P. 99/LXXIII The Journal of the INSTITUTE OF METALS 172

and

METALLURGICAL ABSTRACTS



In this Issue:

1036. Some Factors in the Reduction of the Iron Content of Magnesium-Base Alloys. F. A. Fox, C. J. Bashrod, and S. E. Mayer

- 1037. A New Aluminium-Rich Phase in the Alloys of Aluminium and Manganese. (Miss) K. Little, G. V. Raynor, and W. Hume-Rothery
- 1038. The Influence of Composition on the Adhesion of Tin-Base Bearing Alloys to Steel. P. G. Forrester and L. T. Greenfield

OCTOBER 1946

Entered at Stationer's Hall

Copyright

PAGE

55

83

91

CHROMIUM

BRONZE

(Protected by British Patents 445620 and 473970)

FOR

LOW RATE OF WEAR HIGH RESISTANCE TO SHOCK HIGH FATIGUE STRENGTH IN

BEARINGS AND SLIDING MEMBERS

FORGED • ROLLED • EXTRUDED D.T.D. 354

> SAND CASTINGS AND CENTRIFUGAL CASTINGS

J. STONE & Cº LTD DEPTFORD · LONDON · S·E·14 ANY SIZE OR SHAPE UP TO TWELVE INCHES DIAMETER CONTINUOUS LENGTHS UP TO SIXTY FIVE FEET

ALUMIN

Why not use extrusions

to cut production costs

ALUMINIUM Alloys are of fine appearance, well endowed to repel corrosion, and cover a wide strength range. They are ideal for forming by extrusion.

Extruded sections in an almost limitless range of shapes can be produced quickly and cheaply costs of special dies are low. Continuous extrusions up to 65 ft. long are produced in many alloys

and they may be readily manipulated to any desired form without risk of fracture or distortion.

a

In many industries,

Manufacturers have learned from practical experience that Aluminium Alloy extrusions can substantially reduce production costs, eliminate costly machining, simplify assembly methods and increase output.

ALLOYS

If you have a tricky problem that might be solved by the use of

> Aluminium extrusions, you are invited to write to the Aluminium Development Association for helpful advice and technical data.

THE ALUMINIUM DEVELOPMENT ASSOCIATION 67 BROOK STREET · LONDON · W.I. Tel: MAYFAIR 7501/8

"ANALOID" (reg'd.) SYSTEM of RAPID ANALYSIS

New Development : RAPID METHODS USING SPEKKER ABSORPTIOMETER

for det. Si, Mn, Cu, Ni, Fe, Ti in ALUMINIUM ALLOYS

also Si, Mo, Mn, Cr, V, Ni in STEEL, IRON

Send for Booklet No. 321 to RIDSDALE & CO., LTD. 234 Marton Rd., Middlesbrough

BUREAU OF ANALYSED SAMPLES, Ltd.

Send for List of ANALYTICALLY STANDARDIZED SAMPLES (FERROUS AND N/F) FOR ORDINARY WET ANALYSIS

also for preparing graphs for SPEKKER ABSORPTIOMETER Photo-electric methods

234 Marton Rd., Middlesbrough

M.S.3a.R

BEING A

MOVE AHEAD

It has always been our policy to anticipate the metallurgical and engineering problems that arise in industry. Modern and fully-equipped research laboratories, highly-qualified metallurgists provide the means. A substantial contribution towards the solution of vital and intricate war-time problems is one result. Another lies in the assistance we can give in the development of new and improved peace-time products.

THE MOND NICKEL COMPANY LTD GROSVENOR HOUSE, PARK LANE, LONDON, W.1



THIS APPARATUS MAKES POTENTIOMETRIC TITRATION EASIER THAN TITRATION BY COLOUR INDICATOR

With this Mullard Electronic Potentiometric Unit, a robust 'magic-eye' tuning indicator replaces the usual fragile galvanometer. No external battery is needed. Drift, a frequent bug-bear with such apparatus, has been entirely overcome by an ingenious new circuit. The apparatus is unaffected by changes in the supply-mains' voltage, and is equally suitable for research laboratory or factory use. A complete Titration Unit for use in conjunction with the above can also be offered, For further particulars write to:

The Mullard Wireless Service Company Limited,



Mullard MEASURING APPARATUS

(116D)

Measuring Apparatus Section, Century House, Shaftesbury Avenue, London, W.C.2.



GNOME PHOTOGRAPHIC PRODUCTS LIMITED

THE "SUPER" $7'' \times 5''$ ENLARGER

presents a successful combination of Enlarger. Copying Camera with self contained Lighting Outfit and Epidiascopic Printer using Paper Negative Attachment.

The specification includes all main components machined aluminium castings, double optical condensers, 2 lenses 7" and 5.3" in rotating turret, adjustable baseboard for correction of perspective error, film and plate carrier, double extension bellows and many other interesting and original features.

Write for fully illustrated catalogue showing complete range to

21a, WORKING STREET, CARDIFF



Static testing of materials should be supplemented by dynamic tests resembling as closely as possible the operating conditions.

Designers should verify experimentally whether the stressed specimen falls within the Wöhler range, thus assuring safe loading and long life.

The Avery 7301 (73/3051) 'Pulsator' is designed to carry out such tests.

Specimens of material of various shapes can be accommodated, and by the use of special tools, tests can be carried out on a variety of finished parts.



Write for booklet T 2062 to W. & T. AVERY, LIMITED • SOHO FOUNDRY • BIRMINGHAM, 40



ELECTRIC LABORATORY FURNACES

TWO RANGES 1350°C.

1800°C.

SIEMENS-SCHUCKERT (GREAT BRITAIN) LTD GREAT WEST ROAD BRENTFORD, MIDDX

Laboratory Type Muffle Furnace Type GM 6/4/3. Max. Temperature 1350°C Telephone: Ealing 1171-5 Telegrams: Siemensdyn, Brentford



RESISTANCE THERMOMETER CONTROLLER FOR CREEP TESTS, ETC.

This is a purely electronic controller giving an output proportional to the deviation of the temperature from the desired value. It operates up to 800° C. with a platinum resistance-thermometer. Sensitivity one part in 5000.

Primarily developed to control the tem-

perature of creep tesi specimens, the SUNVIC RESISTANCE THERMOMETER CONTROLLER is suitable for high accuracy work within the range covered by platinum and nickel resistance thermometers. For details, please request technical publication RT 10 50.

SUNVIC CONTROLS LTD., Stanhope House, Kean Street, London, W.C.2.

MULLARD-B.T.L. POTENTIOMETRIC TITRATION APPARATUS

An entirely new instrument for potentiometric titrations, an outstanding feature of which is the incorporation of an electric beam indicator as an indicating device in place of a needle galvanometer.



The components are :

TITRATION UNIT comprises a heavy cast iron stand fitted with two burettes, electrode holders, automatic stirring, hot plate, and "Magic Eye" balance indicator.

POTENTIOMETER UNIT. A potentiometer operating from A.C. mains with a range of 0 to 1,600 mv., sensitive to 2 mv. Also provided with sensitivity switch, polarising current switch, and cathode-ray tube indicator.

ELECTRODES. Five interchangeable electrodes, e.g., two platinum, and one each tungsten, calomel and hydrogen, permitting the use of various electrode combinations.

The apparatus may be used for all types of oxidation-reduction and acid-alkali titrations, and in a limited manner for certain pH determinations.

Further details on request.

BAIRD & TATLOCK (LONDON) LTD. 14-17 ST. CROSS STREET, LONDON, E.C.I

Symbolic of COPPER

BOLTON

The old Egyptian "ankh sign" stands for So, too, does the familiar copper. BOLTON triangle. Behind that symbol stands over 160 years of experiment and success in the production of copper and copper base alloys. In quality of material and in technical refinements, BOLTON'S meet all the requirements of this exacting mechanical age.

COPPER & COPPER-BASE ALLOYS FOR **ELECTRICAL & GENERAL ENGINEERING**

In all forms

WIRE, STRAND, SHEETS, STRIP, TUBES, RODS, COMMUTATOR BARS, FORGED MACHINED COMPONENTS. & Etc.



on your product

sets a stamp

MCKECHNIE

metal technique

A component that starts life as a hot brass stamping has the greater probability of survival. The higher tensile, the smoother, sharper finish and absence of imperfections in the finished part are some of the more obvious advantages.

The best results are obtained if you consult us at the blue print stage.

MCKechnie BROS. LTD.

ROTTON PARK ST., BIRMINGHAM, 16

'Phone : Edgbaston 3581 (7 lines)

Branches : London - 62, Brook Street, Will, Phone: Mayfair 6182(3):4. Leeds — Prudential Buildings, Park Row. Phone: Leeds 23044. Manchester — 509-513, Corn Exchange Buildings, 4. 'Phone: Blackfriars 5094. Newcastle-on-Tyre. 90. Difference from the second on-Tyne—90, Pilgrim Street. 'Phone: Newcastle 22718.



Illustration by Edward Wadsworth, A.R.A.



IN COPPER · BRASS · CUPRO-NICKEL · ALUMINIUM

AND ALL THE USUAL NON-FERROUS METALS

IMPERIAL CHEMICAL INDUSTRIES LIMITED LONDON S.W.I





The balance of advantage..



Photo by courtesy of National Smelting Co., Ltd

L. OERTLING, LTD. 110, Gloucester Place, London, W.1 'Phone: WELbeck 2273 In the long run, the best is cheapest—and Oertling British Assay Balances, acknowledged as the world's best for 100 years, are right up to date in design and performance. Write now for full specifications.



TAS/Or 240



De Havilland Gipsy Queen 71 Engine Crankcase and Top Cover cast in ELEKTRON Magnesium Alloy. Illustration by courtesy of the De Havilland Aircraft Co. Ltd.

Comparative weights Crankcase

119 16. Aluminium -FLEKTRON .

Top Cover 50 J Ib. 333 Ib.

Our engineers are readily available for consultation on new products

80 lb.

