurgy. L. supervised the production of a motion picture entitled "Metal Crystals", which required 40 min. showing. He describes the difficulties encountered and the technique adopted in the production of this film.—H. Pl.

Metallography, Fatigue of Metals, and Conventional Stress Analysis. H. G. Moore (*Metallurgia,* 1947, **35**, (210), 290).—A summary of a paper presented at the symposium on the "Failure of Metals by Fatigue" held under the auspices of the Faculty of Engineering, University of Melbourne, Australia.—J. L. T.

Fractography. —— (*Machinery Lloyd,* 1946, **18**, (4), 81).—"Fractography" is described as a new metallurgical technique for studying fractures in metals. Two main operations are carried out; first, an individual facet is selected for examination by the aid of a magnifying glass; second, the specimen is mounted between clamps at right angles to the axis of the microscope by means of a simple orienting mechanism. Neither polishing nor etching is performed, the actual plane of weakness being the only surface examined.—H. Pl.

The National Physical Laboratory [Use of Electron Microscope]. —— (*Machinery Lloyd*, 1946, **18**, (15), 82–83).—Reference is made to the use of the electron microscope in the metallurgical laboratory. By indirect methods, magnifications up to 10,000 dia. have been obtained which are superior in definition to those obtained in optical microscopes at a magnification of 1000 dia.—H. Pl.

Direct Determination of Stacking Disorder in Layer Structures. W. H. Zachariasen (*Phys. Rev.*, 1947, [ii], **71**, (10), 715–717).—Theoretical. Irregularities in the relative displacement of the layers parallel to their own planes occur in many crystals of the layer-structure type. This stacking disorder gives rise to characteristic features in the X-ray and electron-diffraction patterns of such crystals. A stack of N identical, parallel, and equi-distant layers is used as a simple model; irregularities in the relative displacements parallel to the plane of the layers correspond to stacking disorder. It is shown that X-ray diffraction data permit a direct determination of the Fourier coeff. of the functions which describe the stacking disorder.—W. H.-R.

For *A.S.T.M. Standards*, see pp. 126, 130.

IV.—DENTAL METALLURGY

The Use of Base-Metal Alloys in Casting. Paul Collins (*J. Dental Research*, 1946, **25**, (3), 158).—Summary of a paper presented to the International Association for Dental Research. The development of industrial casting practices based on the lost-wax method common in dentistry, and the extent of the application in industry, are described. The nature of the investment used for casting Vitallium-type alloys for supercharger buckets and other aircraft-engine parts are discussed. Practice and experience gained from dental casting practices were of value to the industrialist. In like manner it is expected that added information gained by industrial research during recent years will be of importance in the future improvement of design and soundness of quality dental structures.—Author.

Developments in Investments for the Casting of Gold Alloys and Base Metals. T. E. Moore (*J. Dental Research*, 1946, **25**, (3), 158).—Summary of a paper presented to the International Association for Dental Research. The composition and physical and chemical properties of the various investment types that are used in dentistry to make inlays and partial-denture castings of gold and base-metal alloys are discussed. The application of the dental investments and the lost-wax process to industrial use for casting critical war parts of high-m.p. chromium alloys is also described. New investments and processes that were developed and used during the war are reviewed.—Author.

***A Study of Investment Expansions Required for Gold Inlay Castings.** Claude Watts (*J. Dental Research*, 1946, **25**, (3), 160).—Summary of a paper presented to the International Association for Dental Research. This is a preliminary report giving the results of expansion tests on an investment material and includes data on thermal expansion, setting expansion, and hygroscopic expansion. A comparison of results obtained by two different methods of determining setting expansion is made. Consideration is given to the effect of the shape of the wax pattern on the investment expansion. Results of experimental tests on inlay castings are given, correlating such factors as type of inlay gold, total investment expansion, and fit of the casting.—Author.

***Linear Casting Shrinkage of Gold and Its Alloys.** George M. Hollenback (*J. Dental Research*, 1946, **25**, (3), 159).—Summary of a paper presented to the International Association for Dental Research. The linear casting shrinkage of gold was established as 1·65%±0·03%; previously, the accepted figure had been 1·25%. Alloying metals reduce the shrinkage considerably, but the reduction is not proportional to the percentage of the alloying metal; the effect of different metals should be investigated.—J. L. T.

***Effects of Variation in the Mercury : Alloy Ratio Upon the Amalgam Filling.** Ralph W. Phillips (*J. Dental Research*, 1946, **25**, (3), 183).—Summary of a paper presented to the International Association for Dental Research. The purpose of the investigation was to determine the importance of strict adherence to the recommended ratio of mercury and alloy in the manipulation of dental amalgam. Six alloys of varying grain-size were used and three different mercury : alloy ratios: (1) 15% less mercury than recommended, (2) recommended ratio, and (3) 15% more mercury than recommended. The percentage of residual mercury was determined in each case, and the physical properties tested.—J. L. T.

Physical Metallurgy of Precious-Metal Alloys. E. M. Wise (*J. Dental Research*, 1946, **25**, (3), 159).—Summary of a paper presented to the International Association for Dental Research. Discussion is given of the properties of the individual precious metals and the systems gold–silver–copper, palladium–silver–copper, as well as the more complicated alloys containing platinum and palladium derived from these systems, which are the basis for the alloys broadly employed in dentistry. Precious-metal alloys having higher m.p. are also described. Attention is given to some of the precipitation-hardening transformations and the melting behaviour of dental alloys. —AUTHOR.

***Effects of Heat-Treating [Silver-] Amalgam Alloy Ingots Before Cutting Into Filings.** K. W. Ray (*J. Dental Research*, 1946, **25**, (3), 159).—Summary of a paper presented to the International Association for Dental Research. Variation in heat-treatment of silver-amalgam alloy ingots before they are cut into filings can alter the properties of the amalgam made from the filings considerably if the alloy contains 70% silver; but in an alloy containing 68% silver the properties are not affected.—J. L. T.

Development of Silver Alloys with Specialized Physical Characteristics. John Shell (*J. Dental Research*, 1946, **25**, (3), 160).—Summary of a paper presented to the International Association for Dental Research. During the last ten years, numerous rather complicated and unusual alloys of silver have been employed for specific industrial uses. The requirements may vary from a high electrical conductivity to a high tensile strength. Silver as a basis for such alloys has been found to contribute remarkable properties not generally attainable by the use of any other metal.—AUTHOR.

V.—POWDER METALLURGY

The Use of Ultra-Fine [Copper] Particles in Powder Metallurgy. Henry H. Hausner (*Materials and Methods*, 1946, **24**, (1), 98–102; also (summary) *Metallurgia*, 1947, **35**, (210), 315–316; and *Mécanique*, 1946, **30**, (339), 283).—The use of a new type of fine copper powder, having an average dia. of 2 μ and more uniform than "-325 mesh" powder, is discussed. Used alone, it gives high densities with low compacting pressures. Mixtures with coarser copper, tin, or tungsten powders flow well and give the highest densities with high compacting pressures.—J. C. C.

Heavy Alloy. G. H. S. Price (*Indian Eng.*, 1947, **121**, (1), 42–43).—P. describes a "heavy alloy" developed by the General Electric Company, Ltd. It is a product of powder metallurgy containing 90% tungsten with nickel and copper. The alloy can be machined, punched, and drilled with ease, and has a tensile strength of 42 tons/in.^{2}, yield point of 38 tons/in.^{2}, compressive strength of over 130 tons/in.^{2}, and an elongation of 3%. The alloy, which is twice as heavy as steel, has a modulus of elasticity of 32 × 10^6 lb./in.^{2} and a Brinell hardness of 290. It has been used in aircraft for flight-control surfaces and crankshafts, as well as in gyroscopes and gyro-compasses. It is an ideal material for arcing contacts of oil-immersed heavy-current circuit breakers.—S. K. G.

Powdered Metal *vs.* Other High-Production Methods. Herbert Chase (*Materials and Methods,* 1946, **24**, (2), 363–369).—Powder-metallurgy products can be made in sizes up to about 8 in.^{2} in cross-sectional area and 3 in. high, with some limitations on shape, with little labour and negligible scrap loss to reasonable dimensional tolerances. Surfaces are smooth and it is possible to incorporate inserts. Comparisons are drawn with products formed by sand- or die-casting, stamping, or machining.—J. C. C.

Powder Metallurgy: The Key to High-Temperature Power Applications. —— (*Machinery Lloyd,* 1946, **18**, (4), 95).—A review of the research projects of the American Electro-Metal Corporation is given which includes (1) finding a combination of refractory metals and refractory ceramics which will resist high temp., (2) the combining of metals and plastics so as to lend the strength of the metals to the mixture, (3) the development of high-strength alloy-steel parts for quantity production through powder metallurgy. "Sinteel G" is one of the firm's products; this is a 100%-dense "bronze", produced by infiltrating molten copper into porous steel.—H. Pl.

Some Aspects of the Problem of Powder Metallurgy. A. Martigny (*Usine Nouvelle,* 1947, **3**, (34), 12; (35), 12).—A review of recent technical advances in the manufacture and usage of metallic powders.—J. L. T.

Extruding Powdered Metals to Form Synthetic Welding Wires. F. G. Daveler (*Machinery Lloyd,* 1946, **18**, (26), 86–89).—An alloy welding rod composed of drawn wire clad with alloying elements has been produced by powder-metallurgy methods. The production of this new-type wire has paved the way for development of a method of extruding powdered metals and compacting them around a wire, emphasis being placed on control of particle size and selection of a suitable lubricant.—H. Pl.

New Ceramic Combines Ceramic Materials and Powdered Metals. Henry H. Hausner (*Ceram. Ind.*, 1946, **47**, (4), 87–105; (5), 90–96).—A discussion of the procedures applied in powder metallurgy and ceramic practice. H. compares these processes and the materials employed in each field, and suggests that the way is open for new ceramic–metal products. A few examples, illustrated with photomicrographs of compound materials, are given.—J. S.

For *A.S.T.M. Standards,* see p. 130.

VI.—CORROSION AND RELATED PHENOMENA

Corrosion of Light Alloys. —— (*Metal Progress,* 1946, **49**, (5), 1028, 1030, 1032, 1034).—A summary of German work published in *Korrosion u. Metallschutz* and *Aluminium* in 1943 and 1944. Stress-corrosion of aluminium-rich aluminium–zinc–magnesium forging alloys containing over 5% zinc and magnesium together, has been found by German workers to depend on quenching temp. as well as on conditions after homogenization. The effect of reducing quenching temp. for cold-worked and quench-hardened alloys to just below solution temp. was observed under different conditions of exposure, cooling, and ageing. Stress-corrosion in specimens aged at room temp. and at high temp. improved at the expense of mechanical properties, but air-cooled specimens remained superior. Water-quenched and subsequently age-hardened samples showed increased sensitivity to stress-corrosion after annealing at 175°–265° F. (80°–130° C.); improved resistance was conferred by water-quenching from 715° F. (380° C.) and normalizing at 212° F. (100° C.), but this did not apply to specimens aged for long periods. Structural deterioration of aluminium and magnesium by corrosion, as described by W. Patterson, depends both on the nature of the phases present (i.e. on the p.d. between them) and on the arrangement of the phases in the structure; secondary constituents less "noble" than the matrix will be dissolved out, further penetration then depending on the properties of the matrix. If the latter is the less "noble", it will be attacked at the boundaries between phases, and graining and pitting will result. A 2-phase structure with a definite phase arrangement is regarded as an essential condition for corrosive deterioration in light alloys, the presence of certain phases usually indicating instability. Factors in "layer" corrosion, intercrystalline corrosion, and weld cracking are reviewed, the diminished weld cracking of magnesium–manganese–cerium alloys after additions of aluminium being associated with the form in which $CeMg_9$ and $CeAl_2$ respectively are deposited at the grain boundaries.—P. R.

Developments in Corrosion Studies and Corrosion Control. H. M. Olson (*Iron Steel Eng.*, 1946, **23**, (1), 80–95).—A review of American literature on corrosion (mainly water corrosion) and its prevention, covering the period 1935–45. A *bibliography* of 100 references is appended.—M. A. V.

Corrosion. M. G. Fontana (*Machinery Lloyd*, 1946, **18**, (14), 67–73; (17A), 37–41).—F. arbitrarily classifies corrosion into eight forms: (1) uniform attack, normally characterized by a chemical or electrochemical reaction; (2) pitting, very localized attack; (3) galvanic, which is not necessarily limited to direct contact of two dissimilar metals, but may occur in a system wherein a complete electric circuit exists; (4) dezincification, which can be checked for by the addition of certain alloying elements; (5) stress-corrosion, which is a function of stresses, temp., and concentration of corroding influence; "caustic embrittlement" and "season cracking" are examples; (6) erosion corrosion, which occurs frequently in pumps, valves, lines, centrifugals, &c.; (7) intergranular corrosion; and (8) concentration cell, which involves differences in environment, in contrast to the galvanic type. Mention is made of the work of the Corrosion Research Centre at the Ohio State University.
—H. Pl.