STERLING METALS LTD

TELEPHONE: COVENTRY 89031 (& LINES)

TELEGRAMS : STERMET, PHONE, COVENTRY



Pitchfords 2333



THE BRITISH METAL CORPORATION LIMITED

> PRINCES HOUSE. 93 GRESHAM STREET. LONDON, E.C.2 Tel. No, Monarch 8055

47, WIND STREET, SWANSEA Tel. No. Swansea 3166 Tel. No. Central 6441

17 SUMMER ROW. BIRMINGHAM

xiv

ILFORD

INDUSTRIAL X-RAY

PRODUCTS

Trial and error is sometimes the quickest way of solving a technical problem, but in the matter of finding the right sensitive material for any subject in Industrial Radiography, the hard work has already been done by Ilford Limited. As a guide to the comprehensive range offered for this work, the booklet 'Ilford Products for Industrial Applications of X-Rays and Gamma Rays' will be found of great assistance. A copy of it will be gladly sent on request.



ILFORD

ILFORD X-RAY FILMS

Industrial X-ray Film A

A general purpose film for use with or without screens.

Industrial X-ray Film B

A high contrast non-screen film for direct exposures (or with metal screens) for maximum flaw-discrimination.

> Industrial X-ray Film C

A slow fine-grain non-screen film for high resolution in crystallography or in the radiography of light alloys.

ILFORD LIMITED . ILFORD . LONDON



OUR specialised knowledge is offered to you in castings of PHOSPHOR BRONZE, GUNMETAL, ALUMINIUM, MAN-GANESE-BRONZE, and in ALUMINIUM-BRONZE which possesses a Tensile strength of 45 tons per sq. in.

NON-FERROUS

CASTINGS

Fully approved by Admiralty and A.I.D.

* BIRSO ' Chill Cast Rods and Tubes, Centrifugally Cast Worm-Wheel Blanks, Finished Propellers and Precision Machined Parts, Ingot Metals, etc.

B85

xvi

T.M.BIRKETT & SONS LT.P. Hanley, STAFFS. PHONE: STOKE ON TRENT 2184-5-6. 'GRAMS: BIRKETT, HANLEY.



The special methods employed in the production of cored and solid bars by the Spuncast

bars by the Spuncast process are the result of many years of ceaseless research and experiment. The object underlying this research was the production of cored bars which should avoid the defects associated with those produced by the chill cast process. The results fully justified the time spent on their achievement.

BRONZE is specially unique characteristics...

Briefly stated, the outstanding characteristics of Spuncast Holfos Bronze are: Freedom from blowholes, uniformity and density of structure, dimensional accuracy and concentricity of the cored hole, freedom from hard spots and the troubles so frequently met when using sand cores.

SPUNCAST HOLFOS BRONZE ELIMINATES WASTERS IN THE MACHINE SHOP

Write for your copy of the HOLFOS book; it fully explains the production, properties and applications of HOLFOS Bronzes.



R.P.1041C

ALUMINIUM Refuse Bins

BRISTOL'S SUCCESSFUL EXPERIMENT

The Bristol City Transport and Cleansing Department collected refuse in wicker baskets each weighing 15 lb. when new, but finally increasing to about 21 lb.

in weight, due to moisture and adherence of refuse. An aluminium container was designed, tried out and found highly successful. It has half the final weight and many times the life of the wicker basket, and is much more hygienic. Aluminium has the necessary lightness and resistance to corrosion for this job.



We supply aluminium and aluminium alloy sheet, extrusions, castings and forgings, to manufacturers, with whom we are pleased to co-operate. If you have any projects in which aluminium might be used to advantage, write to our Technical Development Department, which has been established to advise and assist you.

WE CAN GIVE YOU FACTS ABOUT ALUMINIUM Northern Aluminium Company Ltd. Banbury. Oxon. Makers of Noral Products



ECONOMICAL HEAT-TREATMENT OF NON-FERROUS METALS

FORCED AIR CIRCULATION FURNACES



Besides rapid heating, the ideal plant for modern requirements should provide absolute uniformity of temperature with precise control of treatment in respect of both temperature and time. In addition, simplicity of operation, low running costs, inexpensive maintenance, and safe and cleanly working conditions are obviously desirable. These features are inherent in Wild-Barfield Electric Furnaces. Especially suitable for tempering, secondary hardening of High-Speed Steels, the heat-treatment of aluminium alloys and other non-ferrous materials.



Diagrammatical representation illustrating the principles of the Vertical Forced Air Circulation Furnace.



FURNACES FOR ALL HEAT-TREATMENT OPERATIONS

WILD-BARFIELD ELECTRIC FURNACES LTD.

ELECFURN WORKS, WATFORD BY-PASS, WATFORD, HERTS. Telephone: WATFORD 6094 (4 lines). Telegrams: ELECFURN, WATFORD

in the manufacture of-



Synthetic Ammonia for Fertilisers. Knowles plant plays a great part by providing electrolytic hydrogen of great purity (99.95%). Such plants are often of considerable size absorbing as much as 25,000 k.w.

In some installations, the Knowles equipment is used on off-peak loads, a convenient and economical arrangement.

Plants in operation all over the world.



THE INTERNATIONAL ELECTROLYTIC PLANT CO. LTD., SANDYCROFT, CHESTER, Esc.





HIND METAL is behind everything from SAUCEPANS to SPITFIRES

Hind Metal is as essential in making the implements of peace as it was in the construction of the tools of war. The quality is consistently good—and will remain so—and the speed and regularity of delivery is, we believe, without equal.

E.HIND (SOUTH) LTD.

SUPPLIERS OF REFINED IRON, NON-FERROUS AND ALUMINIUM ALLOY INGOTS

24 hours delivery in London, Birmingham, Yorkshire & Lancashire areas

Head Office : SOUTH BANK-ON-TEES, YORKSHIRE

London Office: 2 Caxton St., Westminster, S.W.1. Phone: Whitehall 6310 Birmingham Office: 319 County Chambers, Martineau Street, Birmingham, 2 Phone: Central 1075

QUIZ No. 3

"A piece of machinery has become worn. What would you do with it - throw it Well, what would you do, away or . . Mr. Foreman?"



"Throw it away?" Mr. Foreman sounded incredu-lous. "You can't do things like that in business." "Turn it into scrap, then," corrected the Quiz Master. "You don't do that, either," corrected the Quiz Master, "You don't do that, either," answered Mr. Foreman, "Not nowadays, when you can build things up as good as new, if not better, with metal coatings. Mind you, we always have tried to salvage as much worn machinery as possible — by welding and electro-deposition. But welding causes complications because it requires heat, and electro-deposition is slow and you're limited to size. Metal Spraying is the thing. I could write a book about it."

"Why don't you," asked the Quiz Master. "And have people like you throwing it away," snorted Mr. Foreman. "Not blooming likely. In any case Metallisation Ltd. have already written a book. Why not ask them to send you a copy,"



Write to Metallisation Limited for booklets and information. Contracting : Pear Tree Lane, Dudley. Metal Spraying Plants : Sales Office, Barclays Bank Chambers, Dudley



Pyromaster POTENTIOMETER

No moving parts except when a change in temperature calls for movement when response is immediate-therefore no constantly weaving chopper and scissors linkages and no lubrication. The maintenance of a Pyromaster is reduced to a minimum, being restricted to changing charts and occasionally replacing a battery. The Pyromaster design saves you having to invest in stocks of spares in order to keep

it in commission.



Another feature contributing to fine Pyromaster Performance.

Ask for Pyromaster Publication 106 for full details.



KENT ALLOYS LTD.

LIGHT ALLOY CASTINGS

THE MILES MARATHON

L-ASPU

TRO

KENT ALLOYS LTD.

Head Office ROCHESTER • KENT

KA16

Robert Sharp & Partners



The Journal of the INSTITUTE OF METALS

OCTOBER 1946

CONTENTS PAGE

Institute News and Announcements xxvii

- 1037. "A New Aluminium-Rich Phase in the Alloys of Aluminium and Manganese." By (Miss) K.Little, G.V.Raynor and W. Hume-Rothery . 83
- 1038. "The Influence of Composition on the Adhesion of Tin-Base Bearing Alloys to Steel." By P. G. Forrester and L. T. Greenfield .





91

E SPECIAL BRAZING FLUXES

These solders are ideal for jointing most ferrous and nonferrous metals and alloys, including steel. They are quick flowing and produce joints of extreme strength and with great resistance to vibration. The "Thessco" fluxes are specially compounded to simplify and improve jointing processes.





The Unknown Inventor

Somewhere on some worthy site, a fitting monument should be erected to the memory of all those unknown men and women of bygone ages whose inventions have conferred so many benefits of untold value on mankind. Amongst those inventions whose originators are lost in antiquity, none has been more ubiquitous in its use or has proved of greater practical value than the invention of the spiral thread which forms the principle of the screw. Today no principle has wider applications in everyday life-no process in industry is so common as the cutting of threads on screws, nuts, bolts and innumerable other articles. But the cutting of threads involves a machining operation with its attendant production of scrap-and in pressure diecastings, both can frequently be eliminated by the use of Mazak Zinc Alloy. For internal and external threads

can be cast accurately in Mazak. And through this facility, with its saving in metal and machining operations, Mazak has made possible a not inconsiderable step forward in the application of one of those common but invaluable principles which we owe to the unknown inventor.



 IMPERIAL
 SMELTING
 CORPORATION
 LIMITED

 Zinc
 Zinc Alloys
 Zinc Pigments

 95
 GRESHAM
 STREET + LONDON
 EC

October, 1946.

THE INSTITUTE OF METALS

President :

Colonel P. G. J. GUETERBOCK, C.B., D.S.O., M.C., T.D., D.L., J.P., M.A.

Secretary : K. HEADLAM-MORLEY Editor of Publications: Lieut.-Colonel S. C. GUILLAN, T.D.

POLITECHNI

Administrative and Editorial Offices: Telephone: 4 GROSVENOR GARDENS, LONDON, S.W.1. SLOANE 6233

INSTITUTE NEWS AND ANNOUNCEMENTS

1947 MEETINGS

Annual General Meeting.

THE Annual General Meeting of the Institute will take place in London on Wednesday and Thursday, 5 and 6 March 1947. A dinner-dance at the Savoy Hotel will be held on the evening of 5 March and a very interesting series of visits to institutions and works of metallurgical interest has already been arranged for the afternoon of 6 March. In addition, it is hoped that there will be a suitable visit for members' ladies on that afternoon.

Autumn Meeting.

The Council has received from the Committee of the Scottish Local Section, and has accepted with much pleasure, an invitation to hold the Autumn Meeting in Glasgow in September 1947. Dates will be announced later.

PERSONAL NOTES

MAJOR J. C. P. BALL, D.S.O., M.C. (Member of Council), has been appointed a Director of the Distillers Co., Ltd.

MR. J. GRAY BUCHANAN, J.P., Chairman of William Jacks and Co., last month completed his sixtieth year of association with that firm.

MR. A. CHESTER BEATTY and MR. CLIVE COOKSON have been elected members of the first Council of the British Overseas Mining Association.

DR. P. DUNSHEATH, C.B.E., M.A., was appointed Consulting Engineer to W. T. Henley's Telegraph Works Co., Ltd., on his retirement as Chief Engineer to the Company, a post that he has held since 1934. Dr. Dunsheath, who joined the staff of the Company in 1919 and became a Director in 1937, will retain his seat on the Board.

COLONEL P. G. J. GUETERBOCK, C.B., D.S.O., M.C., T.D., J.P., M.A. (President), has recently been appointed Deputy Lieutenant for the County of Gloucestershire.

DR. HAROLD MOORE, C.B.E. (Past-President), expects to travel to India in November and to spend three months at the Tata Iron and Steel Company's works at Jamshedpur. Dr. Moore has undertaken to advise the Company on matters concerning their research organization and its further development. He hopes to resume his work as Registrar of the Institution of Metallurgists about April of next year.

DR. A. L. NORBURY has resigned from the Ministry of Supply to join Arthur J. Harris and Co., Ltd., and its associate company, Dehydrators, Ltd., Great Crosby, Liverpool 23, as Technical Director.

THE HON. R. M. PRESTON, D.S.O., has been elected Vice-President on the first Council of the British Overseas Mining Association.

MR. L. B. ROBINSON has been appointed Managing Director of the Zinc Corporation jointly with Mr. W. S. Robinson (Member of Council), and Managing Director of New Broken-Hill Consolidated. He has resigned from his position as Joint

Managing Director of the Imperial Smelting Corporation.

Note: Will members kindly send the Editor, for inclusion in these columns, notices of their changes of occupation, movements, &c., which will be of interest to their fellowmembers. Such matter should be received at the Institute's editorial offices not later than the 28th day of each month.

Marriage.

LEES-ROBERTSON. On 17 October 1946, at Glasgow, Mr. D. C. G. Lees, M.A., to Miss M. M. J. Robertson.

Death.

The Editor regrets to announce the death on Monday, 30 September 1946, at his home in Birmingham, of Mr. F. M. WHARTON, M.B.E., of the Hall Street Motal Rolling Co., Ltd.

JOINT COMMITTEE ON METALLURGICAL EDUCATION

The Department of Scientific and Industrial Research Advisory Council's "McCance" Report on "The Supply and Training of Metallurgists" was prepared in May 1944. A year later a meeting was held at 4 Grosvenor Gardens, London, S.W.1, at which representatives from the Institute of Metals, the Iron and Steel Institute, and the Institution of Mining and Metallurgy met to consider how several of the suggestions and recommendations made in the McCance Report could best be followed up when normal peace-time conditions were restored. From this first meeting there had emerged by the end of November 1945, the present Joint Committee on Metallurgical Education, on which four leading British metallurgical institutions are now represented as well as University Professors and teachers of metallurgy in Technical Colleges throughout the country.

The Councils of the participating Institutes are thus able to turn for advice on all matters concerning metallurgical education to a truly representative body, and the profession as a whole now has in effect a "voice" which should be able to speak clearly and with authority on its behalf at any time when occasion demands.

Metallurgy: A Scientific Career in Industry.

The Committee has just issued an attractive booklet entitled "Metallurgy: A Scientific Career in Industry," the production of which is the outcome of one of the recommendations of the McCance Report. Although written more particularly for the Headmasters and Schools' Careers' Masters, it is hoped that many parents and scientificallyminded senior boys will also find this booklet stimulating and informative. It contains an Appendix which lists the Universities and Technical Colleges in this country at which fulltime metallurgical courses aro being given.

Apart from the students, the Committee has been impressed by the potential enthusiasm for and interest in metallurgical processes which younger boys often show, and an endeavour is being made to find a suitable author for a special boys' book on metallurgy which would cater for them.

National Certificates in Metallurgy.

The metallurgical institutes have also established a Joint Committee on National Certificates in Metallurgy, and this Committee a year ago announced a scheme in collaboration with the Ministry of Education for the awarding of Ordinary and Higher National Certificates as the result of examination in conjunction with the pursuance of an approved course of part-time study. This scheme is described in detail in a booklet which is obtainable on application to the Secretary, 4 Grosvenor Gardens, London, S.W.I, and is one which the recently-formed Institution of Metallurgists has accepted as a partqualification in considering applications for its Licentiateships and Associateships.

Other Aims.

These educational activities therefore supplement each other but the objects of the Joint Committee on Metallurgical Education are primarily those of publicising the requirements of the industries and the educational bodies alike, and of helping to take such action as will mutually benefit them. To this end a number of proposals are being actively followed up at the present time and include, for example :

(a) Arrangements for parties of schoolboys to visit metallurgical works, and for men actively engaged in industry to visit schools and talk about the operations and processes with which they are connected. In some cases—and, in fact, whenever possible—these lectures and talks could be practically demonstrated.

(b) The compilation of a comprehensive film library of metallurgical films available in this country, from which a special selection of those suitable for youthful audiences would be made. These films can then be shown to school science societies by a lecturer who will be able to include in his visit an informal talk on metallurgy as a career, answer any questions, and present copies of the brochure to boys who had expressed an interest in the subject.

(c) In the case of boys who are seriously considering entering a works directly after leaving school, or in the case of those who are embarking on a further period of whole-time academic training at a University or part-time evening study at a Technical Institute, it has been emphasized that they should whenever possible be encouraged to undergo at least a fortnight's works experience during one of their holidays shortly before leaving school. Very little in the nature of organized schemes has so far been contemplated in this connection, but the indication is that in the future years something of the kind may well be required.

It is significant that in both the McCance Report and that on "Higher

Technological Education " (the Percy Report), published in 1945 by the Ministry of Education, which deals more specifically with the field of industrial technology and engineering, there is unanimous agreement that much remains to be done in this way.

Works-Experience Courses.

In the field of metallurgy, members of the Joint Committee recognize that the spirit of these reports inspires a hope of considerable developments in which they can actively collaborate. They are therefore undertaking a survey of the present practice and views amongst the Universities in regard to vacation works' experience courses for their students. With the expected increase in members who will come forward for such training during the next few years, many works that have so far not ventured to do so will have to be asked to collaborate in providing the facilities of this kind. The Committee hopes to be able to help them considerably with advice and suggestions and will compile a register of those firms who offer to provide courses, as well as give general guidance as to what facilities are particularly desirable. In return, the works would be saved much troublo and correspondence if the students who were going to come to them were recommended by the Committee representing the University Professors for this purpose. In the less numerous but more complicated cases which will arise through an exchange of metallurgical students between works in this country and those abroad, the connections and general preliminary arrangements could nevertheless be appropriately made in a similar way. In particular, the Committee is considering how it can assist with plans for an exchange between English students and those from France and Sweden next year.

Bursaries and Scholarships.

Since it is also the aim of the Joint Committee on Metallurgical Education to take all reasonable steps to provide for and encourage an increasing number of men of a suitable type to become eligible in due course for a thorough training in metallurgy, it is necessary to increase the number

and value of bursaries and scholarships available to metallurgists. The Committee was therefore closely concerned with the announcement which was made on 27 February 1946, in a letter from Sir William Griffiths. Chairman and Managing Director of the Mond Nickel Co., Ltd., that a sum of £50,000 would be made available during the next seven years to endow a number of special "Mond Fellowships." The prime object for which these will be given has been clearly explained in Sir William Griffiths' letter in which he says: "Indecd I am not sure that it is not in this direction rather than in that of the carrying out of research of adequate quality, that this country has in the past been somewhat other countries such as behind America and Germany. Both questions, that of increasing research and that of securing the prompt and effective utilization of research results, are related to a third—that of the availability for executive and administrative posts in industry of men able to appreciate the technological significance of research and its results." A proliminary announcement on this subject has already been made.

In due course the special awards Sub-Committee set up to handle the machinery of the Mond Fellowships, will make a statement and invite applications for the first Fellowships which will be awarded next year.

In April 1946, the services of Dr. Norman Stuart were engaged as Education Officer to assist the Committee with its work : all enquiries relating to this subject should therefore be addressed to him at 4, Grosvenor Gardens, London, S.W.1.

LETTER TO THE EDITOR

DEAR SIR,

It was my pleasure to attend the Autumn Meeting of the Instituto of Motals on 11 September, the first that I have been able to attend for many years. From the last occasion I have the most vivid memory that the Chairman interrupted a member who was making a contribution to the discussion with the comment that ho was obviously reading from notes, a procedure which could not be allowed, as contributions to the oral discussion must be extemporary.

At the recent meeting I was impressed by the strain on the Chairman and, for that matter, on the atmosphere of the meeting by the necessity to cut down contributions and the most disappointing lack of facility for the author to reply. Written comments, as read out, were so long and often so detailed that it was difficult for either author or members to follow all the matters raised.

Would not the re-introduction of a gentlemen's agreement to make only extemporary contributions result in a natural limitation of the matter discussed to important headlines and such saving of time as would enable the authors to make replies as they might wish ?

The facilities for written contributions do make up for any limitations of such procedure.

Yours, etc.,

JOSIAH W. JONES,

Senior Lecturer, Materials and Metallurgy, College of Aeronautics.

Cranfield, Beds. 7 October 1946.

LOCAL SECTIONS NEWS

With a return to more normal conditions the Committees of the Local Sections have been able to plan Section activities on pre-war lines, and attractive programmes have been arranged. Many members will, of course. receive detailed programmes and announcements of their own Sections'

activities, but, for the benefit of a wider circle, the names of the Officers of the Committees and the programmes of meetings and other functions are detailed below. Members from other areas will be particularly welcome at these meetings if their arrangements make it convenient to attend.