For *A.S.T.M. Standards*, see pp. 126, 130.

VII.—PROTECTION

(Other than by Electrodeposition.)

The Alumilite Process. R. H. Pettit (*Modern Metals*, 1947, **3**, (7), 16–18).—The uses of the Alumilite (sulphuric acid anodizing) process are described, but no details of operation are given.—N. B. V.

Anodic Treatment for Aluminium-Base Alloys. (Chromic Acid Process.) —— (*Aeronaut. Material Specification (S.A.E.)*, 1947, (**AMS 24,700**), 2 pp.).—A revised specification.

Developments in Tinplate Substitutes. —— (*Tin*, **1947**, (May), 22–23).—Although no electrolytic tinplate is as yet being manufactured in Great Britain, a large plant is in the course of erection in the works of Richard Thomas and Baldwin in South Wales. Other substitutes for tin, or hot-dipped tinplate, have not proved satisfactory.—J. S.

Actual State of Our Knowledge on the Brittleness of Galvanized Malleable Black-Heart Cast Iron. —— (*Fonderie*, 1947, (**13**), 487–495).—A review of the researches of W. R. Bean, H. Marshall, T. Kituka, and M. Leroyer. The cast iron is not brittle when its phosphorus content is less than 0·10%, or after heating for 30 hr. at 950° C. followed by 40 hr. at 670° C. and quenching in water.—M. E.

Flame Spraying. P. G. Clements (*Machinery Lloyd*, 1946, **18**, (14), 84–85; (21A), 53–55).—The Schori metal-powder pistol is used for spraying protective zinc and decorative bronze coatings. Usually zinc is sprayed to a thickness of 0·003 in. at the rate of 250 ft.^{2}/hr. The sprayed coating is less brittle and much thicker than the old galvanized coating.—H. Pl.

Protection by Means of Metallic Deposits. J. Kamecki (*Hutnik*, 1946, **13**, 70–82).—[In Polish]. Different methods of depositing tin and zinc on metals are discussed.—W. J. W.

Protective and Decorative Finishes. I.—Protective Chemical Methods and Pre-Treatment of Metals. R. E. Blakey (*Machinery Lloyd*, 1946, **18**, (13), 67–76).—Treatments of the simple inversion type for copper, copper alloys, aluminium alloys, zinc-base alloys, and magnesium alloys are described. Electrodeposited coatings and sources of corrosion troubles are dealt with. The M.B.V. process for aluminium alloys gives an excellent basis for paints, but the E.W. process produces a film which gives a higher degree of corrosion protection. Aluminium anodizing treatments, including the Bengough–Stuart and sulphuric acid processes, are also reviewed.—H. Pl.

Paint Research Station Investigates Raw Material. L. A. Jordan (*Board of Trade J.*, 1947, **153**, (2648), 1630–1631).—A brief survey of progress in the manufacture of paints, and their use in protecting metal surfaces from corrosion.—J. L. T.

Treatments for Metal Surfaces Prior to Painting. E. F. Hickson and W. C. Porter (*Product Eng.*, 1947, **18**, (8), 128–130).—A summary of standard practice in the treatment of metal surfaces, ferrous and non-ferrous.—H. V.

For *A.S.T.M. Standards*, see pp. 126, 128, 130.

VIII.—ELECTRODEPOSITION

***Measurement of Embrittlement During Chromium and Cadmium Electroplating and the Nature of Recovery of Plated Articles.** Carl A. Zapffe and M. Eleanor Haslem (*Trans. Amer. Soc. Metals*, 1947, **39**, 241–258; discussion, 258–260).—The hydrogen embrittlement produced in annealed and cold-drawn wires of AISI 440-C 17% chromium stainless-steel wire by chromium plating is, unexpectedly, much more severe than that produced by straight cathodic pickling at the same temp. and c.d. In cadmium plating also, in which only about 10% of the current is utilized in liberating hydrogen, the embrittlement is greater than that produced by cathodic pickling. Embrittlement was measured by a reverse-bend test. Chromium-plated specimens carrying a light deposit and cadmium-plated specimens recover ductility on heating at 100° C. In this operation, an initial recovery is followed by an "ageing relapse", when recovery is suspended (and a temporary increase in brittleness may occur) due to redistribution of hydrogen between core and coating. On further heating, recovery proceeds to finality. Heating in aqueous solutions appears to be considerably more effective in removing hydrogen than heating in oil or argon. With thick chromium deposits, only partial recovery can be effected by heating at 100° C. Even at 300° C. recovery is incomplete; and although the original bend values are obtained after heating at 400° C., the structure of the steel core and coating are affected.—J. C. C.

Chromium Plating of Cylinder Bores and Piston Rings. E. V. Paterson (*Machinery Lloyd*, 1946, **18**, (3), 67–70).—The Van der Horst method of porous chromium plating has considerably increased the life of cylinder liners. In the case of one medium-sized Diesel engine of 400/600 mm. bore with chromium-plated liners, wear averaged only 0·0002 in. per 1000 running hr. Porosity is obtained by a current-reversing treatment, and it is possible to obtain a 40%-porous surface. A minimum plating thickness of 0·0005 in. is recommended. Some good results have been secured by chromium-plating piston rings, but it is definitely not advantageous to employ chromium-plated rings with a chromium-plated bore.—H. Pl.

Hard Chromium Plate and Its Uses. J. M. Hosdowich (*Materials and Methods*, 1946, **24**, (4), 896–900; correspondence, (6), 1493–1494).—Uses of thick electrodeposits of chromium are listed.—J. C. C.

Chromium Plating, Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1947, (**AMS 2406**), 3 pp.).—Specifications for chromium plating on ferrous materials to increase abrasion resistance are given.—J. L. T.

***Determination of the Thickness of Chromium Deposits on Nickel by the Drop Test.** E. S. Spencer-Timms (*Galvano*, 1947, **16**, (127), 7–10).—Translated from *J. Electrodepositors' Tech. Soc.*, 1946, **21**, 79–90; see *Met. Abs.*, 1947, **14**, 112.—J. L. T.

Copper Plate as a Stop-Off When Nitriding. W. V. Sternberger and E. R. Fahy (*Metal Progess*, 1946, **50**, (4), 673).—Stress is laid on the importance of the type of copper deposit used as a mask in nitriding if the cycle is relatively long; the experience of C. J. Miller to the opposite effect was derived from a 65-hr. cycle only. The effect of sand blasting was to increase the depth of coating needed for protection rather than to improve the uniformity of plating.—P. R.

[Production of] Ultra-Thin Nickel Ribbons [for Use in Bolometers]. Frank G. Brockman (*Metal Progress*, 1946, **49**, (6), 1172).—Thin ribbons of nickel have been produced by electrodepositing nickel on copper foil from a nickel sulphate + ammonium chloride + boric acid bath, shearing the foil into ribbons of the required dimensions, attaching these to a frame of platinum wire, and dissolving the copper electrochemically in a cyanide bath. The ribbons, which may be only 0·1 μ thick, are used as sensitive filaments in bolometers (for the measurement of minute quantities of radiant heat, e.g. in astronomy and spectroscopy).—P. R.

Tin Plating. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 2408**), 2 pp.).

Has Electrolytic Tinplate Come to Stay in the U.S.A.? —— (*Tin*, **1947**, (Mar.), 20).—The development of the technique during the war of electrodepositing tin at high speeds and high c.d. resulted in the establishment in the U.S.A. of large plants for the manufacture of electro-tinplate. Constructed originally with an eye on a possible scarcity in tin, these plants to-day supply electrolytic tinplate to a widening market. While hot-dipped tinplate holds almost the whole market in Great Britain, in America the percentage of electrolytic to hot-dipped tinplate was 47% in 1946. A revised conservation order permitting a wider scope for electrolytic tinplate than before is another sign that it has come to stay in the U.S.A.—J. S.

Continuous Electro-Zinc Plating. —— (*Machinery Lloyd*, 1946, **18**, (3), 88).—Zinc can be deposited on continuous strips of steel up to 38 in. in width at a speed of 160 ft./min.—H. Pl.

Abstracts of Papers Presented at the 33rd Annual Convention of the A.E.S. —— (*Monthly Rev. Amer. Electroplaters' Soc.*, 1946, **33**, (7), 707–711, 745).—Abstracts of these papers are given: *William Blum*, "Wartime Activities on Plating at the National Bureau of Standards"; *Abner Brenner* and *Grace E. Riddell*, "Nickel Plating on Steel by Chemical Reduction"; *Abner Brenner* and *Walter A. Olson*, "Purification of Rhodium-Plating Baths"; *J. Edward Bemiller*, "Corronizing Wire Screen Cloth Using Radiant Heating"; *Theodore Voyda*, "X-Ray Diffraction Studies of Electrodeposits"; *Paul R. Cutter*, "Manodyzing and Dye-Colouring Magnesium Alloys"; *George Shore*, "Plating with Acid Copper Solution"; *A. W. Hothersall*, "Review of Developments in Electroplating in Great Britain During the War"; *C. J.*

Lewis, "Disposal of Plating-Room Waste Liquors in Compliance with Stream-Pollution Laws"; *Van M. Darsey*, "Effect of Surface Preparation on the Durability of Organic Coatings"; *F. L. Scott*, "Resins of the Vinyl Family in Metal Finishing"; *C. W. Smith*, "Examination of Electro-Cleaned Steel by the Electron-Diffraction Technique".—J. L. T.

Technical Advances in Electroplating. Allen G. Gray (*Steel*, 1946, **119**, (2), 102–104, 106, 108).—A summary of the proceedings of the 1946 Convention of the American Electroplaters' Society.—M. A. V.

Electroplating by Brush. —— (*Metal Finishing*, 1947, **45**, (9), 84).—Engineering data sheet.—J. L. T.

Precision Metal Parts Produced by Electroforming. H. R. Clauser (*Materials and Methods*, 1946, **24**, (1), 112–116).—Parts up to ½ in. thick are produced by electrodeposition of iron, copper, or nickel on a matrix made from either a bismuth–lead type of alloy of low m.p., a steel mandrel coated with a parting compound (of tin, cadmium, wax, or lacquer), or from a metal such as aluminium, zinc, or magnesium that can subsequently be dissolved. The products have an exceptionally high surface finish and can be made in intricate shapes to close dimensional tolerances ($\pm 0{\cdot}0002$ in.). Some applications are described.—J. C. C.

For *A.S.T.M. Standards*, see p. 130.

XI.—ANALYSIS

Distinguishing the Common Aluminium Alloys. Frank C. Bennett, Jr. (*Metal Progress*, 1946, **50**, (4), 659, 661).—Characteristic ingredients in certain light alloys can be detected, and in some cases the group of alloy identified, by simple chemical tests. Mn in 17S and 24S is detected by treatment with conc. HNO_3 and a little sodium bismuthate after the detection of Cu with NaOH, the excess NaOH being removed by gentle washing; a purple colour is produced, while the Mn-free 11S gives no colour. Alloy 3S, which does not contain Cu, is not blackened by NaOH but gives the purple coloration if Mn is present. Successive treatment with conc. HCl, 20% H_2SO_4, phenol in glacial acetic acid, and *s*-diphenylcarbazide under stated conditions produces a characteristic rose colour with 52S, 53S, and 61S.—P. R.

Rapid Method for the Determination of Total Platinum Metals. V. M. Mukhachev (*Zavod. Lab.*, 1946, **12**, (11/12), 927–929.—[In Russian]. A method is proposed for the separation of the Pt metals from a solution of a 3-mm.-dia. Cu wire.—N. A.

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

A New Portable Hardness Tester. —— (*Indust. Diamond Rev.*, 1947, [N.S.], **7**, (82), 266).—A description of a new hardness tester employing a 136° diamond pyramid. The specimen is gripped in a vice and the load applied hydraulically; the indentation is measured with a microscope.—R. W. R.

Hardness-Testing Method for Small Cylindrical Work-Pieces. M. C. Attinger (*Indust. Diamond Rev.*, 1947, [N.S.], **7**, (82), 264–265).—A translation of *Bull. Ann. Soc. Suisse Chronométrique et du Laboratorie Suisse de Recherches Horlogères* (*Lausanne*), 1946, **2**, 321.—R. W. R.

New Machines for Creep and Creep-Rupture Tests. M. J. Manjoine (*Machinery Lloyd*, 1946, **18**, (25), 96–101).—M. describes machines designed at the Westinghouse Research Laboratories to test high-temp. materials. The lever-arm creep machine is used for long-term tests and the screw-driven creep-rupture machine for the shorter tests. Both machines are described, together with the two different types of extensometers used. To demonstrate the types of tests made on the two machines, a high-temp. alloy was subjected to a series of tests in which the time to rupture varied over a wide range. Methods of representation of the family of creep-rupture curves and the significance of the " transition point " are discussed.—H. Pl.

The Tensile Test. L. Sanderson (*Machinery Lloyd,* 1946, **18,** (18), 85–88).—S. gives an elementary explanation of limit of proportionality, yield point, max. stress, proof stress, and elongation, and gives details of the B.S.I. standard tensile test-pieces.—H. Pl.

The Testing of Sheet Metal for Pressings. M. C. Boulet (*Usine Nouvelle,* 1947, **3,** (18), 9; (19), 12).—A review of testing machines.—M. E.

Supersonic Inspection of Materials. H. R. Clauser (*Materials and Methods,* 1946, **24,** (2), 379–384).—The principles and applications of reflection and transmission methods of supersonic inspection are outlined.—J. C. C.

For *A.S.T.M. Standards,* see pp. 126–131.

RADIOLOGY

***Radiography and the Fatigue Strength of Spot Welds in Aluminium Alloys.** R. C. McMaster and H. J. Grover (*Weld. J.* (*J. Amer. Weld. Soc.*), 1947, **26,** (3), 223–232).—A series of spot welds, in two-layer combinations of 19 S.W.G. Alclad 24S-T, were prepared under a range of operating conditions. The present report is of a preliminary nature, but indicates that radiography provides a sensitive method of evaluating the properties of spot welds which affect fatigue strength. Fatigue failure occurred in five characteristic ways, which are described. The tensile strength and high-stress fatigue life appeared to be determined primarily by the size of the nugget at the faying plane, whereas the low-stress, long-life fatigue failure was frequently related to the dia. of the corona ring (peripheral zone of bonding between the aluminium surfaces). Increasing the nugget size results in a smaller relative gain in fatigue strength than in tensile strength. It is desirable that welds likely to be subject to fatigue conditions should possess good corona bonding. Inclusions of aluminium cladding in the nugget provide nuclei for the propagation of cracks in high-stress fatigue tests. In the case of simple shear loading, cracks and defects in the nugget have little influence on the fatigue strength since failure occurs at the faying plane or at the extremities of the weld.—P. H.

Importance of Radiography in Inspection. E. L. LaGrelius (*Found. Trade J.*, 1947, **82,** (1606), 139–140).—A general review of current practice in metallurgical radiology.—J. E. G.

Industrial X-Ray Developments. George W. McArd (*Mass Production,* 1947, **23,** (9), 42–46).—An elementary account of some recent applications in metallurgy and elsewhere.—R. W. R.

20-Million-Volt Betatron. —— (*Steel,* 1946, **119,** (22), 68–69, 92).—A description of the betatron and its use in industrial radiography. Material of thickness at least 3 in. can be examined with it.—M. A. V.

For *A.S.T.M. Standards,* see p. 127.

XV.—FOUNDRY PRACTICE AND APPLIANCES

Making a Light Alloy-Snap Flash. J. A. McIntosh (*Found. Trade J.*, 1947, **81**, (1598), 313).

Control of Bronze Melts for the Production of Pressure-Tight Castings. W. A. Baker (*Found. Trade J.*, 1947, **82**, (1610), 229–233; discussion, (1614), 317–318, 324; and *Metal Ind.*, 1947, **71**, (3), 43–46).—Read to the Institute of British Foundrymen. A review of current research on the mechanism involved in the formation of porosity and its effect on the properties of bronze castings. B. discusses the practical application of these researches, with particular reference to the production of sand castings required to be pressure-tight in service.—J. E. G.

***Improvements in Hollow Sticks and Billets by Casting on to Metal Cores [Bronzes and Gun-Metals].** W. T. Pell-Walpole (*Found. Trade J.*, 1947, **81**, (1597), 285–293; **82**, (1602), 44).—It is submitted by P.-W. that the asbestos-wrapped core process should be employed for cored sticks with cores up to 2½ in. dia., and the split-core process for core sticks requiring thicker cores. Cores up to 2½ in. dia. and up to 3 ft. long should be wrapped with asbestos paper (0·015 in. thick), allowing one complete wrapping per 1 in. of core thickness. The core should possess a smooth surface, its dia. being tapered $\frac{1}{16}$ in./ft. length. The asbestos paper should be sealed on to the core with a suspension of 5% aluminium powder in a 2% aqueous solution of a dextrine-type gum; this also serves as a core coat. Before use, the coated core should be baked for not less than 15 min. at 300° C. After the casting has solidified and cooled to approx. 300° C., it should be stripped, water quenched, and allowed to stand for 5 min., after which the core may be readily tapped out. Cores of dia. greater than 2½ in. should be split vertically to form four equal segments. From each radial face a cut should be taken of 0·015 in./in. of core dia. In use, the four segments should be heated to 100° C., dressed with resinous aluminium paint, and set up in the mould with asbestos paper inserts (previously baked at 300° C.) placed between each segment. After the casting has cooled to approx. 300° C., one of the core segments is tapped out, thus releasing the remaining three segments. For either type of core, bronze should be degassed by melting under an oxidizing flux (1 part copper-mill scale, 1 part sea sand, and 1 part either of fused borax or of a lead-free glass). The flux must be removed before casting, and, when scrap or ingot charges have been melted, the necessary additions must be made for oxidation losses (e.g. approx. 0·5% tin, and 0·2–0·3% phosphorus for 2B8 bronze; 0·5% tin and 0·5% zinc for gun-metals; and 0·5% tin and 1% lead for leaded bronzes). The bronze should be top-poured through a pre-heated, moisture-free refractory nozzle. The pouring rate is given by the formula $R = KD$, where R is the rate in lb./min., K is a constant depending on the phosphorus content, and D is the sum of the internal and external dia. of the casting. The value of K should be taken as 6 when the phosphorus content is less than 0·25%, 5 for 0·5–1% phosphorus, and 4 for 1·5–2% phosphorus. The number of streams should be two for castings up to 2 in. dia., four up to 4 in. dia., six up to 8 in. dia., and twelve for larger castings.—J. E. G.

The Use of Base-Metal Alloys in Casting. (Collins). See p. 104.

Sound Copper Castings. L. Sanderson (*Machinery Lloyd*, 1946, **18**, (15), 92–93).—The employment of a modern furnace which has been designed with due attention to melting vol., burner tip dia., choice of lining to provide max. heat radiation in minimum time inside the furnace, correct air pressure and vol., full combustion control, and automatic proportioning, will ensure the production of superior copper melts. Moulding-sand permeability should be about 25, and bottom pouring is recommended.—H. Pl.

Magnesium : Cast Alloys. G. Fitzgerald-Lee (*Machine Shop Mag.*, 1947, **8**, (8), 79–81).—A summary of the properties and applications of magnesium alloys (Magnuminium and Elektron series).—H. V.

Magnesium Moulding Sands. F. A. Allen (*Light Metals*, 1947, **10**, (110), 120–123).—A. introduces the usual sand techniques employed in magnesium foundries and emphasizes their principal disadvantage, which is that the sands are difficult to work; being mainly synthetic, the moulds dry off quickly, and accidental damage is difficult to repair. A. states that equally effective inhibition can be achieved by a special mixture which confers better moulding properties and less tendency to dry out. The novelty in the mixture proposed consists of the addition to the sand of solid boric acid and solid ammonium bifluoride. If these two substances are mixed, an unexpected reaction takes place, and a wet mass is formed. When the sand is milled, the reaction occurs, and moisture is liberated. It is suggested that the chemically evolved water is more effective in wetting the sand than is the water added to it in the ordinary way. Brief test results are given showing that sand containing these inhibitors (as well as the usual sulphur) behaves better from a foundry handling point of view than similar sand containing only the conventional inhibitors.—F. A. F.

[Discussion on R. S. Busk and E. G. Bobalek's Paper :] "Hydrogen in Magnesium Alloys." (——) See p. 101.

[Discussion on R. M. Parke and J. L. Ham's Paper :] "The Melting of Molybdenum in the Vacuum Arc." (——) See p. 97.

Induction Melting Furnaces. (Chesnut). See p. 115.

Some Notes on Feeding. S. L. Finch (*Found. Trade J.*, 1947, **82**, (1613), 297–303; (1614), 319–324; discussion, **83**, (1618), 3–6).—Presented at the Annual Conference of the Institute of British Foundrymen. A detailed account of (1) the mechanism of crystallization, solidification, and shrinkage, (2) the principle of directional solidification, and (3) the factors affecting flow of metal from feeder head to casting.—J. E. G.

[Further Discussion on J. L. Francis's Paper :] "Some Casting Troubles." —— (*Found. Trade J.*, 1946, **80**, (1581), 344).—Cf. *ibid.*, 1946, **79**, 1554, 103–111; see *Met. Abs.*, 1946, **13**, 309.—W. G. A.

Current Problems. Tom Shanks (*Found. Trade J.*, 1946, **80**, (1577), 241–243).—Inaugural Address to the Scottish Branch of the Institute of British Foundrymen.—W. G. A.

The Modern Foundry. —— (*Usine Nouvelle*, 1947, **3**, (12), 12).—A review of English and American methods.—M. E.

Progress in Casting. A Review of American Foundry Practice. —— (*Metallurgia*, 1947, **36**, (212), 97–99).—A digest of papers in *Foundry*, 1946, **74**, (1), 70–103; see *Met. Abs.*, 1946, **13**, 231.—M. A. V.

Vacuum Plate Method for Casting in Porous Moulds and Patterns. Les Wilson (*Materials and Methods*, 1946, **24**, (6), 1505–1506).—A note. In this technique, the plaster mould is placed on a marble plate directly above a hole leading to an aspirator or vacuum pump. A retaining ring is placed around the mould and the space between the ring and the pattern sealed with "Plastiflex". The vacuum system will then abstract air and gases from the mould during the pouring operation.—J. C. C.

Some Notes on the Surface Drying of Moulds. A. Cracknell and F. Cousans (*Found. Trade J.*, 1947, **82**, (1614), 313–315; (1615), 343–347; (1616), 365–369).—Presented at the Annual Conference of the Institute of British Foundrymen. An account of the factors affecting the surface drying of moulds. The authors conclude : (1) that it is unnecessary for the mould temp. to attain 100° C. for the drying of the surface to be accomplished in a reasonable time; in fact, if air is used for drying at a temp. greatly in excess of 300° C. the surface layer of the mould forms an easily broken shell; (2) skin-dried moulds may be cast satisfactorily with the moisture content of the mould reaching its original value a little over ½ in. from the surface; (3) a high vol. of air at a moderate temp. is necessary to avoid spalling and maintain reasonable drying periods; (4) moulds left to stand after skin drying continue to lose moisture; (5) moulds air dried at shop temp. attain a condition similar to that of skin-dried moulds which have been allowed to stand; (6) the rate of air drying of a mould appears to be an inverse function of the permeability; (7) the employment of a fixed skin temp. in order to attain uniform results is not possible; and (8) skin-dried moulds left to age for short periods can be used satisfactorily.—J. E. G.

Patterns for a Production Foundry. G. A. Pealer (*Found. Trade J.*, 1946, **80**, (1572), 109–110).—Summary of a paper read before the American Foundrymen's Association; see *Met. Abs.*, 1947, **14**, 24.—W. G. A.

Cellulose Derivatives as Core Binders in German Foundries. O. R. J. Lee (*Found. Trade J.*, 1947, **82**, (1606), 135–136).—Details are given of two Alkylin binders, viz. Alkylin 360, a sawdust-like solid described as methyl cellulose, and Alkylin 260, cellulose glycollic acid. The chief characteristics of these binders are: (1) the development of a low hot strength, thus overcoming tearing difficulties in light-alloy castings; (2) low decomposition temp. which results in excellent knock-out characteristics; (3) low gas evolution; and (4) low drying temp. (150° C.).—J. E. G.

Improvements in the Manufacture of Metal Castings by the Centrifugal Method. —— (*Machinery Lloyd*, 1946, **18**, (26), 89–90).—This improved method of manufacturing castings by the centrifugal process is applicable to the rapid casting of any relatively short hollow body. A characteristic feature is that during the casting operation gases are evacuated from the interior of the casting.—H. Pl.

Precision Casting of High-Melting-Point Alloys Containing Nickel. H. Evans, P. S. Cotton, and J. Thexton (*Found. Trade J.*, 1947, **82**, (1609), 205–210; (1610), 223–227; discussion, (1615), 337–342; (1616), 369; **83**, (1621), 64; and (summary) *Aircraft Prodn.*, 1947, **9**, (106), 303–307).—Read to the Institute of British Foundrymen. A detailed and illustrated account of the technique employed for the manufacture of castings in high-m.p. nickel alloys by the lost-wax process. The procedure employed involves the use of zircon flour in the sprayed coating and sillimanite in the investment. —J. E. G.

Principles of Precision Investment Casting. Kenneth Geist and Robert M. Kerr, Jr. (*Found. Trade J.*, 1947, **82**, (1611), 247–254; (1612), 269–273; (1613), 291–296; discussion, (1615), 337–342, (1616), 369; **83**, (1621), 64).—An A.F.A. exchange paper presented at the Annual Conference of the Institute of British Foundrymen. The authors give a detailed and illustrated account of the lost-wax process of investment moulding. Other aspects discussed include plant layout and factors influencing casting design.—J. E. G.