The Local Sections have played a very important part in the Institute's development and activities, but the part that they will play in the future is likely to be even more important. It is hoped that there will be large attendances at the Section meetings and that all classes of members will, during the forthcoming session, back up their local Committees and make their Section's winter sessions an outstanding success from the scientific and technical and also from the social points of view.

COMMITTEES

The officers of each of the Local Sections for the session 1946-47 are as detailed below.

Birmingham.

- E. A. Bolton, M.Sc. (Chairman).
- R. Chadwick, M.A., (Vice-Chairman).
- E. H. Bucknall, M.Sc. (Hon. Secretary).
- A. MacArthur (Hon. Treasurer).
- Maurice Cook, D.Sc., Ph.D. (representative on the Co-ordination Committee of the Midland Metallurgical Societies).
- J. A. A. Fraser (Past-Chairman).
- J. W. Jenkin, Ph.D. (Past-Chairman).
- A. Pinkerton (Past-Chairman).
- J. O. Hitchcock, B.Sc.
- W. R. T. King. G. S. G. Primrose, A.R.T.C.
- A. E. Smith (representing Associates).
- F. E. Stokeld.
- B. Thomas.

London.

- J. H. Watson, M.B.E., M.C., Ph.D.,
- A.R.C.S., A.R.S.M. (Chairman).
- W. F. Randall, B.Sc., A.R.S.M. (Vice-Chairman).
- J. D. Grogan, B.A. (Hon. Treasurer).
- E. C. Rhodes, Ph.D., B.Sc. (Hon. Secretary).
- G. L. Bailey, M.Sc.
- John Cartland, M.Sc.
- Bruce Chalmers, D.Sc., Ph.D.
- J. C. Chaston, Ph.D., B.Sc., A.R.S.M.
- F. T. Davis.
- R. G. Harper, M.Sc.
- E. A. G. Liddiard, M.A.
- F. G. Morris.
- A. J. Murphy, M.Sc.
- C. E. Ransley, Ph.D., M.Sc.
- H. G. Warrington.

Scottish.

- A. B. Graham (Chairman).
- A. Craig MacDonald, B.Sc. (Vice-Chairman).
- Professor G. Wesley Austin, O.B.E., M.Sc. (Past-Chairman).
- Matthew Brownlie (Hon. Treasurer).
- Matthew Hay (Hon. Secretary).
- E. H. A. Carlton.
- J. E. Chard, B.Sc., A.R.S.M.
- J. W. Donaldson, D.Sc. S. E. Flack. N. I. Macleod.

- D. Turner.

Sheffield.

- Frank Mason (Chairman).
- H. G. Dalo (Vice-Chairman).
- Major F. Orme, T.D., M.Met. (Hon. Secretary /Treasurer).
- Professor J. H. Andrew, D.Sc. (Past-Chairman).
- T. B. Bowker.
- H. P. Gadsby (representing Associates).
- Kenneth Gray.
- W. R. Maddocks, Ph.D., B.Sc.
- J. H. G. Monypenny.
- S. R. Shutt, Assoc.Met. (representing Associates).

Swansea.

- Harry Davies (Chairman).
- D. W. Hopkins, B.Sc. (Hon. Secretary).
- K. M. Spring (Hon. Treasurer).
- A. Adlington.
- G. L. Evans, B.Sc.
- R. Grenfell.
- Roosevelt Griffiths, M.Sc.
- E. A. Hontoir, B.Sc.
- H. Stone.

PROGRAMMES FOR 1946-47 SESSION

Birmingham.

1940.	
Thurs., 3 Oct.	Open Discussion : "The Drafting and Interpretation of Metallurgical Specifications."
Thurs., 7 Nov.	Mr. H. W. G. Hignett, B.Sc. ; (Subject to be announced later).
Thurs., 28 Nov.	Professor L. Aitchison, D.Met., B.Sc. : "Developments in
the state of the state	Metallurgy at Birmingham University."
Thurs., 5 Dec.	Dr. N. P. Allen, M.Met.: "Creep."
1947.	
Thurs., 2 Jan.	Professor M. L. Oliphant, Ph.D., F.R.S.: "Metallurgical
	Aspects of Atomic Energy."
Thurs., 23 Jan.	Open Discussion : "Scale Removal."
Thurs., 6 Feb.	Mr. Eustace C. Larke: "Some Aspects of Rolling Re- search."
Thurs., 27 Feb.	Mr. C. W. George : "Investigation of Failures."
Thurs., 6 Mar.	Professor F. C. Thompson, D.Met. : " Damping Capacity."
Thurs., 27 Mar.	Exhibition of film, and a talk, on "Drop Forgings" (ar-
	ranged by Deritend Stamping Co., Ltd.).
Thurs., 24 Apr.	Special meeting of the Local Section.

All meetings take place in the Lecture Hall of the James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m. The programme has been arranged jointly by the Midland Metallurgical Societies, comprising —in addition to the Local Section of the Institute of Metals—the Birmingham Metallurgical Society and the Staffordshire Iron and Steel Institute.

London.

1946.	
Thurs., 10 Oct.	Extraordinary General Meeting. Dr. J. H. Watson, M.B.E., M.C., A.R.C.S., A.R.S.M.: "The Purple Alloy of Gold and Aluminium."
Thurs., 14 Nov.	Professor D. Hanson, D.Sc. : "Metallurgical Education"
	7 p.m.).
Fri., 6 Dec.	Supper Dance.
Thurs., 12 Dec.	Dr. L. Northcott: "Centrifugal Casting" (Joint Meeting with Institute of British Foundrymen).
1947.	
Thurs., 9 Jan.	Mr. A. Makower, M.A. : "Lead."
Thurs., 13 Feb.	Mr. F. W. Cuckow : "The Electron Microscope."
Thurs., 13 Mar.	Dr. J. W. Jenkin, B.Sc. : "The Manufacture of Seamless Steel Tubes."
Thurs., 10 Apr.	Annual General Meeting.
	Open Discussion on "New Testing Methods for Metals," introduced by short papers by Mr. H. J. Cuckow, Mr. B. A. Minter and M. D. O. Sarroll, and M. M. S. Sarroll, and M. Sarroll, and
A STREET, MARKEN	R. A. Mintern, and Mr. D. O. Sproule.
A 17 . 7 . 7	

All the above-mentioned functions (including supper-dance) except the meeting on 14 Nov., 1946, will be held at 4, Grosvenor Gardens, S.W.1, at 7 p.m.

Scottish.

1946.

Tues., 17 Sept.

pt. Works visit to Fairfield Shipbuilding and Engineering Co., Ltd., Engineering Dept., Govan, Glasgow, S.W.1, at 2.30 p.m.

1946.	
Mon., 14 Oct.	Mr. P. T. Holligan : "Modern Trends in Bearing Metals."
Mon., 11 Nov.	Mr. S. H. Hawkins: "Temperature Measurement and
	Control."
Mon., 9 Dec.	Mr. J. F. B. Jackson, B.Sc.: "The Importance of Centri-
" augura la s	fugal Casting and Composition in Relation to Gearing
	Bronzes."
1947.	THE PARTY IS A PRIME OF THE AT A PRIME
Mon., 20 Jan.	Brains Trust.
Mon., 10 Feb.	Dr. E. Voce, M.Sc. : "Copper."
Mon., 10 Mar.	Works visit (to be announced later).
Mon., 14 Apr.	Annual General Meeting. Further details to be announced
	later.

The Meetings are held at the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, at 6.30 p.m. A light snack meal is served before each meeting from 6 to 6.30 p.m.

Sheffield.

1947.	
Mon., 20 Jan.	Dr. C. J. Smithells, M.C.: "Recent Developments in the Aluminium Industry" (meeting with Sheffield Society of Engineers and Metallurgists). At Royal Victoria Hotel, Sheffield, at 6.15 p.m.
Fri., 14 Feb.	Details to be announced later. At the Mining Lecture Theatre, Department of Applied Science, The University, St. George's Square, Sheffield, at 7.30 p.m.
Fri., 14 Mar.	Professor H. W. Swift, M.A., D.Sc.: "The Mechanism of Sheet-Metal Drawing" (preceded by demonstrations—in the Engineering Laboratorics of Sheffield University—of apparatus used in the research); Annual General Meeting. At the Mining Lecture Theatre, Department of Applied Science, The University, St. George's Square, Sheffield, at 7.30 p.m.
Swansea.	
1946.	
Tues., 8 Oct. Tues., 29 Oct.	Mr. Harry Davies : Chairman's Address. Mr. W. A. C. Newman, B.Sc., A.R.S.M., A.R.C.S. : "Some Metallurgical Aspects of Minting."
Tues., 19 Nov.	Mr. R. Chadwick, M.A.: "Some Relationships in Com- mercial Light Alloys."
Tues., 10 Dec.	Dr. J. C. Chaston, B.Sc., A.R.S.M. : "Gold and Silver."
1947.	And the second
Tues., 14 Jan.	Professor W. R. D. Jones, D.Sc.: (Subject to be notified later).
Tues., 11 Feb.	Dr. L. B. Pfeil, A.R.S.M.: "Some Aspects of Nickel Alloys for Elevated Temperatures."
Fri., 14 Mar.	Discussion on Fuel Requirements of Metallurgical Processes. (Joint Meeting with the Local Section of the Institute of Fuel.)
Tues., 15 Apr.	Dr. N. P. Allen, M.Met.: "Some Present Aspects of the Creep-Resistance of Alloys."
The meeting	s will be held at the Royal Institution. Victoria Street.

The meetings will be held at the Royal Institution, Victoria Street, Swansea, at 6.30 p.m., except in the case of the meeting to be held on 14 January 1947, which will be held at the Metallurgy Department, University College, Cardiff, at 6.30 p.m.

OTHER NEWS

British Overseas Mining Association.

This Association was incorporated in England on 13 August 1946, with registered offices at 2 and 3 Crosby Square, London, E.C.3. Its objects are to promote and protect the interests of all companies and firms in the United Kingdom engaged in, or interested, directly or indirectly, in mining enterprises overseas, and to act as a representative body to which the British Government can refer on all matters affecting the industry.

Chemical Society Research Fund.

A meeting of the Research Fund Committee of the Chemical Society will be held in November. All persons who have received grants should send in their reports to the Chemical Society not later than I November 1946. Applications for grants must be received on or before I November 1946. The income arising from the Donation of the Worshipful Company of Goldsmiths is principally devoted to the encouragement of research in Inorganic and Metallurgical Chemistry.

Experimental Stress Analysis Group.

At a recent meeting in London the formation was discussed of a Society to concern itself with photoelasticity. A Committee was elected to make arrangements for a meeting within twelve months at which papers will be read and the future constitution of the Group decided. Research workers and others interested in oxperimental stress analysis are invited to communicate with the Hon. Secretary, Mr. E. K. Frankl, Engincering Laboratory, Cambridge.

"Britain Can Make It" Exhibition.

The "Britain Can Make It" Exhibition in London includes a number of exhibits of non-ferrous interest. Among them is "The Sheet Lake," composed of stainless steel, copper, brass, gilding metal, and aluminium sheets, while "trees" fabricated from copper, aluminium, zine, magnesium, and tin make up a suitable background. These are to be seen in Section 2, Group UU.

Appointments Service.

The Ministry of Labour and National Service announces that, by means of a new teleprinter network, vacancies notified by the morning post to any one of their Regional Appointments Offices will now be in all other offices by noon the same day. In most cases, details of suitable candidates registered at Regional Appointments Offices will be on their way to employers on the same day.

Awards to Inventors.

The Royal Commission on Awards to Inventors has issued a pamphlet giving its terms of reference, its rules of proceduro, and general instructions to intending claimants. Copies can be obtained from H.M. Stationery Office, price 3d., post free. The Commission will not begin its public hearings before 12 November 1946.

MEETINGS OF OTHER SOCIETIES

THE CHEMICAL SOCIETY.—Professor G. D. Preston, M.A., Sc.D.: Lecture, "Microscopy with Electrons and X-Rays." (Joint meeting with the Local Section of the Royal Institute of Chemistry to be held at Marischal College, Aberdeen, on Friday, 25 October 1946.)

THE CHEMICAL SOCIETY.—Dr. C. H. Desch, F.R.S. : Lecture, "Chemistry in the Metallurgical Industries." (Joint meeting with the South Yorkshire Section of the Royal Institute of Chemistry, the Sheffield Metallurgical Association, and the University Chemical Society, to be held in the Chemistry Lecture Theatre of Sheffield University on Thursday, 21 November 1946, at 6 p.m.)

INSTITUTE OF WELDING.—The Sir William J. Larke Medal Paper, 1946. (Wednesday, 30 October 1946.)

IRON AND STEEL INSTITUTE.—Autumn Meeting, Wednesday, 13 November 1946. 10 a.m.-12.30 p.m.: Papers on ferrous subjects. 12.45-2.15 p.m.: Buffet Luncheon at London Missionary Society, Livingstone Hall, 42 Broadway, London, S.W.1. 2.30-5 p.m.: Papers on ferrous subjects. 8-9.30 p.m.: Films on ferrous metallurgical subjects. Thursday, 14 November 1946. 9.30 a.m.-12.30 p.m.: Papors on ferrous subjects. 12.45-2.15 p.m.: Buffet Luncheon at London Missionary Society. 2.30-5 p.m.: Papers on ferrous subjects. (Meetings at the Institution of Civil Engineers, Great George Street, London, S.W.1.)

MANCHESTER METALLURGICAL SOCIETY.—Dr. S. J. Kennett, B.Sc., A.R.S.M., D.I.C.: "The Electron Microscope as an Aid to Metallurgy." (Engineers Club, Albert Square, Manchester, Wednesday, 23 October 1946 at 6.30 p.m.)

MANCHESTER METALLURGICAL SOCIETY.-Mr. W. A. Baker, B.Sc.: "Modern Non-Ferrous Foundry Control." (Engineers' Club, Albert Square, Manchester, Wednesday, 6 November 1946, at 6.30 p.m.)

MANCHESTER METALLURGICAL SOCIETY.—Dr. R. Genders, M.B.E.: "Wartime Metallurgical Developments in Great Britain." (Engineers' Club, Albert Square, Manchester, Wednesday, 20 November 1946, at 6.30 p.m.)

APPOINTMENTS REQUIRED AND VACANT.

ALUMINIUM LABORATORIES LIMITED, BANDURY, OXON., invite applications for the position of CHEF LIMRANIAN AND INFORMATION OFFICER, to be responsible for organizing and enlarging library covering metallurgy, physics, chemistry, engineering, geology, and patents. His work would include supervision of central technical files, abstraction, co-ordination, and translation of literature, particularly on the research and development of aluminium and its alloys and their application to industry, also the maintaining of contacts with sources of information in associated companies in other countries. Good language and scientific qualifications are required and will command an appropriate salary.

APPLICATIONS are invited for the position of Chief Metallurgist, Applicants must have practical experience in aircraft light alloys and steels, and their heat and protective treatments. A good knowledge of works' practice is required, which should include fusion and resistance welding. A fully qualified metallurgist is preferred, but is not essential, Applications by letter to Airspeed Ltd., Christchurch, Hants.

APPLICATIONS are invited for a Metallurgist having practical experience in alrepart light alloys and steels and familiar with their heat and protective treatments, and able to carry out routine analyses and checks on works' processes, with some experience in the examination of fusion welds. Candidates need not be fully qualified metallurgists. Applications by letter to Alrspeed Ltd., Christchurch, Hants,

EDITORIAL ASSISTANT (JUNIOR) required for publications of a metallurgical society. Knowledge of metallurgy and of German essential, but previous editorial experience is not necessary. Box No. 178, Institute of Metals, Grosvenor Gardens, London, S.W.1. LEAD SHEET AND PIPE MANUFACTURERS-WORKS MANAGER required, London area; knowledge of improving and refining an advantage. Write fully stating age, experience, and salary required. Box No. 175, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

MANAGER required to take charge of a nonferrous Wire Mill at Birmingham Works of Henry Wiggin & Co., Ltd. Age not to exceed 40 years. Excellent position for experienced man with good organizing ability. Apply, stating experience and salary required, to Managing Director, Wiggin Street, Birmingbam 16.

METALURGISTS, Chemists, or Physicists with metallurgical experience are required for the Research Department, English Electric Company, Limited, Stafford, for senior positions in expanding Metallurgical Laboratory. Salary according to qualifications. Apply Superintendent of Technical Personnel, English Electric Co., Queens House, Kingsway, W.O.2.

SENIOR PHYSICIST required to take charge of Physics section, Research Laboratory, Birmingham, Honours Degree Physics, with at least five years research experience in physical metallurgy. Must have knowledge of modern theory of solids, X-ray crystal analysis, methods of determination of materials and experience in the application of this knowledge to the study of metals and alloys. Evidence of administrative and organizing ability advantageous. Apply to Manager, Development and Research Department, The Mond Nickel Co., Ltd., Grosencon House, Park Lane, London, W.1, stating age, experience, qualifications, salary required, etc. Mark envelope "Confidential S.P."

.

NOTICE TO AUTHORS OF PAPERS

- 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.I.
- 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 and will also be printed in the Journal as soon as possible after the final decision of the Publication Committee to accept 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.*) should 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-ordinates 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., must be 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 24 in. wide (four to a plate); 2 in. deep by 21 in. wide (six to a plate). Magnifications of photomicrographs must be given in each case. Photographs for reproduction should be avoided of each. Lengthy descriptions to photomicrographs should be avoided where possible, owing to the very limited space available on the plates.
- 7. Tables or Diagrams. Results of experiments, &c., may be given in the form of tables or figures, but (unless there are exceptional reasons) not both.
- 8. Overseas Authors. Authors resident in countries distant from Great Britainare requested to name, if possible, agents in Britain to whom may be referred matters concerning their papers, including proofs for correction. Translations from foreign languages should preferably be accompanied by a copy of the MS. in the language of the author.
- 9. Reprints. Individual authors are presented with 50, two authors with 70, and three with 90, reprints (in cover) from the *Journal*. Additional reprints can be supplied at rates to be obtained from the Editor.
SOME FACTORS IN THE REDUCTION OF THE **1036** IRON CONTENT OF MAGNESIUM-BASE ALLOYS.*

By F. A. FOX,[†] M.Sc., MEMBER, C. J. BUSHROD,[‡] M.Sc., and S. E. MAYER,[‡] Ph.D., STUDENT MEMBER.

(55)

SYNOPSIS.

Small quantities of iron, present as an impurity, are removed from magnesium-base alloys by allowing manganese-rich particles to sottle out of the molten alloy. The authors carried out experiments to establish the optimum conditions for this mechanism to operate.

Afthough the removal of iron from magnesium-aluminium alloys is efficiently carried out by the process, particularly if two successive settling operations are employed, it is not so readily accomplished in the case of binary magnesium-manganese alloys. Virgin melts do not give such good results after treatment as do melts containing considerable proportions of secondary ingot, apparently because of the lower initial iron content of the latter.

Possible mechanisms for the iron-removal process are discussed in relation to the results of small, medium and large scale settling experiments.

Additional experiments were carried out to ascertain the most suitable steel for making crucibles for remelting the alloys of low iron content. A high-manganese, high-carbon austenitic steel gave the most interesting results. A "seasoning" effect was detected whereby suspended samples of crucible material appear to contaminate a melt, held in a graphite pot, at a progressively decreasing rate.

Evidence is given in Appendix I to show that the ratio of manganese in solution to that out of solution is of great importance in connection with the corrosion behaviour of the binary magnesium-manganese alloys.

INTRODUCTION.

In previous papers ^{1, 2, 3} two of the authors described experiments on the effect of iron on the rate of corrosion of magnesium alloys. While not all the claims that have been made for low-iron magnesium alloys could be confirmed, it was found that there are certain advantages ³ in a low iron content. The investigations described in the present paper were carried out to establish a procedure, applicable to large-scale production, by which various magnesium alloys could, if desired, be made consistently with iron contents of the order of 0.002%.

In making 2-ton melts of the standard magnesium-aluminium containing alloys (e.g. Elektron A8 and AZ91, conforming to D.T.D.

* Manuscript received April 9, 1946.

† Chief Metallurgist, Magnesium Elektron, Ltd., Clifton Junction, near Manchester.