Developments in Investments for the Casting of Gold Alloys and Base Metals. (Moore). See p. 104.

Engineering and Design of Aluminium Permanent Moulds. E. G. Fahlman, E. V. Blackmun, W. J. Brinkman, H. R. Doswell, W. J. Klayer, G. C. Kohls, C. H. Morrison, and E. C. Nocar (*Modern Metals*, 1947, **3**, (7), 24–25).—A concise account of the advantages and disadvantages of the gravity die-casting process, with notes on the design of dies.—N. B. V.

Shrinkage Allowance in Die-Casting Die Design. R. L. Wilcox (*Tool and Die J.*, 1947, **12**, (10), 68–71).—It has been found that published data on solidification shrinkage are usually excessive for die-casting work. The factors affecting the solidification shrinkage of zinc-base alloys, such as rate of cooling, methods of pouring, mould material, &c., are discussed. W. states that one reason why practical shrinkage allowances in die-casting design work are usually less than those calculated is the fact that the actual average temp. at which a casting is formed in a die is below the freezing point of the alloy. Another important factor tending to reduce the shrinkage-allowance factor from the calculated value is the shape of the casting or its ability to shrink freely in the die. Any restriction on shrinkage in the die, e.g. at the gate opening, gate runner, and overflow wells, will prove the normal shrinkage-allowance factor excessive.—J. S.

Steels for Die-Casting Die Blocks. James L. Erickson (*Materials and Methods,* 1946, **24**, (2), 389–396).—A comprehensive survey.—J. C. C.

For *A.S.T.M. Standards,* see pp. 127–129.

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

Selenium Fume Exposure. Marshall Clinton, Jr. (*J. Indust. Hyg. Toxicol.,* 1947, **29**, (4), 225–226).—A description of cases of selenium poisoning which occurred when some aluminium contaminated with selenium (scrap selenium-rectifier plates) was accidentally charged into a reverberatory furnace melting scrap aluminium. Some of the furnace workers experienced severe symptoms of a temporary nature, rather similar to those produced by sulphur dioxide, but all completely recovered during the course of the next two days. It is concluded that the unpleasant irritating effects limited exposure to the time necessary to escape from the contaminated atmosphere, so that in no instance did significant exposure occur.—R. W. R.

XVII.—FURNACES, FUELS, AND REFRACTORY MATERIALS

Induction Melting Furnaces. Frank T. Chesnut (*Amer. Foundryman,* 1947, **11**, (3), 22–25).—A general review in which are discussed the relative advantages and disadvantages of high-frequency induction furnaces and submerged-resistor furnaces for the melting of non-ferrous metals and alloys.—J. E. G.

Producing High-Purity Metals with Vacuum. J. D. Nisbet (*Iron Age,* 1947, **159**, (25), 56–59).—N. describes a vacuum-melting system in which a centrifugal operation is performed and an arrangement provided for loading and making additions to the furnace without disturbing the vacuum. He outlines the procedure for producing a 6-lb. ingot under less than 50 microns pressure. —J. H. W.

Industrial Fuel in Victoria. J. R. Nicholson (*Proc. Soc. Chem. Ind., Victoria,* 1946, **46**, (1), 739–753; discussion, 753–754).—Among the methods suggested for the more efficient use of coal is the employment of recuperators in industrial furnaces. Tables show the saving in fuel with two different types of recuperators.—J. L. T.

XVIII.—HEAT-TREATMENT

Induction Heating. Edwin Laird Cady (*Materials and Methods,* 1946, **24**, (2), 400–410).—A " materials and methods " manual. Basic types of equipment are described and costs discussed. Uses for hardening and forging ferrous materials are outlined and reference made to induction brazing and soldering.—J. C. C.

Induction Heating. N. R. Stansel (*Iron Steel Eng.,* 1946, **23**, (1), 102–111). —The thermal, electrical, and magnetic properties of metals affecting the induction-heating process are discussed, and formulæ quoted relating the electrical, physical, and geometrical quantities involved in practice. These formulæ are illustrated graphically. The applications of the process to melting, mass heating, and surface heating are considered.—M. A. V.

Coax Coil for Heating Small Holes. David Baumoel (*Electronics*, 1947, **20**, (9), 160, 162).—An induction-heating work coil is described for the heat-treatment of the inside surfaces of small holes between $\frac{3}{16}$ and $\frac{5}{8}$ in. dia. Co-axial conductors are used. Provision can be made for cooling of the conductors and for quenching of the work-piece in hardening operations.—D. M. L.

How Industry is Using H.F. Heat in Production. —— (*Electronic Ind. and Instrumentation*, 1947, **1**, (7), 5).—A series of photographs is given, showing the use of H.F. heating in production processes where high production rate and close control of heated area are essential. The illustrations show the annealing of chain pins, the silver soldering of a three-piece tube assembly and kitchen utensils, the brazing of radio components, and the edge-glueing of wooden spars.—D. M. L.

Cleaning and Heat-Treating Aluminium Alloy [Castings]. (Rogers, Carl, Seabury, and Smith). See p. 118.

***Effects of Heat-Treating [Silver-]Amalgam Alloy Ingots Before Cutting Into Filings.** (Ray). See p. 105.

[Correspondence on F. W. Jones and W. I. Pumphrey's Paper :] "Some Experiments on Quenching Media." (Miss) R. E. W. Gunn (*J. Iron Steel Inst.*, 1947, **156**, (4), 524).—Cf. *ibid.*, 1947, **156**, 37; see *Met. Abs.*, this vol., p. 61. The calculation of the centre temp. of cylinders, using Schmidt's method in the manner suggested by J. and P., frequently leads to arithmetical fluctuations. G. suggests a way, also based on Schmidt's method, in which these fluctuations may be avoided.—R. W. R.

For *A.S.T.M. Standards*, see pp. 129–131.

XIX.—WORKING

***Research on the Forgeability of Light Alloys.** Paul Bastien (*Publ. Sci. Tech. Ministère Air* (*France*), *Rapport* No. **196**, **1946**, 76 pp.).—Static and dynamic bending tests give information on the forgeability of a new alloy rapidly and easily. The temp. range over which an alloy can be forged is thus obtained. To investigate the influence of an isolated factor such as crystal size, the most sensitive test is shock bending. The results obtained by B. using such tests are in good agreement with the results obtained in industry. The effect of composition on forgeability is such that when the amount of added metal exceeds the limit of solid solubility at the temp. in question, the extent to which the alloy may be hot worked depends on the constituent precipitated from the solid solution, its nature and form, &c. The study of the plastic deformation of various binary alloys by laboratory procedures, such as those described, which permit quantitative data to be obtained, enables general laws of forgeability applicable to new alloys to be deduced.—J. L. T.

Advantages of Forgings Over Castings. —— (*Non-Ferrous Forgings Digest*, 1947, **2**, (3)).—A brief review.—J. L. T.

Details of a New 18-in. Reversing Cold Steckel Mill. L. W. Law (*Sheet Metal Ind.*, 1947, **24**, (243), 1349–1351, 1365).—R. Gr.

The Application to Shaping Processes of Hencky's Laws of Equilibrium. E. Siebel (*J. Iron Steel Inst.*, 1947, **155**, (4), 526–534; discussion, **156**, (4), 511–522; and *Iron and Steel*, 1947, **20**, (6), 266–268).—The use of Hencky's Laws enables the principal stresses in a body being plastically deformed to be calculated from a knowledge of the slip-line system. Using the rules propounded by Prandtl, S. has deduced the slip-line systems operating in a number of metal-working processes, including direct compression, die-forging, rolling, drawing, extrusion, and piercing. The effect of friction is considered. In some instances (drawing, extrusion, and piercing) mathematical expressions for the forces acting are derived from consideration of the slip-line diagrams. The method employed assumes conditions of const. shear stress, but S. treats the effect of work-hardening mathematically and shows that the method is valid for a work-hardening material, provided that the slip lines possess the same curvature in both directions; in other instances, the error caused by work-hardening is not large, and the method yields an approx. solution.—R. W. R.

Joint Discussion 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, **156**, (4), 511–522).—Cf. *ibid.*, 1947, **155**, (1), 51; see *Met. Abs.*, this vol., p. 63.—J. L. T.

Modern Extruded Metals. E. J. Cartwright (*Machinery Lloyd*, 1946, **18**, (6), 71–75).—Commercially extrudable metals and alloys range from the soft white metals, lead and tin, through the light alloys of aluminium and magnesium, the copper-base alloys, and the yellow metals, to Monel metal and the nickel-rich alloys. Details of the process and descriptions of some modern extrusion machines are given.—H. Pl.

Extruded Shapes Speed Brass Forging Output. Herbert Chase (*Materials and Methods*, 1946, **24**, (1), 103–108).—J. C. C.

[Discussion on J. P. Doan and G. Ansel's Paper:] "Some Effects of Zirconium on Extrusion Properties [and Constitution] of Magnesium-Base Alloys Containing Zinc." (——) See p. 101.

Stamped [Brass and Bronze] Bushings. D. B. Wilkin (*Steel*, 1946, **119**, (22), 64–66, 104).—The stamping of brass and bronze bushings and bearings, steel bushings, and brass ferrules at the works of the National Formetal Company, Cleveland, O., is described.—M. A. V.

Metal Stampings. —— (*Metal Progress*, 1946, **50**, (1), 132, 134, 136, 138).—Advances in production technique and the development of new alloys have extended the applications of stampings; close tolerances permit interchangeability and allow stampings to be built up into complex assemblies or combined with forged or cast pieces. Production, joining, finishing, and application of a protective coating are often undertaken serially in a single factory. Notable advances in practice include (1) improved inspection methods; (2) deep drawing without intermediate annealing; (3) improved welding and brazing methods; (4) introduction of new light alloys; (5) satisfactory enamelled coatings for steels, in some cases successfully used on copper-brazed joints; and (6) production of larger and heavier hot pressings, both in steel and in aluminium and brass. Further development in the press forming of magnesium sheet is regarded as desirable.—P. R.

***The Turning of Light Alloys.** René Schweyckart (*Rev. Aluminium*, 1947, (**130**), 44–51).—A study of the forces acting on tools and of the formation of chips in the turning of light alloys. Stresses are lowest when the ratio of longitudinal feed in mm. per revolution to transverse feed in mm. is greater than 0·4 for pure aluminium and greater than 0·5 for aluminium alloys.—M. E.

The Machining of Magnesium. —— (*Usine Nouvelle*, 1947, **3**, (9), 13). —M. E.

Wet-Belt Machining Method [for Castings]. William F. Schleicher (*Aluminum and Magnesium*, 1947, **3**, (5), 8–10, 20, 22).—S. deals with a new process for grinding metal parts, usually castings, by means of a cooled abrasive belt. The novelty lies in the recent successful development of a suitable belt which will withstand the effects of the coolant, and of special-purpose grinding machines for using them. Flat or curved faces can be surfaced at speeds of the order of 4000 ft./min. for aluminium alloy. The grit may be silicon carbide and is plastic-bonded to a cloth backing; it is applied by an electrostatic method. Tolerances as close as 0·0005 in. have been maintained. The coolant used is soluble oil in water. Particulars of various successful applications are given.—F. A. F.

XX.—CLEANING AND FINISHING

Cleaning and Heat-Treating Aluminium Alloy [Castings]. W. J. Rogers, F. Carl, R. Seabury, and N. Smith (*Modern Metals*, 1947, **3**, (6), 24–26).—A review of current practice.—N. B. V.

Surface Finishes for Aluminium [and Its Alloys]. J. F. Mason (*Machines et Métaux*, 1947, **31**, (349), 311).—Translated from *Iron Age*, 1946, **158**, (9), 40–43; (10), 50–53; (11), 66–69; see *Met. Abs.*, 1946, **13**, 439.—J. L. T.

Electropolishing. Charles L. Faust (*Machinery Lloyd*, 1946, **18**, (12A), 37–43).—F. discusses some of the industrial applications and limitations of electrolytic polishing. Its applicability to the polishing of recessed surface areas is cited as the outstanding advantage of the process. For practical purposes, ferrous alloys are generally polished in the same solutions, whereas special combinations are used for the non-ferrous metals. Electropolishing uniformly removes the excess metal from the outside dia. of screws so that it can be replaced by electrodeposited metal and still maintain the dimensional tolerances originally specified.—H. Pl.

Vapour Blast: Some Recent Developments. D. Grant (*Machinery Lloyd*, 1946, **18**, (22), 67–72; (25A), 37–41).—Difficulties in maintaining an "electro-clean" surface during the scouring of a 40 ft. × 60 ft. steel sieve prior to copper plating were overcome by using a technique known as "copper multi-coating". In this process, both the cleaning of the steel and the work-hardening of the deposit were carried out with a low-velocity heavy-sand abrasive stream, the plating proceeding at the same time.—H. Pl.

XXI.—JOINING

Soldered *versus* Double-Seamed Closures. C. H. Hannon (*Metal Progress*, 1946, **49**, (6), 1171–1172).—Capacitor casings of standard type can be sealed without soldering by using a double-seamed closure, mechanically spinning the cover on to the body, and applying a metallic sealing adhesive before the final heat-treatment. The adhesive must be unaffected by the thermal treatment and must not contaminate the dielectric material.—P. R.