‡ Formerly Metallurgist, Magnesium Elektron, Ltd., Clifton Junction, near Manchester.

VOL. LXXIII.

F

Specifications Nos. 59A and 136A, respectively *), it was observed at an early date, in the melting shops of Magnesium Elektron, Ltd., and elsewhere, that although metal ingots produced in the early stages of casting had an iron content of approx. 0.025%, there was some variation of iron content in the ingots cast later.

Analyses of ingots selected from production melts of Elektron A8 and AZ91 (several ingots being taken at various stages of pouring of each melt), showed that the iron content progressively decreased from the beginning to the end of the pouring operation, which usually takes about 50 min. These results are summarized in Figs. 1 and 2,



FIG. 1.—Mean Iron Content of Selected Ingots of Eight 2-Ton Melts, Conforming to D.T.D. Specification No. 59A, Taken at Various Stages of Pouring (Scatter, of Results is Indicated). Ingot Samples Taken After Pouring Increasing Amounts of Metal from Beginning to End of Cast.

which show that the iron content of the final ingots was frequently very low (< 0.005%), suggesting that iron was settling out from the melt. This supposition was confirmed by analyses of metal residues

* The nominal compositions of Elektron alloys discussed in this paper are given below :---

		Constituent, Per Cent.			
Elektron Alloy. D.T.D. Specification.		Al.	Zn.	Mn.	
A8 AZ91 AM503 AZM	59A 136A 142A 259	8-0 9-5 6-0	0.5 0.5 1.0	0·3 0·3 1·5 0·3	

the Iron Content of Mg-Base Alloys

recovered from entanglement with flux at the extreme bottom of the large crucibles used, as in these small shots the iron content was always high (sometimes as much as 1.5%), this metal apparently having acted as the receiver for settled iron for all the rest of the melt. It was found that manganese settled similarly, concentrations of this element in metal residues being sometimes as great as 10%.

These observations appeared to show that appreciable settling of



FIG. 2.—Mean Iron Contents of Selected Ingots of Ten 2-Ton Melts, Conforming to D.T.D. Specification No. 136A, Taken at Various Stages of Pouring (Scatter of Results is Indicated). Ingot Samples Taken After Pouring Increasing Amounts of Metal from Beginning to End of Cast.

manganese and iron occurred during the normal production melting cycle; it was probable that the two effects were associated,⁴ and it seemed that it might be possible to control settling in such a way as to produce metal of low iron content by fairly simple modifications of existing melting-shop technique, and, at the same time, to throw light on the mechanisms involved.

EXPERIMENTAL.

For convenience of discussion, the experiments are described in two sections. Section I deals with those on a small and medium laboratory scale, being primarily of exploratory and theoretical interest, and Section II with those on a full-production scale, in which the results of the smaller scale investigations were applied.

As the main object of this work was reduction of the iron content of standard magnesium-base alloys, in the small-scale experiments attention had obviously to be given to the material of the melting crucible. Experience had shown that electrode graphite was a crucible material that would not of itself cause contamination by iron. Tests were necessary with ferrous crucibles, since existing industrial equipment depends largely on the use of steel crucibles.

In earlier experiments, it was found that there was negligible pick-up of iron from the "Melrasal" melting and refining fluxes.* As there was no advantage, therefore, in using high-purity fluxes, as opposed to the standard fluxes, the latter were used throughout the investigation described below.

I.-SMALL-SCALE EXPERIMENTS.

1.—Small-Scale Settling Experiments.

Preliminary small-scale melts were made in both graphite and mild steel crucibles, using about 3 lb. of metal in each case. They were prepared from "Melpure" electrolytic magnesium (for typical analysis, see Table I) and high-purity zinc (99.99%), aluminium (99.99%), and

TABLE I.-Typical Analysis of "Melpure" Magnesium Ingot.

Constituent, Per Cent.									
A].	Al. Zn. Mn. Sl. Cu. Fc. Pb. Sn. Ca. Cd. Ni.								Ni.
0.02 0.002 0.05 0.007 0.005 0.035 0.01 <0.003 <0.004 <0.004 <0.002									

manganese chloride (99.7% purity, with < 0.03% iron), to give an 8% aluminium alloy (Elektron A8) of composition conforming to D.T.D. Specification No. 59A (containing about 0.5% zinc).

The magnesium was melted under a cover of "Melrasal" protective flux, and the alloying materials added at 760° C. The manganese

* Fluxes made under British Patents Nos. 539,023, 561,748, 539,024, 562,597, and 562,636, which may be consulted for the composition ranges. The fluxes used in this investigation had the approx. percentage compositions :

		Melrasal Z.	Melrasal E.
MgCl.		. 11	36
CaCl		. 42	16
NaCI .	THE LEAST	. 27	10
KCl .	- 100 A 4	. 18	7
MgO .			10
CaF ₂ .	1.		19

Balance includes moisture.

the Iron Content of Mg-Base Alloys

chloride additions of from 0.5 to 3.0% (corresponding to approx. 0.2 to 1.3% manganese) were made, and stirred in, after the introduction of the zinc and aluminium. Melts prepared in this way had, immediately after the addition of the manganese chloride, an iron content of about 0.03%. The melt was then refined by stirring in "Melrasal" refining flux, and allowed to stand for settling in the temperature ranges shown in Table II, but without applying the superheating treatment. It was found that the final manganese content of the alloy increased from 0.25 to only 0.5% as the chloride addition was increased from 0.5 to 3.0%, and that the excess manganese settled to the bottom of the crucible. The metal was then cast into small ingots of about $\frac{1}{2}$ lb. each, which were later cut for analysis.

Similar preliminary experiments were carried out in which the manganese was added in the form of electrolytic manganese powder (99.9%) pure, containing 0.02% iron) all passing a 30 B.S.S. sieve with at least 90% held on a 100-mesh B.S.S. sieve. In addition, melts were made of the binary alloy of magnesium with 1.5% manganese, corresponding to the chemical requirements of D.T.D. Specification No. 118 (Elektron AM503), using a technique essentially similar to that described above and with the manganese added in some cases as chloride and in others in the form of metallic powder.

As convection currents in the molten metal might seriously reduce the efficiency of the settling process, even when the metal was held at approximately constant temperature, duplicate experiments were carried out in which an annular gas burner was fixed at and around the top of the crucible, thus maintaining a small temperature gradient in the metal which, it was intended, would restrict convection. Typical results of these experiments are given in Table II.

In none of the melts described and made in mild steel crucibles was there any appreciable reduction in iron content as a result of the settling treatment, and it may be presumed that while iron settlement is occurring the melt nevertheless remains saturated with iron owing to dissolution of that metal from the crucible wall. In a later section of this paper numerical data are given of the order of magnitude of this dissolution of iron in various conditions.

The analyses given in Table II indicate, however, that removal of iron by manganese occurs in melts of Elektron A8 made in graphite crucibles and also that the process is very efficient when steps are taken to eliminate serious convection currents; this applies (though the data are not included in the Table) whether the manganese is added as chloride or as metallic powder. The efficiency of the process for the removal of iron increased with increasing additions of manganese

chloride up to about 2%; larger additions produced no further improvement in efficiency.

Additions of manganese as metallic powder had to be made in small quantities at a time and with constant stirring, otherwise hard insoluble manganese-rich pellets formed at the bottom of the crucible. With melts of Elektron AM503 on the same scale, however, although the results obtained * were qualitatively similar, the process was by no

Charles and a second					N.P.C.				
		Alloy (Elektron Designation).							
11 30 W 14 MM	A8.	A8.	Δ8.	A8.	AM503.	AM 503.	AM	503.	
Crucible material	graphite	graphite	graphite	mild	graphite	graphite	grap	hite	
Total charge, kg.	1.3	1.35	1.3	1.45	1.2	1.2	1.	2	
MnCl, addition, % .	0.75	1.85	0.75	2.4	2.5	3.7	2.5	1.5	1
Annular gas burner	760	160	160	760	760	110	10	10	60
Settling temp., °O.	no	A. A	no	Jes	yes	yes	ye	8	ttlin
Top of melt . Settling temp., °C.	650	740	709	720	730	740	740	740	0.86
Bottom of melt .	(presoli- difica-	680	700	690	680	680	680	680	lduo
Settling time, hr.	tion)	1	1	1	1	1	1	1	P
Casting temp., ° C.	650	680	650	680	680	680	680	680	J.
Fe lst ingot .	0.005	0.003	0.006	0.013	0.010	0.025	0.0	08	
3rd ,,	0.012	0.003	0.015	0.012	0.011	0.032	0.0	08	
5th "		0.003		0.013	1.01		1.2		
2nd ,, .	0.13	0.24	0.20	0.43	1.66	0.89	1.3	3	
3rd ,,	0.15	0.26	0-30	0.36	1.62	0.16	1.3	5	
5th		0.28		0.45		***			

TABLE II.—Typical Results of Small-Scale Experiments on Iron Removal with Manganese.

means so efficient as with the alloy containing aluminium. This dissimilarity was not unexpected, as the particles in Elektron AM503 (primarily manganese) and in aluminium-containing alloys (manganesealuminium compounds) are distinctly different in nature and probably differ in their affinity for iron; the relative importance of the various mechanisms of association of iron with these particles is likely to be different.

Whereas with Elektron A8 the efficiency of iron removal appears

* It will be noted that the iron contents, as shown in Table II, tend to increase in successive ingots, as contrasted with the implications of Figs. 1 and 2. This is because, in the small-scale work dealt with in Table II, there was little possibility of the iron-rich settled material escaping the casting operation and being entrapped at the extreme bottom of the pot, which did occur in the two-ton melts dealt with in Figs. 1 and 2.

to be independent of the way in which the manganese is added, in the case of Elektron AM503, the effective removal of iron occurs only when the manganese is added as a chloride. This effect is very probably due to the fact that the coarser and fewer manganese particles present when manganese is added to magnesium as a metallic powder settle out too quickly to be of much use in removing iron; when the manganese is added as manganese chloride, however, large numbers of smaller particles are formed which settle out slowly and carry a certain amount of iron with them. In the case of the alloys containing aluminium, the addition of manganese in either form results in the production of small particles of a manganese-aluminium compound which settle out slowly, taking the iron with them. The size of the manganese-rich particles in the magnesium-manganese alloy made with manganese chloride, and in the magnesium-aluminium-manganese alloy made by either method, has been observed microscopically. The size of the manganese particles in manganese-magnesium alloys prepared with metallic manganese is known only in so far as the size of the original manganese particles added (i.e., before solution) is known by sizing analysis. Micro-examination of the settled residues, where large particles are ultimately found, is uncertain, but, as X-ray examination has not indicated the formation of compounds in this system in the experimental conditions used, it is most unlikely that new particles will be formed, and the only particles present are those originally added, but decreased in size owing to dissolution of manganese in the magnesium. It is not altogether surprising, therefore, that the mode of addition of the manganese to the alloys containing aluminium does not materially influence the efficiency of iron removal.

In view of partial success attained in settling experiments carried out with Elektron AM503 when manganese was added as chloride, an attempt was made to repeat the settling process on an alloy which had already been subjected to this treatment, in order to reduce the iron content still further. An Elektron AM503 melt, which had already been settled, was remelted in graphite and given a second settling treatment, as a result of which the iron content was reduced from 0.011 to about 0.008%. In view of this result, it was considered that experiments on the production of Elektron AM503 of low iron content should be made on a larger scale. The larger scale melts (2 tons), however, showed a relatively greater inefficiency of iron removal. In consequence, it was decided that iron-precipitating agents other than manganese would have to be used for this alloy (in spite of possible disadvantages of such processes), in order to find an economical method for the regular production of Elektron AM503 of low iron content.

It has been shown (see also Appendix I) that in making up the binary alloy of magnesium and manganese it is desirable to use electrolytic manganese, rather than manganese chloride, to produce alloys of maximum corrosion-resistance; the reason for this is not directly connected with the iron content of the alloy, however. The bulk of the further investigation described here is confined to the alloys containing aluminium.

2.-Medium-Scale Settling Experiments.

Three melts of Elektron A8 (conforming to D.T.D. Specification No. 59A) were made from electrolytic magnesium, using a technique essentially similar to that described above, the manganese being introduced as chloride. The first melt was made in a crucible which was approx. 12 in. high and 10 in. in dia., and had a capacity of 30 lb. magnesium; the second was made in a 60-lb. crucible, which had been designed to give a high depth : diameter ratio and measured 24 in. high \times 8 in. in diameter; while the third was also made in the 60-lb. crucible and "top heating" was introduced, as already described, to reduce convection currents. In the last-mentioned case the metal was cast into standard 5-lb. ingots. Both crucibles were of mild steel. The results of analyses on the ingots poured from these melts are given in Table III.

The results of the 30-lb. melt confirmed experience obtained prior to this investigation, that it is not possible to reduce the iron content substantially in the small-scale remelting of ingots. There was little improvement when using the larger crucible with a more favourable depth : diameter ratio. With "top heating" and the use of the large crucible, however, there was great improvement, and a proportion of the resulting alloy was of suitably low iron content.

3.—Experiments to Assess Relative Rates of Pick-Up of Iron from Various Ferrous Materials.

These experiments were carried out to determine to what extent the composition of the crucible might affect the degree of iron pick-up. Ingots of Elektron A8 of low iron content were melted in a graphite crucible and the alloy kept at a fixed temperature, as shown in Table IV, and under cover of a refining flux. A sample of the ferrous alloy to be studied, consisting of a bar of circular or elliptical cross-section, was then partly immersed in the molten alloy for $1\frac{1}{2}$ hr., after which the alloy was stirred, cast in the form of $\frac{1}{2}$ -lb. ingots, and analysed. This technique of partial immersion was used because it had been found that the most severe attack on a steel crucible occurs at the metal-to-flux interface, rather than below the level of metal.

The ferrous materials studied were : Mild steel. 12% Silicon cast-iron. Grey cast-iron. 4% Manganese, low-carbon steel. 12% Manganese, low-carbon steel. 13% Manganese, 1-3% carbon steel.

In all cases the surfaces were prepared by pickling in hydrochloric acid and shot blasting. Details of the areas exposed, and the results of these tests, are given in Table IV.

TABLE III.—Results of Medium-Scale Settling Experiments with Manganese.

	Alloy (Elektron Designation).				
and a state of the state of	A8.	A8.	A8.		
Crucible material	mild steel $(10'' \times 12'')$	mild steel $(8'' \times 24'')$	mild steel $(8'' \times 24'')$		
Total charge, lb.	33	67 2.5	60		
Alloving temp., °C.	760	760	760		
Top heating used	No	No	Yes		
Settling temp., °C. Top of melt .	690	690	720		
" " Bottom of					
melt .	690	690	680		
Settling time, hr.	1	200	1		
Lasting temp., °C.	0-010	0.017	0.010		
ingot analysis, % re. ist ingot .	0.033	0.011	0.010		
3rd	0.019	0.016	0.008		
4th	0-019		0.007		
5th "	0.019	0.010	0.000		
6th "	0.019	5	0.005		
7th "	0.033	0.018	0.004		
8th "			0.004		
9th "	• • •	0.017	0.008		
I0th "	1.	0.014	0.009		
lith "		0.014	0.000		
Mn latingot	0.28	0.20	0.09		
2nd	0.32	0.20	0.25		
3rd	0.34	0.28	0.24		
4th ,, .	0.35		0.24		
5th "	0.35	0.28	0.23		
6th "	0.34		0.25		
7th "	0.33	0.26	0.23		
8th " .		0.0*	0.19		
9th ,,	***	0.25	0.20		
10th ,, .	177	0.96	0.16		
1101 s, .	1000	0-20	0.20		
12011 99 •	man in the	A A A A A A A A A A A A A A A A A A A	0 20		

It was found that there is little difference in the pick-up of iron by magnesium-base alloys at 800° C. from these ferrous materials (as shown by a single test), and that the rate of pick-up from the grey iron, which has a ferritic matrix, is substantially the same as that from the steels. The pick-up of iron from the high-silicon material, however, was rather more serious than that from four of the others, but was not accompanied by a corresponding pick-up of silicon.

It had been observed that the rates of pick-up of iron in production melting-shop conditions were not so great as would be expected from the experiments described above. Another series of experiments was,

TABLE IV.—Relative Pick-Up of Iron from Various Ferrous Materials.

Charge (total), kg. Crucible material. Ferrous alloy studied .	1·2 graphite mild steel	1·2 graphite 12% silicon iron	1-2 graphite grey cast iron	1.2 graphite 4% man- ganese steel	1.2 graphita 12% man- ganese steel	1.0 graphite 13% man- ganese, 1.3% carbon steel
Approx. area of sample exposed to contact by molten metal and flux, 8q. cn Holding time, hr. Holding temp., °C. Analysis, % Fe. 1st ingot 2nd , 3rd , 4th , Sil. 1st , Average % pick-up of Fe per kg. charge/hr./ dm. ^s exposed .	60 1½ 800 0.011 0.012 0.013 0.016	55 11 800 0.010 0.035 0.034 <0.01 0.038	65 11 800 0.012 0.012 0.016 0.017	105 11 800 0.026 0.024 0.022 0.022 0.018	105 11 800 0-034 0-030 0-031 0-031 	60 1½ 850 0.037 0.034 0.033 0.033

(Low-iron Elektron A8 ingot, iron content <0.001%, used in all cases.)

therefore, conducted in the manner described below, to test samples of the two steels which were most likely to be useful in practice. The test-pieces were of circular or elliptical cross-section.

Initial experiments were conducted as described above. The steel specimens were then cleaned superficially by washing off the flux with water and by wire brushing. They were again immersed in fresh fluxcovered samples of molten high-purity magnesium alloy at the same temperature, and for the same time, as before. This procedure was repeated for 4-5 cycles in each case. The results of two tests are given in Tables V and VI, which show that there is a progressive decrease in the rate of pick-up of iron, even from mild steel. In the case of the high carbon-high manganese steel, however, this decrease is more pronounced, and it seems possible to remelt and superheat low-iron magnesium-base ingots in "seasoned" crucibles made of this material without notable increase in the iron content.

In these experiments with manganese-steel there was no evidence

of pick-up of manganese by the melt; this, however, initially contained about 0.2% manganese, so that a small pick-up would not readily be observed.

To obtain some information on the decrease in reactivity (iron transmission to the melt) of the steel, spectrographic and micrographic

TABLE V.—Effect of Repeated Immersion of a 0.35% Carbon Steel in High-Purity Elektron A8, Iron Content 0.001%, Contained in Graphite Crucibles.

Charge . Exposed surface area of th Nominal analysis of steel :	e steel Carbon Manganes Silicon	1.2 . 100 s . 0.3 se. 0.6	kg. g.cm. 5% 50% 20%	
Holding time, hr. Holding temp., ° C. Analysis after exposure, %. Fe 1st ingot 2nd ,, 3rd ,, 4th ,, Average % pick-up of Fe per kg. charge/ hr./dm. ² exposed .	$ \begin{array}{r} 1\frac{1}{2}\\ 850\\ 0.026\\ 0.022\\ 0.024\\ 0.022\\ 0.012\\ \end{array} $	$ \begin{array}{c} 1\frac{1}{2}\\ 850\\ 0.020\\ 0.018\\ 0.020\\ 0.017\\ 0.015 \end{array} $	$ \begin{array}{c} 1\frac{1}{2}\\ 850\\ 0.015\\ 0.010\\ 0.014\\ 0.012\\ 0.010\end{array} $	$ \begin{array}{r} 1\frac{1}{2} \\ 850 \\ 0.004 \\ 0.004 \\ 0.004 \\ 0.003 \\ 0.003 \\ 0.003 \end{array} $

TABLE VI.—Effect of Repeated Immersion of a 13% Manganese, 1·3% Carbon Steel in High-Purity Elektron A8, Iron Content 0·001%, Contained in Graphite Crucibles.