***Contribution to the Study of the Phenomena of Expansion and Shrinkage [in Soldering].** P. Berthet (*Soudure et Techniques Connexes*, 1947, **1**, (1/2), 25–33; and (abridged) *Weld J.* (*J. Amer. Weld. Soc.*), 1947, **26**, (7), 370–371s).—B. describes a method of measuring the shrinkage of solder on sheets by means of bend tests. Increasing the speed of the process decreases the shrinkage of the solder.—M. E.

Brazing Lawn-Mower Rotors. —— (*Electronics*, 1947, **20**, (9), 168, 170).—An illustrated description of the brazing of three parts—spider, driver-shaft, and bearing retainer—in one operation. Four assemblies are brazed at one time, the complete heating cycle being 30 sec. The method of assembly and the system of jigs for holding the assemblies in the heating coils are described. The brazing medium is silver solder.—D. M. L.

Automatic Induction Brazing Speeds Tool Tipping. —— (*Iron Age*, 1946, **157**, (15), 54–55).—The author describes the induction brazing of tungsten carbide tips on to cutting tools. The use of induction heating results in a considerable saving of time.—R. W. R.

Eutectic Low-Temperature Welding. R. D. Boyle (*Australasian Eng.*, **1946**, (Aug.), 71–73).—B. describes the eutectic low-temp. welding process, which, though similar to brazing, differs from it in that the temp. used is below the m.p. of the filler metal. The latter is specially chosen to form easily a eutectic with the parent metal. Suitable alloys have been developed for use with cast iron, steel, copper alloys, and aluminium alloys.—N. B. V.

***Static and Fatigue Tests of Arc-Welded Aluminium Alloy 61S-T Plate.** E. C. Hartmann, Marshall Holt, and A. N. Zamboky (*Weld. J.* (*J. Amer. Weld. Soc.*), 1947, **26**, (3), 129–138s).—The tests were conducted on 15 types of panels fabricated by arc welding from $\frac{3}{8}$-in.-thick aluminium alloy of nominal composition: copper 0·25, magnesium 1·0, silicon 0·6, chromium 0·25%, balance aluminium. Panels with dressed butt welds gave the highest fatigue strengths observed in these tests, with values of 49–54% of the solid specimen. Fatigue failure in this type of joint was associated, in very many cases, with spatter marks on the parent plate. Static tensile tests showed a max. joint efficiency of approx. 50% in the case of butt welds without dressing. As with most of the other types of panels, butt joints gave tensile values in excess of the tensile strength of the annealed material. The least satisfactory joints in either tensile or fatigue tests were those of asymmetrical design. No improvement in tensile strength, or fatigue strength at long life, was observed as a result of scalloping the edges of the plates. Inferior results were obtained from panels with splice plates fastened by fillet welds across the main joint.—P. H.

Fabricating Sheet-Metal Parts of Jet Engines. Harold A. Knight (*Materials and Methods,* 1946, **24**, (6), 1461–1465).—Brief notes are given on the welding of Inconel combustion-chamber liners.—J. C. C.

Fine Silver Welded Tubing. J. G. Henderson (*Product Eng.*, 1947, **18**, (6), 160).—Practical hints on the welding of silver and the handling of silver tubing. The density, tensile strength, elongation, hardness, m.p., thermal conductivity, malleability, ductility, and work-hardenability of 99·9% commercial silver are tabulated.—J. L. T.

Ensuring the Best Results from Welding. R. King (*Mass Production,* 1947, **23**, (10), 65, 74).—An elementary account of some points of technique. —R. W. R.

Modern Resistance Welding: Costs, Design, and Application. W. Bernard (*Australasian Eng.*, **1946**, (Sep.), 58–63).—A paper read before the Australian Welding Institute, Sydney Branch. Spot, projection, and seam welding are reviewed.—N. B. V.

Some Fundamental Principles for the Resistance Welding of Sheet Metal. H. E. Dixon (*Sheet Metal Ind.*, 1947, **24**, (243), 1430–1435).—The factors which influence the spot welding of aluminium-base alloys are considered under the following heads: contact resistance, welding heavy gauges, effect of material composition, and general features in spot welds (coated Duralumin-type alloys). Flash and butt welding of light alloys are also considered.—R. Gr.

Design of Fixtures for Projection Welding. Mario L. Ochieano (*Iron Age,* 1946, **157**, (18), 55–56).—Some simple rules are given.—R. W. R.

Technique for the Gas Welding of Magnesium Alloys. (*Brit. Weld. Research Assoc. Pub.*, 1946, **T.16**, 38 pp.).—This useful brochure was prepared by a special panel of a Committee of the British Welding Research Association, and covers the whole field of gas welding of magnesium alloys, except that the repair of castings is not dealt with in detail. The booklet is comprehensive and deals with the effect of composition of the alloy, the welding flame, fluxes, design, and manipulation. Finishing and protective treatments are described at some length, and weld defects and inspection are also considered. There are more than twenty illustrations, including photomicrographs. —F. A. F.

***The Chemical Surface Treatment of Magnesium Alloy Sheet for Spot Welding.** W. F. Hess, T. B. Cameron, and D. J. Ashcraft (*Weld. J.* (*J. Amer. Weld. Soc.*), 1947, **26**, (3), 170–190s).—The suitability of various reagents for preparing magnesium alloys for spot welding has been investigated. A solution of universal application, containing 10% chromic acid and 0·05% sodium sulphate is given particular attention. This solution has a relatively short active life and requires regeneration by addition of sodium sulphate. Analytical control is necessary, and suitable methods are discussed. Material from one supplier responded satisfactorily to a solution of chromic acid without additions, and this was attributed to a trace of sulphate acquired by the surface of the sheet when in the mill. Plain chromic acid solutions differ from other reagents in producing a discontinuous attack, which gives a longer active life to the bath. Results are improved and chromic acid saved if this treatment follows a hot alkaline cleaner. Solutions of chromic and nitric acids are not readily adaptable to different alloys and tempers, and are critical in use. The first step in surface preparation was degreasing in trichlorethylene. A 20% solution of acetic acid was effective in removing chromate pickle finish, leaving a surface suitable for preparation by other reagents. Where spot welding is envisaged, it is an advantage to use stock which has not received a chromate pickle finish. Chemical preparation is convenient for spot welding and is in no way inferior to scratch brushing, following which treatment the surface resistance will rapidly increase in hot and humid atmospheres. The use of chemically prepared stock gives a longer electrode tip life.—P. H.

High-Speed Spot Welding. Bernard Gross (*Iron Age*, 1946, **157**, (8), 52–55).—G. discusses the advantages of spot welding and describes the welding machines and techniques used. Various means of speeding-up the process are considered.—R. W. R.

Inspection and the Resistance Spot Welding of Light Alloys. Michael Smith (*Australasian Eng.*, **1946**, (Mar.), 45–48).—An account of the spot-welding process and of the duties of Government inspectors.—N. B. V.

Spot Welding of Assemblies. Floyd Matthews (*Aero Digest*, 1947, **54**, (4), 82).—Spot-welding procedure for the fastening of internal corrugated stiffener panels to the centre wing skin sections at the Boeing Aircraft factory is summarized. A preliminary determination of the electrical resistance between surface films is carried out, and adjustments are made to the cleaning procedure until this resistance is less than 21 microhms.—H. Pl.

***Radiography and the Fatigue Strength of Spot Welds in Aluminium Alloys.** (McMaster and Grover). See p. 111.

Welding. H. E. Linsley (*Iron Age*, 1946, **157**, (1), 136–138, 141, 278, 280, 282).—A review of the position of welding at the beginning of 1946. Some recent developments, such as the spot welding of heavy-gauge aluminium sheet and the Heliarc welding of stainless-steel sheet, are described. —R. W. R.

The Principles of Welding Metallurgy. J. Candlish (*Australasian Eng.*, **1946**, (May), 36–46).—A paper read before the Sydney Branch of the Australian Welding Institute.—N. B. V.

Machining of Arc-Welded Products. Walter J. Brooking (*Iron Age*, 1943, **152**, (24), 54).—B. stresses the advantages which frequently accrue from the pre-machining of parts and sub-structures, and describes the precautions which must be taken when welding these to the main assembly.—R. W. R.

Symposium " Welding and Health ". (1) Welding and Fire. D. V. Mills (*Australasian Eng.*, **1946**, (Aug.), 73–74); **(2) Welding and Electric Shocks.** H. S. Lloyd (*ibid.*, (Sep.), 48–49); **(3) Welding and Eyes.** R. G. Giovanelli (*ibid.*, (Oct.), 89–90); (4) **Welding and Fumes.** Gordon C. Smith (*ibid.*, (Nov.), 79–81).—Papers read at a symposium held by the Australian Welding Institute. Health hazards in welding are dealt with and precautions described.

—N. B. V.

Rotor-Blade Production [Use of Cycleweld Cements]. John T. Parsons (*Aero Digest*, 1947, **54**, (3), 73, 132–134).—Cycleweld cements develop thoroughly satisfactory values on a collar-to-spar application when the procedure is rigidly controlled and the fixtures are properly designed. P. describes methods of overcoming difficulties due to the expansion of the Sikorsky R-5 spar and the tendency of joints to slide out of alignment just before the curing temp. of these cements.—H. Pl.

For *A.S.T.M. Standards*, see p. 128.

XXII.—INDUSTRIAL USES AND APPLICATIONS

Air-Conditioning System for the Martin 3–0–3 [Aeroplane]. P. H. Portteus (*Modern Metals*, 1947, **3**, (7), 14–15).—A description of the part played by light-alloy components in aircraft pressurizing and air-conditioning equipment.—N. B. V.

The Tucker [Automobile] Gets Under Way. W. B. Griffin (*Modern Metals*, 1947, **3**, (7), 12–13).—A brief description of the " Tucker '48 ", which is planned to incorporate a much greater quantity of light metals than any previous car.—N. B. V.

New [Aluminium] Chemical Drum. —— (*Modern Metals*, 1947, **3**, (7), 19).—Designed primarily for transporting hydrogen peroxide, the 30-gal. drum described may also be used for a wide range of other chemicals. The drum is made by Heliarc-welding together of two deep-drawn halves of high-purity (99·6% and over) aluminium, and is reinforced with high-strength alloy extrusions. It weighs 34 lb., or about half the weight of a comparable steel drum.—N. B. V.

Aluminium and Its Alloys in Present-Day Construction. G. W. McArd (*Mech. World*, 1947, **122**, (3166), 279–281).—A brief review of the applications and advantages of aluminium alloys in building construction and automotive engineering.—R. W. R.

Aluminium Jeep Tops. J. A. Carson (*Modern Metals*, 1947, **3**, (6), 16).

—N. B. V.

Designing a Combination Lighter and Cigarette Case [in Aluminium Alloy Die-Castings]. Fred F. Fukal (*Modern Metals*, 1947, **3**, (6), 20–21).—N. B. V.

Paint-Spraying Equipment Utilizes Aluminium Forgings. —— (*Modern Metals*, 1947, **3**, (7), 30).—The one-piece body of the spray gun described here is of a high-strength aluminium alloy forged and heat-treated to give max. strength. The total weight of the gun is 26 oz.—N. B. V.

Pressed [Aluminium Alloy] Pistons for Heavy-Duty Diesel Engines. L. P. Gibson (*Machinery Lloyd*, 1946, **18**, (25A), 46–50).—Experience gained with pressed pistons in the aircraft industry has been applied to heavy-duty oil engines. " Y " alloy is considered as the strongest known piston alloy, while an aluminium–12% silicon alloy, " Lo-Ex ", has a slightly lower coeff. of expansion and possesses relatively high hot-strength values. G. summarizes the fundamental differences between cast and pressed pistons and outlines the press-shop technique.—H. Pl.

Precision [Aluminium Alloy] Trailer Coaches. —— (*Modern Metals*, 1947, **3**, (6), 27).—For the all-metal caravan trailer described, 3S sheet is used for walls and roof in conjunction with 24S-T Alclad extrusions.—N. B. V.

Aluminium Water Pump [for Cooling Automobile Engines]. —— (*Modern Metals*, 1947, **3**, (6), 15).—The pump described weighs 40% less than a cast-iron one, reduces corrosion troubles in the cooling system, and leads to higher engine efficiency.—N. B. V.

Light Metals and Tenite Plastic for Piano Actions. —— (*Modern Metals*, 1947, **3**, (7), 27).—Magnesium alloy extrusions are used for the main rail and hammer rail.—N. B. V.

Magnesium in Electrical Batteries. Harold A. Knight (*Materials and Methods*, 1946, **24**, (6), 1469–1472).—The construction and characteristics of magnesium–silver-chloride batteries with sea water as electrolyte are briefly discussed; dimensions and discharge data of some commercial cells are tabulated.—J. C. C.

Engraved Magnesium Plates Cut Printing Costs. —— (*Modern Metals*, 1947, **3**, (7), 28–29).—Reprinted from *Editor and Publisher*, 19 July 1947. The possibility of reducing newspaper production costs by as much as 50% is opened up by the process described, which consists of photo-engraving matter typed by electromatic proportional-spacing machines. All typesetting and stereo-casting is thereby eliminated. Magnesium is used for the plates because it is light and easy to etch. The plates can be used on either flat-bed or rotary presses.—N. B. V.

Selling Magnesium in Canada. A. C. Norcross (*Modern Metals*, 1947, **3**, (6), 12–14).—A survey of the wide range of products of a Canadian magnesium foundry.—N. B. V.

Manufacturing a Magnesium Combination Storm and Screen Window. —— (*Modern Metals*, 1947, **3**, (7), 20–21).—N. B. V.

Mechanical Filtration with Metal Filter Cloths. R. F. Black (*Nickel Bull.*, 1947, **20**, (1/2), 33–34).—Abstracted from *Internat. Sugar J.*, 1946, **48**, 207–208.—J. S.

[Production of] Ultra-Thin Nickel Ribbons [for Use in Bolometers]. (Brockman). See p. 109.

[Zinc] Die-Casting to Relieve Labour Shortage. —— (*Mech. World*, 1947, **122**, (3165), 259–260).—A description of the merits of zinc-base die-castings, as opposed to cast-iron sand castings, for electrical switch-gear.—R. W. R.

Zinc Alloy [Die-]Castings. New Applications. — Grunberg (*Usine Nouvelle*, 1947, **3**, (17), 11).—A brief report of a paper presented at le Centre d'Études Supérieures de Métallurgie. The chief cause of failure of die-castings is intercrystalline corrosion. Three alloys have been standardized in America: Zamak 2, 3, and 5. They have many uses in small decorative parts, especially when chromium plated.—J. L. T.

Zinc Alloy Moulds for Short Runs. —— (*Modern Plastics*, 1946, **23**, (12), 150).—To produce small quantities of clear plastic models at low cost and with equipment available in the U.S. Army model shops, a new process using zinc alloy moulds has been evolved.—H. Pl.

The Production of Die-Castings for Ford Carburetters. Herbert Chase (*Machinery* (*Lond.*), 1947, **71**, (1818), 242–246).—J. C. C.

Development in Aircraft-Engine Metallurgy, 1920–1946. Walter E. Jominy (*Metal Progress*, 1946, **50**, (4), 687–690).—Outstanding metallurgical advances in aircraft-engine production from 1920 onwards include: (1) the use of sintered carbides; (2) induction heating; (3) chromium plating; (4) the availability of new materials: accounts are given of the applications of magnesium castings, silver (especially in bearings), aluminium alloy forgings, and Nitralloy; and (5) the control of grain-size in steel.—P. R.

Naval Engineering Duty in War-Time. Richard Doughton, Jr. (*Metal Progress*, 1946, **50**, (3), 455–461).—The metallurgical aspects of naval engineering are reviewed. Under war conditions, difficulty was caused by the use of such substitute materials as lead for tin in bearing metals and the softer grades of Monel metal for K-Monel in pump impeller rings, casing rings, and impeller nuts. Const. maintenance of a high standard of efficiency was demanded, as was a wide variety of repairs at sea, often of major importance. Large vessels possessed a machine shop, blacksmith's and coppersmith's shops, and welding and flame-cutting equipment, together with melting and annealing equipment built up by the engineering personnel. Stock materials included mild-steel bar and rod, brass, copper, and Monel metal bar and sheet, and several types of electrode, zinc bars, and plate. Accounts are given of the casting of zinc pencils from spelter when rod was no longer available and of the use of 25 : 20 chromium–nickel electrodes.—P. R.

Centrifugal Castings in the Shipbuilding Industry. N. Sokolov (*Fonderie*, 1947, **1**, (14), 546–548).—A condensed translation from *Sudostroenie*, **1945**, (3/4), 25–31; see *Met. Abs.*, 1946, **13**, 373).—J. L. T.

Hard Alloys Go Underground. Sheldon P. Wimpfden (*Min. and Met.*, 1947, **28**, (483), 148–149).—Describes the application of tungsten carbide insert-bits in rock drills.—N. B. V.

Mechanized Wiring. John Markus (*Sci. American*, **1946**, (Aug.), 63–65).—Many hand operations in wiring various electrical and electronic mechanisms can be eliminated by the use of sprayed-metal coatings, preformed and welded harnesses, and metallic paints applied through silk screens.—H. Pl.

Metal Coatings on Ceramics. E. Rosenthal (*Electronic Eng.*, 1946, **18**, (222), 241–242, 262).—The Schoop spraying process is being applied with satisfactory results to high-voltage power bushings. The adherence is improved if the coating is applied to a glaze having a lower softening temp. than the porcelain body. Not all metals adhere equally well; in the case of copper it is advisable that ground layers of other metals should first be applied. The application of the coating by cathode volatilization or by reduction of metals from salt solutions has the disadvantage, in common with the Schoop process, that dimensional control of the deposited layer is extremely difficult. The burning of metal preparations containing ceramic fluxes on to the ceramic has solved the problem of adherence, and details of this process are given. A ceramic rod can be covered with a thin, burnt-on silver coating, the thermal expansion of which is solely determined by the thermal expansion of the ceramic. Use is made of this fact in the manufacture of metallized ceramic coils which exhibit inductance changes which vary little with varying temp.—H. Pl.

Metal-Coated Plastics. —— (*Modern Plastics*, 1946, **24**, (4), 106–108).—There are three ways of applying films of metal to plastic surfaces: (1) *in vacuo* and at high temp., when the metal disintegrates and falls like dew on the plastic model, (2) a shiny metallic spray can be applied to plastics by air pressure, and (3) a coating of silver can be painted or screen-printed on a plastic surface; this silver deposit acts as an electrical conductor for the application of an electroplated coat. A recent application of metal spraying is a radio chassis, in which the metal connections are sprayed on to a plastic housing in one operation. The sprayed metal forms strips 0·1 in. wide and 0·0002 in. thick, eliminating the need for a soldering iron in radio assembly.—H. Pl.

[Metals in] Plastics Engineering in 1946. —— (*Modern Plastics*, 1947, **24**, (5), 137–146).—Many new aircraft will have flooring made with honeycomb faced with an aluminium alloy skin. In one installation, a 35% saving in weight, with a 30% increase in strength, was effected. Vacuum evaporation is used to apply metallic coatings to plastics. Coatings of aluminium and silver on sheet methyl methacrylate give very good mirror surfaces. The advantages of beryllium copper as a mould material for plastics are given.—H. Pl.

Metal Thread Sealed Between Acetate Film. —— (*Modern Plastics*, 1946, **24**, (3), 121).—A metallic yarn which will not tarnish with age or exposure to light is the latest fashion discovery. The aluminium, gold, silver, or copper yarns are sealed between two plies of specially formulated cellulose acetate film. The metallic yarns are supplied mainly in flat form, $\frac{1}{64}$ or $\frac{1}{32}$ in. wide. In each width there are two grades, one yielding (for aluminium) 4600 yd./lb. in the $\frac{1}{32}$-in. width and 8600 yd./lb. in the $\frac{1}{64}$-in. width, and the other grade yielding, for these widths, 6000 and 11,000 yd./lb., respectively.—H. Pl.

Coming Changes in Metal Economics. Fred P. Peters (*Sci. American*, **1946**, (Dec.), 258–260).—Light metals are likely to be in a better competitive cost position in 1955. Copper, zinc, and lead are likely to be more expensive in a few years. The power required to machine several common metals is in the proportion: magnesium 1·0, aluminium alloys 1·8, yellow brass 2·3, cast iron 3·5, mild steel 6·3, and nickel alloys 10·0. Shortage of tin in America has led to the substitution of aluminium and aluminium-coated steel for tinplate; aluminium, beryllium, silicon, and manganese bronzes are making inroads on the tin-bronze markets.—H. Pl.

Heavy Alloy. (Price). See p. 105.

Rubber–Metal Composites. James A. Merrill (*Materials and Methods*, 1946, **24**, (4), 891–895; and (summary) *Machines et Métaux*, 1947, **31**, (341), 8).—Characteristics of natural and synthetic rubbers which can be bonded to metals are outlined, and some typical applications of bonded composites are described.—J. C. C.

SPECIFICATIONS FOR COPPER AND COPPER ALLOYS

Copper Sheet and Strip: Annealed. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4500B**), 2 pp.).—A revised specification.—J. L. T.

Brass Sheet and Strip: Half Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4507A**), 2 pp.).—A revised specification.—J. L. T.

Phosphor-Bronze Strip. Spring Temper. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4510B**), 2 pp.).—A revised specification.—J. L. T.

Bronze Strips. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4520C**), 2 pp.).—A revised specification.—J. L. T.

Brass Rods and Bars. Free Cutting: Half Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4610C**), 3 pp.).—A revised specification.—J. L. T.

Naval Brass. Rods and Bars: Half Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4611A**), 2 pp.).—A revised specification.—J. L. T.

Brass Forgings. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4614C**), 2 pp.).—A revised specification.—J. L. T.

Silicon-Bronze Bars. Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4615A**), 2 pp.).—A revised specification.—J. L. T.

Manganese-Bronze Forgings. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4619A**), 2 pp.).—A revised specification.—J. L. T.

Phosphor-Bronze Bars. Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4625C**), 2 pp.).—A revised specification.—J. L. T.

Aluminium-Bronze Bars. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4630B**), 2 pp.).—A revised specification.—J. L. T.

Aluminium-Bronze Bars. Silicon. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4631A**), 2 pp.).—A revised specification.—J. L. T.

Aluminium-Bronze Bars. Hard. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4632A**), 2 pp.).—A revised specification.—J. L. T.

Beryllium-Copper Alloy Bars and Forgings. Solution-Treated. —— (*Aeronaut. Material Specification* (*S.A.E.*), 1946, (**AMS 4650B**), 2 pp.).—A revised specification.—J. L. T.

Standard [A.S.T.M.] Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (B4–42). —— (*Book of A.S.T.M. Standards*, **1946**, (Pt. IB), 1–4); **Standard [A.S.T.M.] Specifications for Electrolytic Copper**

Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars (B5–43). —— (*ibid.*, 5–8); Standard [A.S.T.M.] Specifications for Electrolytic Cathode Copper (B115–43). —— (*ibid.*, 9–10); Standard [A.S.T.M.] Specifications for Fire-Refined Copper Other than Lake (B72–33). —— (*ibid.*, 11–12); Tentative [A.S.T.M.] Specifications for Oxygen-Free Electrolytic Copper Wire Bars, Billets, and Cakes (B170–44T). —— (*ibid.*, 341–343); Tentative [A.S.T.M.] Specifications for Fire-Refined Copper for Wrought Alloys (B216–46T). —— (*ibid.*, 344–345); Standard [A.S.T.M.] Specifications for Phosphor Copper (B52–46). —— (*ibid.*, 13–14); Standard [A.S.T.M.] Specifications for Silicon Copper (B53–46). —— (*ibid.*, 15–16); Standard [A.S.T.M.] Specifications for Hot-Rolled Copper Rods for Electrical Purposes (B49–41). —— (*ibid.*, 17–19); Standard [A.S.T.M.] Specifications for Hard-Drawn Copper Wire (B1–40). —— (*ibid.*, 20–23); Standard [A.S.T.M.] Specifications for Medium-Hard-Drawn Copper Wire (B2–40). —— (*ibid.*, 24–27); Standard [A.S.T.M.] Specifications for Soft or Annealed Copper Wire (B3–45). —— (*ibid.*, 28–31); Standard [A.S.T.M.] Specifications for Hard-Drawn Copper Alloy Wires for Electrical Conductors (B105–39). —— (*ibid.*, 32–36); Standard [A.S.T.M.] Specifications for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors (B48–45). —— (*ibid.*, 37–41); Standard [A.S.T.M.] Specifications for Tinned Soft or Annealed Copper Wire for Electrical Purposes (B33–46). —— (*ibid.*, 42–47); Standard [A.S.T.M.] Specifications for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft (B8–46). —— (*ibid.*, 48–54); Standard [A.S.T.M.] Specifications for Bronze Trolley Wire (B9–46). —— (*ibid.*, 55–60); Standard [A.S.T.M.] Specifications for Copper Trolley Wire (B47–46). —— (*ibid.*, 61–65); Standard [A.S.T.M.] Specifications for Figure-9 Deep-Section Grooved and Figure-8 Copper Trolley Wire for Industrial Haulage (B116–46). —— (*ibid.*, 66–70); Tentative [A.S.T.M.] Specifications for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members for Electrical Conductors (B172–45T). —— (*ibid.*, 346–350); Tentative [A.S.T.M.] Specifications for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members for Electrical Conductors. (B173-45T). —— (*ibid.*, 351–355); Tentative [A.S.T.M.] Specifications for Bunch-Stranded Copper Conductors for Electrical Conductors (B174–45T). —— (*ibid.*, 356–359); Tentative [A.S.T.M.] Specifications for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes (B189–45T). —— (*ibid.*, 360–364); Tentative [A.S.T.M.] Method of Test for Resistivity of Copper and Copper Alloy Electrical Conductors (B193–45T). —— (*ibid.*, 365–369); Tentative [A.S.T.M.] Specifications for Brass Sheet and Strip (B36–46T). —— (*ibid.*, 370–376); Tentative [A.S.T.M.] Specifications for Leaded-Brass Sheet and Strip (B121–46T). —— (*ibid.*, 377–383); Tentative [A.S.T.M.] Specifications for Cartridge-Brass Sheet, Strip, Plate, Bar, and Discs (B19–46T). —— (*ibid.*, 384–389); Tentative [A.S.T.M.] Specifications for Cartridge-Brass Cartridge-Case Cups (B129–46T). —— (*ibid.*, 390–392); Tentative [A.S.T.M.] Specifications for Gilding-Metal Strip (B130–46T). —— (*ibid.*, 393–398); Tentative [A.S.T.M.] Specifications for Gilding-Metal Bullet Jacket Cups (B131–46T). —— (*ibid.*, 399–401); Tentative [A.S.T.M.] Specifications for Copper–Nickel–Zinc and Copper–Nickel Alloy Sheet and Strip (B122–46aT). —— (*ibid.*, 402–408); Tentative [A.S.T.M.] Specifications for Aluminium-Bronze Sheet and Strip (B169–46T). —— (*ibid.*, 409–413); Tentative [A.S.T.M.] Specifications for Beryllium-Copper Alloy Strip (B194–46aT). —— (*ibid.*, 414–417); Tentative [A.S.T.M.] Specifications for Beryllium-Copper Alloy Strip, Special Grade (B195–46T). —— (*ibid.*, 418–421); Tentative [A.S.T.M.] Specifications for Copper Sheet, Strip, and Plate (B152–46T). —— (*ibid.*, 422–428); Standard [A.S.T.M.] Specifications for Rolled Copper Alloy Bearing and Expansion Plates for Bridge and Other Structural Uses (B100–46). —— (*ibid.*, 71–73); Standard [A.S.T.M.] Specifications for Phosphor-Bronze Sheet and Strip (B103–46). —— (*ibid.*, 74–80); Standard

[A.S.T.M.] Specifications for Copper–Silicon Alloy Plate and Sheet for Pressure Vessels (B96–46). —— (*ibid.*, 81–83); **Standard [A.S.T.M.] Specifications for Copper–Silicon Alloy Sheet and Strip for General Purposes (B97–46).** —— (*ibid.*, 84–88); **Standard [A.S.T.M.] Specifications for Copper Plates for Locomotive Fireboxes (B11–46).** —— (*ibid.*, 89–91); **Standard [A.S.T.M.] Specifications for Copper Alloy Condenser-Tube Plates (B171–46).** —— (*ibid.*, 92–95); **Standard [A.S.T.M.] Specifications for Lead-Coated Copper Sheets (B101–40).** —— (*ibid.*, 96–98); **[A.S.T.M.] Standard Hardness-Conversion Table for Cartridge Brass (E33–42).** —— (*ibid.*, 324–326); **Tentative [A.S.T.M.] Method of Alternate-Immersion Corrosion Test of Non-Ferrous Metals (B192–44T).** —— (*ibid.*, 780–792); **Tentative [A.S.T.M.] Method of Total-Immersion Corrosion Test of Non-Ferrous Metals (B185–43T).** —— (*ibid.*, 793–802); **Standard [A.S.T.M.] Specifications for Copper Rods for Locomotive Staybolts (B12–46).** —— (*ibid.*, 99–100); **Standard [A.S.T.M.] Specifications for Free-Cutting Brass Rod and Bar for Use in Screw Machines (B16–46).** —— (*ibid.*, 101–105); **Standard [A.S.T.M.] Specifications for Copper–Silicon Alloy Rods, Bars, and Shapes (B98–46).** —— (*ibid.*, 106–111); **Standard [A.S.T.M.] Specifications for Copper–Silicon Alloy Wire for General Purposes (B99–46).** —— (*ibid.*, 112–115); **Standard [A.S.T.M.] Specifications for Copper and Copper-Base Alloy Forging Rods, Bars, and Shapes (B124–46).** —— (*ibid.*, 116–118); **Standard [A.S.T.M.] Specifications for Brass Wire (B134–46).** —— (*ibid.*, 119–123); **Standard [A.S.T.M.] Specifications for Manganese-Bronze Rods, Bars, and Shapes (B138–46).** —— (*ibid.*, 124–129); **Standard [A.S.T.M.] Specifications for Leaded Red-Brass (Hardware Bronze) Rods, Bars, and Shapes (B140–46).** —— (*ibid.*, 130–133); **Standard [A.S.T.M.] Method of Mercurous Nitrate Test for Copper and Copper Alloys (B154–45).** —— (*ibid.*, 134–136); **Tentative [A.S.T.M.] Specifications for Naval-Brass Rods, Bars, and Shapes (B21–46aT).** —— (*ibid.*, 429–433); **Tentative [A.S.T.M.] Specifications for Copper Bus-Bars, Rods, and Shapes (B187–46T).** —— (*ibid.*, 434–439). **Tentative [A.S.T.M.] Specifications for Beryllium-Copper Alloy Rod and Bar (B196–46aT).** —— (*ibid.*, 440–444); **Tentative [A.S.T.M.] Specifications for Beryllium-Copper Alloy Wire (B197–46aT).** —— (*ibid.*, 445–447); **Tentative [A.S.T.M.] Specifications for Copper–Nickel–Zinc Alloy Wire (B206–46aT).** —— (*ibid.*, 448–453); **Tentative [A.S.T.M.] Specifications for Copper Rods, Bars, and Shapes (B133–46aT).** —— (*ibid.*, 454–459); **Tentative [A.S.T.M.] Specifications for Phosphor-Bronze Rods, Bars, and Shapes (B139–46aT).** —— (*ibid.*, 460–465); **Tentative [A.S.T.M.] Specifications for Aluminium-Bronze Rods, Bars, and Shapes (B150–46aT).** —— (*ibid.*, 466–470); **Tentative [A.S.T.M.] Specifications for Copper–Nickel–Zinc Alloy Rod, Bar, and Wire (B151–46aT).** —— (*ibid.*, 471–476); **Tentative [A.S.T.M.] Specifications for Phosphor-Bronze Wire (B159–46aT).** —— (*ibid.*, 477–479); **Tentative [A.S.T.M.] Methods of Preparation of Micrographs of Metals and Alloys (E2–44T).** —— (*ibid.*, 803–813); **Standard [A.S.T.M.] Specifications for Copper and Copper Alloy Seamless Condenser Tubes and Ferrule Stock (B111–46).** —— (*ibid.*, 137–141); **Standard [A.S.T.M.] Specifications for Seamless Copper Boiler Tubes (B13–41).** —— (*ibid.*, 142–144); **Standard [A.S.T.M.] Specifications for Copper Pipe, Standard Sizes (B42–46).** —— (*ibid.*, 145–148); **Standard [A.S.T.M.] Specifications for Seamless Copper Tubing, Bright Annealed (B68–46).** —— (*ibid.*, 149–152); **Standard [A.S.T.M.] Specifications for Copper Water Tube (B88–46).** —— (*ibid.*, 153–157); **Standard [A.S.T.M.] Specifications for Seamless Brass Boiler Tubes (B14–18).** —— (*ibid.*, 158–160); **Standard [A.S.T.M.] Specifications for Red-Brass Pipe, Standard Sizes (B43–46).** —— (*ibid.*, 161–164); **Tentative [A.S.T.M.] Specifications for Seamless Copper Tubes (B75–46aT).** —— (*ibid.*, 480–485); **Tentative [A.S.T.M.] Specifications for Miscellaneous Brass Tubes (B135–46aT).** —— (*ibid.*, 486–491); **Tentative [A.S.T.M.]**

Specifications for Copper Bus-Pipes and Tubes (B188–46T). —— (*ibid.*, 492–497); Standard [A.S.T.M.] Method of Test for Expansion (Pin Test) of Copper and Copper Alloy Tubing (B153–45). —— (*ibid.*, 165–166); Tentative [A.S.T.M.] Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (B30–45T). —— (*ibid.*, 498–502); Standard [A.S.T.M.] Classification of Cast Copper-Base Alloys (B119–45). —— (*ibid.*, 167–170); Standard [A.S.T.M.] Specifications for Steam or Valve Bronze Castings (B61–46). —— (*ibid.*, 171–173); Standard [A.S.T.M.] Specifications for Composition-Brass or Ounce Metal Castings (B62–46). —— (*ibid.*, 174–176); Standard [A.S.T.M.] Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B66–46). —— (*ibid.*, 177–179); Standard [A.S.T.M.] Specifications for Car and Tender Journal Bearings, Lined (B67–46). —— (*ibid.*, 180–182); Tentative [A.S.T.M.] Specifications for Bronze Castings for Turntables and Movable Bridges and for Bearing and Expansion Plates of Fixed Bridges (B22–46T). —— (*ibid.*, 503–505); Tentative [A.S.T.M.] Specifications for Leaded High-Strength Yellow Brass (Manganese Bronze) Sand Castings (B132–46T). —— (*ibid.*, 506–508); Tentative [A.S.T.M.] Specifications for Tin-Bronze and Leaded Tin-Bronze Sand Castings (B143–46T). —— (*ibid.*, 509–512); Tentative [A.S.T.M.] Specifications for High-Leaded Tin-Bronze Sand Castings (B144–46T). —— (*ibid.*, 513–516); Tentative [A.S.T.M.] Specifications for Leaded Red-Brass and Leaded Semi-Red-Brass Sand Castings (B145–46T). —— (*ibid.*, 517–520); Tentative [A.S.T.M.] Specifications for Leaded Yellow-Brass Sand Castings for General Purposes (B146–46T). —— (*ibid.*, 521–524); Tentative [A.S.T.M.] Specifications for High-Strength Yellow-Brass (Manganese Bronze) and Leaded High-Strength Yellow-Brass (Leaded Manganese Bronze) Sand Castings (B147–46T). —— (*ibid.*, 525–528); Tentative [A.S.T.M.] Specifications for Aluminium-Bronze Sand Castings (B148–46T). —— (*ibid.*, 529–532); Tentative [A.S.T.M.] Specifications for Leaded Nickel-Brass (Leaded Nickel-Silver) and Leaded Nickel-Bronze (Leaded Nickel Silver) Sand Castings (B149–46T). —— (*ibid.*, 533–536); Tentative [A.S.T.M.] Specifications for Silicon-Bronze and Silicon-Brass Sand Castings (B198–46T). —— (*ibid.*, 537–540); Tentative [A.S.T.M.] Recommended Practice for Preparing Tension-Test Specimens for Copper-Base Alloy Castings (B208–46T). —— (*ibid.*, 541–543); Tentative [A.S.T.M.] Specifications for Copper-Base (Brass) Alloy Die-Castings (B176–42T). —— (*ibid.*, 671–672); Tentative [A.S.T.M.] Methods of Radiographic Testing of Metal Castings (E15–39T). —— (*ibid.*, 860–864); Tentative [A.S.T.M.] Industrial Radiographic Terminology for Use in Radiographic Inspection of Castings and Weldments (E52–45T). —— (*ibid.*, 872); Standard [A.S.T.M.] Specifications for Brazing Solder (B64–43). —— (*ibid.*, 206–207).

ALUMINIUM AND ITS ALLOYS

Tentative [A.S.T.M.] Specifications for Aluminium for Use in Iron and Steel Manufacture (B37–46T). —— (*Book of A.S.T.M. Standards*, 1946, (Pt. 1B), 544–545); Tentative [A.S.T.M.] Specifications for Aluminium-Base Alloys in Ingot Form for Sand Castings, Die-Castings, and Permanent-Mould Castings (B179–46T). —— (*ibid.*, 546–548); Tentative [A.S.T.M.] Specifications for Aluminium-Base Alloy Sand Castings (B26–46T). —— (*ibid.*, 549–555); Tentative [A.S.T.M.] Specifications for Aluminium-Base Alloy Permanent-Mould Castings (B108–46T). —— (*ibid.*, 556–559); Tentative [A.S.T.M.] Specifications for Aluminium and Aluminium Alloy Bars, Rods, and Wire (B211–46T). —— (*ibid.*, 560–565); Tentative [A.S.T.M.] Specifications for Aluminium and Aluminium Alloy Sheet and Plate (B209–46T). —— (*ibid.*, 566–574); Tentative [A.S.T.M.] Specifications for Aluminium Sheet and Plate for Use in Welded Pressure Vessels. (B178–46T). —— (*ibid.*, 575–578); Tentative [A.S.T.M.] Specifications for Aluminium–Manganese Alloy Sheet and Plate

for Use in Welded Pressure Vessels (B126–46T). —— (*ibid.*, 579–582); **Tentative [A.S.T.M.] Specifications for Aluminium Alloy Drawn Seamless Tubing (B210–46T).** —— (*ibid.*, 583–586); **Tentative [A.S.T.M.] Specifications for Aluminium and Aluminium Alloy Metal Arc-Welding Electrodes (B184–43T).** —— (*ibid.*, 587–590); **Standard [A.S.T.M.] Specifications for Aluminium Ingots for Remelting (B24–46).** —— (*ibid.*, 183–184); **Standard [A.S.T.M.] Method of Test for Dielectric Strength of Anodically Coated Aluminium (B110–45).** —— (*ibid.*, 185–186); **Standard [A.S.T.M.] Method of Test for Sealing of Anodically Coated Aluminium (B136–45).** —— (*ibid.*, 187); **Standard [A.S.T.M.] Method of Test for Weight of Coating on Anodically Coated Aluminium (B137–45).** —— (*ibid.*, 188–189); **Tentative [A.S.T.M.] Specifications for Aluminium-Base Alloy Die-Castings (B85–46T).** —— (*ibid.*, 669–670).

MAGNESIUM AND ITS ALLOYS

Standard [A.S.T.M.] Specifications for Magnesium Ingot and Stick for Remelting (B92–45). —— (*Book of A.S.T.M. Standards*, **1946**, (Pt. 1B), 190–191); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloys in Ingot Form for Sand Castings, Die-Castings, and Permanent-Mould Castings (B93–45T).** —— (*ibid.*, 591–592); **Tentative [A.S.T.M.] Specifications for Mangesium-Base Alloy Sand Castings (B80–45T).** —— (*ibid.*, 593–596); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Permanent-Mould Castings (B199–45T).** —— (*ibid.*, 597–599); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Bars, Rods, and Shapes (B107–45T).** —— (*ibid.*, 600–603); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Forgings (B91–45T).** —— (*ibid.*, 604–606); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Sheet (B90–46T).** —— (*ibid.*, 607–609); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Extruded Round Tubing (B217–46T).** —— (*ibid.*, 610–613); **Tentative [A.S.T.M.] Specifications for Magnesium-Base Alloy Die-Castings (B94–44T).** —— (*ibid.*, 673–674).

ZINC, LEAD, AND TIN

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XXIII.—MISCELLANEOUS

Aluminium Developments. Some Aspects of Progress. S. A. J. Sage (*Metallurgia*, 1947, **35**, (208), 193–196; correspondence, (210), 297).—War-time technical progress in the extraction and fabrication of aluminium is reviewed. It was found possible to produce aluminium of 99·997% purity for high-strength alloys, of which new varieties were developed. These could be clad with high-purity aluminium or a 1%-zinc alloy, to prevent corrosion. Other notable developments were in the field of surface finishing, X-ray inspection technique, and rolling.—M. A. V.

Digest of Specifications for Zinc and Zinc Alloys. Robert S. Burpo, Jr. (*Materials and Methods*, 1947, **25**, (1), 117).—Data sheet.—J. L. T.

***An Illusion of Size [of Metallic Coins].** Robert Weil (*Phil. Mag.*, 1947, [vii], **37**, (272), 643–648).—According to Loewenstein (*Nature*, 1945, **155**, 672), bright and dull threepenny pieces appear to differ in size, the duller being the larger. A white background is said to invert the phenomenon, while a dark or neutral background shows it more clearly. Hartridge (*Nature*, 1945, **156**, 118) suggested a physical explanation, and criticized interpretations based on psychological grounds. The effect is examined for different coins under different conditions of illumination, background, surface condition, &c., using a number of independent observers. It is improbable that the effects can be explained by considering the way in which the edges of the coin enter into the problem, and Loewenstein's suggestion of a psychological basis for the phenomenon must be considered further.—W. H.-R.

Metals, Minerals, and Research. Clyde Williams (*Trans. Canad. Inst. Min. Met.*, 1947, **50**, 131–137 (in *Canad. Min. Met. Bull.*, 1947, (**419**)); and *Min. and Met.*, 1947, **28**, (483), 140–143).—An address. W. reviews metallurgical advances made during the war and emphasizes the importance of research in the future.—N. B. V.

Industrial Research. (Sir) Clifford Paterson (*Engineer*, 1947, **183**, (4755), 215).—A speech at the 1947 annual luncheon of the Parliamentary and Scientific Committee.—J. L. T.

The Metallurgist Aids the Chemist. L. Sanderson (*Machinery Lloyd*, 1946, **18**, (24), 103–105).—S. summarizes many war-time developments, including the development of a new gas-turbine alloy containing chromium 33·3, molybdenum 30·8, and iron 35·9%. Zinc in contact with steel at high temp. causes rapid corrosion. Pliability of hot-dipped zinc coatings on steel is improved by an initial roughening of the steel surface. A brilliant multi-coloured electroplate has been obtained from a solution of 20 g./l. ammonium molybdate with 1 g./l. sodium cyanide. Adhesion of tin bearings is improved by the initial tinning of the steel backing piece with a solid solution of tin–antimony compound in lead, which is capable of dissolving up to 7% iron.
—H. Pl.

Isotopes in Chemistry and Metallurgy. Hugh S. Taylor (*Metal Progress*, 1946, **49**, (6), 1207–1208).—Urey's discovery of the heavy isotope of hydrogen led to rapid developments in this field, 277 stable isotopes, 9 naturally occurring radio-elements, and 370 isotopes in which the product nucleus was not stable having been observed by 1940. Large-scale separation of isotopes of both light and heavy elements was achieved during the war on an industrial scale, and the corresponding separations of intermediate stable isotopes should also become practicable. Neutrons, now available as a result of nuclear-fission processes, may in future be used for the bombardment of atoms. Applications of isotopes include: (1) the elucidation of the mechanism of the ammonia synthesis and of the role of catalysts in synthesizing hydrocarbons; (2) the use of radio-active isotopes in tracer techniques, e.g. in investigating reactions between gases and solids, grain-growth, diffusion through lattices and along crystal boundaries, alloy structures, &c.; (3) in industrial analysis, especially in automatic and recording methods, problems of fuel flow, and low-pressure work, e.g. in tracing leaks.—P. R.

Physics; Aeronautical Investigations; Industrial Chemistry; Radio-Physics; Lubricants and Bearings; Building Materials Research; Other Investigations. —— (*19th Ann. Rep. Council Sci. Indust. Research, Australia*, **1945**, 90–128).—A statement is made of all the researches conducted for the Australian Council for Scientific and Industrial Research during 1945, and accounts are given of work in progress. No detailed results are given, but a *bibliography* dealing with the results of the research is included.—H. J. A.

Autumn Meeting of the Société Française de Métallurgie (Paris, October 1946). —— (*Tech. Moderne*, 1947, **39**, (5/6), 101–104).—Summaries of these papers are given: *A. Jaquerod*, "Deviations from Hooke's Law; a Method to Determine Them Experimentally"; *L. Guillet*, "Influence of Structure and Chemical Composition on the Damping Capacity of Some Copper Alloys"; *P. Lacombe*, "On a New Method of Preparing Single Crystals of Super-Purity Aluminium"; *P. Lacombe* and *L. Beaujard*, "Contribution to the Micrographic Study of the Hardening and Recrystallization of Super-Pure Aluminium"; *J. Hérenguel*, "Study of the Intergranular Cohesion of Al–Zn–Mg Alloys. Its Relation to Corrosion under Tension"; *P. Morize*, *P. Lacombe*, and *G. Chaudron*, "The Physico-Chemical Properties of Electrolytically Polished Surfaces"; *L. Jenicek*, "Experimental Study of Metallic Diffusion by the Thermomagnetic Method"; *M. Paič*, "X-Ray Study of the Structure of Al–Pb and Al–Pb–Mg Alloys".—J. L. T.

New Metals for Old. (Sir) Edward Appleton (*J. Inst. Brit. Found.*, 1947, **1**, (5), 40–42; also *Found. Trade J.*, 1947, **82**, (1608), 185–191; and *Engineering*, 1947, **164**, (4251), 69; (4252), 90–91).—The 1947 Edward Williams Lecture to the Institute of British Foundrymen.—J. E. G.

Presidential Address [to the Institute of British Foundrymen]. Percy H. Wilson (*Found. Trade J.*, 1947, **82**, (1607), 163–166; and *Engineering*, 1947, **164**, (4250), 30–31).—J. E. G.

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XXV.—BOOK REVIEWS

Introduction to Electron Optics. The Production, Propagation, and Focusing of Electron Beams. By V. E. Cosslett. Med. 8vo. Pp. xii + 272, with 155 illustrations. 1946. Oxford: Clarendon Press. (20*s.* net.)

In these days, it is impossible to wander very far afield in Research or Industry without coming across some electronic device or other doing very useful work. The appearance of a book of this type about electron optics is therefore to be sincerely welcomed. When reviewing a book for a metallurgical journal, the reviewer is expected to indicate whether it is a good book, and whether it is of primary interest to the bulk of the metallurgical profession. The answers to these two questions in the present case are respectively "Yes" and "No". The book is written primarily for students of physics, and is based upon a series of lectures given at Oxford to undergraduates in their final year of the Honour School of Physics. The treatment is intermediate between that usually adopted in the most comprehensive treatises, and that found in short monographs for readers who are already familiar with the fundamentals of the subject, and thus fills a gap in the literature previously available to students. Though not excessively mathematical, the book assumes a good grounding in the calculus.

In the first 147 pages, the fundamentals of the theory of electron motion in electromagnetic and electrostatic fields are carefully and adequately presented. The characteristics of the electromagnetic and electrostatic lenses are discussed, and methods of calculating the field distribution in such lenses, and the path of an electron subject to these fields, are given. Except for relatively simple cases, the mathematics is prohibitively complicated, so that use must be made of experimental measurements with models such as the electrolytic trough and the gravitational model, which are interestingly described. Electromagnetic and electrostatic focusing are considered in detail, together with the determination of focal lengths.

Images formed by electron lenses are subject to a number of aberrations. The book contains a very clear treatment of the general problem, with specific sections on spherical and chromatic aberrations, distortion, curvature of the field and astigmatism, and coma; there is a brief discussion of the problem of correction. To each chapter is appended a *bibliography* for the student who wishes to go into the subject more deeply.

The remainder of the book (some 120 pages) is devoted to a description of a selection of the many modern industrial and research appliances which rely on electron optics, including the electron microscope, electron-diffraction apparatus, and the cathode-ray tube Here the treatment appears to be occasionally too superficial, but the text is interesting throughout. The reader who is not too up to date in his knowledge of the junior members of the "thingummytron" family will be introduced to several of them here. The reviewer must confess (though hardly with shame, since it does not sound too respectable) that he himself had never met the "Rhumbatron". Devices used in radar and television are also included.

An Appendix of 14 pages is devoted to the main principles of the Hamiltonian mathematical methods, since these afford one of the most useful approaches to advanced electro-optical theory.

While the book is really a relatively detailed introduction for the physics student, it is well worth the study of the general scientific reader who has an interest in the subject of electron optics. Research workers in any branch of science who have to employ electronic devices in their work will also find the book useful, though detailed monographs on the use of the more usual electronic tools are in most cases already available.—G. V. Raynor.

Thorpe's Dictionary of Applied Chemistry. Edited by M. A. Whiteley. Fourth edition (revised and enlarged). **Vol. VIII.—Meth.–Oils, Essential.** With an index by J. N. Goldsmith. Med. 8vo. Pp. viii + 679, illustrated. 1947. London: Longmans, Green, and Company, Ltd. (80*s*. net.)

The new edition of "Thorpe", completely rewritten, goes from strength to strength. The present volume will, no doubt, appeal particularly to organic chemists for its masterly monographs on methylanthracene (35 pp.) and naphthalene (176 pp.); but every metallurgical chemist will find the articles on drop reactions in microchemistry and on microchemical operations (by Prof. L. S. Theobald and the late W. F. Boston, respectively) first-rate as authoritative up-to-date surveys of this important field of analysis. The monograph on "minerals and X-ray analysis", by Dr. F. A. Bannister, is a model of conciseness and includes a comprehensive annotated table, compiled from the literature up to the end of 1940, with X-ray data of about 300 minerals. There is an excellent account of the electron microscope by Prof. E. F. Burton, but optical microscopy, somewhat surprisingly, is not treated. Prof. Byron A. Soule, of the University of Michigan, contributes an article on nomenclature and chemical literature which will, it may be hoped, be widely read. The strictly metallurgical entries include articles on molybdenum, "Monel" metal, and nickel, and appear, on the whole, to be adequate; although that on molybdenum is not as up to date as might be expected and contains some loose writing and a few curious statements. It is, for instance, not easy to understand why "rapid heating" should be a characteristic of a molybdenum-wound furnace; and although molybdenum may have been proposed by some early enthusiast for jewellery purposes, it is certainly not generally regarded as a good substitute for platinum. These are very minor matters, however; this is a most excellent volume.—J. C. Chaston

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