Charge Exposed surface area of the Nominal analysis of steel :	e steel Carbon Manganes Silicon	. 1.2 . 85 sc . 1.39 sc. 13% . 0.49	kg. 1.cm. %	
Holding time, hr. Holding temp., °C. Analysis after exposure, %. Fe 1st ingot 2nd " 3rd " 4th " Average % pick-up of Fe per kg. charge/ hr./dm. ² exposed	$ \begin{array}{c} 1\frac{1}{2} \\ 850 \\ 0.016 \\ 0.014 \\ 0.014 \\ 0.015 \\ 0.012 \end{array} $	$ \begin{array}{c} 1\frac{1}{2} \\ 850 \\ 0.014 \\ 0.014 \\ 0.013 \\ 0.013 \\ 0.011 \end{array} $	$ \begin{array}{c} 1\frac{1}{2} \\ 850 \\ 0.002 \\ 0.002 \\ 0.002 \\ 0.002 \\ 0.0016 \end{array} $	11 850 0.002 0.002 0.002 0.002 0.002 0.002

examinations were made of the surface after cleaning from adherent flux and magnesium. It was found that after repeated immersion in the melt the surface layers were decarburized, whichever steel was used. In the case of the austenitic manganese steel it was also found that after exposure the surface layers contained considerable quantities of aluminium and some magnesium. Although a similar pick-up was noted

in the case of the plain carbon steel, it extended for only a very small distance into the steel and the concentrations of aluminium and magnesium were spectrographically estimated to be quite small. Metallographic examination showed that this pick-up of aluminium and magnesium, together with the decarburization, gave rise to a duplex surface zone in the case of the steel containing manganese. The outer layer appeared to be ferritic only, while the inner layer appeared to have a more complex structure; this is shown in Fig. 3 (Plate III). Fig. 4 (Plate III) shows the decarburized zone normally found after prolonged use on a crucible made from 0.4% carbon steel, and is similar to that obtained in the mild steel specimen used in the tests just described. This photograph shows the decarburization encountered in melting material of normal purity; the effect is attributable to the action of the melting and refining fluxes.

So far as high-purity material is concerned, the "seasoning" effect described above (whereby decreased pick-up of iron occurs as a steel surface is increasingly exposed) appears to be associated with increasing flux-decarburization. It may be that the carbides in the surface of a new sample yield iron * more readily to the magnesium alloy than the ferrite which is subsequently formed.

The "seasoning" effect, if directly attributable to decarburization, is bound to occur, or tend to occur, in ordinary production practice in which 0.30-0.40% carbon steel crucibles are used, and might be thought to provide an "automatic" means of remelting and superheating low-iron magnesium alloy in mild steel crucibles. The phenomena here are probably complex, since, in practice, melting crucibles are frequently cleaned by washing or soaking with water (chloride-laden) or by pickling, whence the nature and reactivity of the superficial hydroxide or other layer is also involved, and "seasoning" may not take place to the same extent as in the laboratory experiments reported above. Alternatively, a surface layer responsible for "seasoning" may be dissolved away in the prolonged washing-soaking treatments given in production foundries.

All the experiments referred to in Tables II and III were carried out in freshly pickled (though not new) crucibles, in order to obtain reproducible results. A distinct tendency to "seasoning" effects was found with used mild steel crucibles which were not pickled or washed between melts with water in the presence of residual flux. Even in

^{*} The carbon released from steel melting-crucibles does not seem to be an effective element in the grain refinement of magnesium-aluminium alloys, in spite of recently published evidence that the addition of carbon to these alloys can cause grain refinement in the absence of superheating.

these conditions, however, the pot-area : metal-volume ratios in smallscale melting are such that no completely satisfactory removal of iron can be achieved.

It has been observed previously ⁵ that a "seasoning" effect in mild steel can be obtained by keeping the steel surface in contact with magnesium in the absence of flux. It was stated that the effect is due to pick-up of magnesium by the steel, and that mild steel containers cease to transmit iron to the molten metal after such a "seasoning" treatment. In the experiments carried out by the present authors, such a pick-up effect was observed only to a very limited extent with mild steel in the presence of flux; however, the investigation referred to above was carried out some time ago, when analytical accuracy in the determination of iron was probably much less than it is at present.

4.—Effect of Manganese Content on Pick-Up of Iron at Various Temperatures.

Nine 2-lb. melts of Elektron A8 of low iron content were made in mild steel crucibles, which were pickled and shot-blasted before each melt. The molten charges were held at various temperatures for $1\frac{1}{2}$ hr., and then cast into ingots and analysed. In some cases an additional $2\frac{1}{2}$ % manganese chloride was added to the alloy immediately after melting, to study the effect of the manganese content on the degree of pick-up of iron. The results of these experiments are given in Table VII.

TABLE VII.—Dependence of Pick-up of Iron on the Temperature and Manganese Content of the Melt.

Charge AS ingot, kg MaCl, addition, % Crucible material . Holding time, hr Holding temp., °C Ingot analysis, %: Fe. 1st ingot 2nd 3rd 4tb	1.2 graph- ite 11 900 0.001 0.002 0.002	1.2 mild steel 11 750 0.004 0.004 0.013	1.2 2.5 nuld steel 11 750 0.005 0.005 0.005 0.005	1.2 mild steel 14 800 0.007 0.014 0.016	1.2 2.5 mild steel 11 800 0.017 0.017 0.019	1.2 mild steel 11 850 0.030 0.029 0.029 0.029 0.027	1.2 2.5 mild steel 14 850 0.027 0.015 0.020 0.015	1.2 mild steel 11 900 0.040 0.040 0.040 0.040	1-2 2-5 mlld steel 1 900 0-019 0-025 0-017 0-015
Per Aseingee ,	0.000	0.001	0.005	0.014	0.017	0.020	0.015	0.010	0.000
zna "	0.002	0.004	0.000	0.014	0.017	0.029	0.010	0.040	0.025
Bru ,1 .	0.002	0.013	0.002	0.016	0.019	0.029	0.020	0.040	0.017
4th ,, .	***		0.002			0-027	0.015	0.040	0.015
5th ,, .						0.029	0.008	0.037	0.004
Mn. 1st ingot .	0.23	0-24	0.71	0-24	0-31	0.23	1.04	0.21	0.91
2nd	0.23	0.24	0.63	0.24	0.33	0.21	1.03	0.21	0.89
3rd	0.23	0.24	0-65	0.24	0.33	0.19	0-93	0.19	0.72
4th			0.69			0.21	0.80	0.21	0.74
5th				***		0.20	0.80	0.22	0.83
	my and all	(Tester		-		-	1.000	-	175 DI

(Low-iron A8 ingot, iron content <0.001%, manganese content 0.23%, used in all cases.)

Table VII shows that, whereas at 750° and 800° C. the greater manganese contents of the charges are associated with greater pick-up of iron, at 850° and 900° C. the greater manganese contents were associated with lower iron contents. It seems evident that while, at a

given temperature, the pick-up of iron from the crucible walls is accelerated by the presence of manganese, the iron content of the resulting metal ingots is also influenced by another factor, viz., the depression of the solubility of iron in molten magnesium-aluminium alloy by the presence of manganese in solution, and the settling of resultant precipitate which may take place. Thus, it appears that the two different roles played by manganese would, with this particular size and shape of crucible and time of exposure, approximately balance at about 825° C.

These results are of interest in connection with the possible reasons for the advantages conferred by the use of manganese-steel crucibles. The pick-up of aluminium and magnesium by the steel surface suggests a "sealing" mechanism, in which, by reason of this pick-up, the surface is passivated against further solvent action of the liquid magnesium alloy. However, it is also possible that manganese is dissolved from the steel simultaneously with the iron, and gives rise to sufficiently high local manganese concentrations at the interface as to cause the iron to be precipitated as quickly as it is formed. As indicated before, no satisfactory method is yet available to test this possibility.

II.—PRODUCTION-SCALE EXPERIMENTS.

1.-Simple Settling Experiments on Virgin Melts.

It is appropriate now to mention the melting shop practice for 2-ton melts at the Clifton Junction works of Magnesium Elektron, Ltd.

The 2-ton charge of magnesium is melted in a mild steel (0-30-0-40% carbon) crucible, heated in a special furnace which is fitted with two rows of gas burners. The temperature of the molten metal is increased to 760° C. when the alloying agents, aluminium and zinc, are added together with 1% manganese chloride (giving a final manganese content in the ingot of about 0-33%). After alloying, the melt is superheated by increasing its temperature to 900° C. (for subsequent grain refinement), and immediately transferred to a cooler. The cooler consists of a water-jacketed crucible-holder, in which water enters at the bottom and overflows at the top; in addition, a fan draws air fromtop to bottom through part of the annular space between the crucible and the water jacket. At 700°-710° C., the crucible is taken to a tilter and the melt poured into ingot moulds. During pouring, undue cooling of the crucible and charge is prevented by the provision of burners in the tilter.

The first experiments were carried out on charges of Elektron A8,

using virgin materials (the magnesium was electrolytic magnesium of "Melpure" grade, containing about 0.03% iron). In the first experiment the only modification from the normal procedure was that the manganese chloride addition was increased to $1\frac{1}{2}\%$; ingots were analysed at 400-lb. intervals throughout the pour, and it was found that in the last 60% of the metal the iron content was < 0.005%, but that the manganese content of the melt showed a distinct gradient, high manganese content being associated with high iron content. The analyses of this melt (No. 5933) are given in the second column of Table VIII.

These results, particularly the variation in manganese content, suggested that stirring after the addition of the larger quantity of manganese chloride had not been sufficiently thorough. A second melt was therefore made in which the procedure was essentially the same, except that the metal was agitated very thoroughly after the addition of manganese chloride. The results of these experiments were much more satisfactory, as 90% of the metal had an iron content of < 0.005%and the manganese content was much more uniform (see the third column of Table VIII, Melt No. 6149).

At this stage it was considered that the convection currents in the crucible might form a serious obstacle to any further improvements in the removal of iron. A special thermocouple was, therefore, prepared of 18-gauge Chromel-Alumel wire, which was mounted in a steel sheath 8 ft. long, $\frac{1}{2}$ -in. in dia., and having a wall thickness of $\frac{3}{32}$ in. The couple was located at the bottom of, and in contact with, the sheath, so that the temperature in the various zones of a 2-ton melt could be measured with reasonable accuracy having regard to the limited amount of conduction which would take place in a longitudinal direction through the thin wall of the sheath.

No temperature gradients were detected whether the crucible was in the furnace, the cooler, or the tilter. It was concluded, therefore, that, if they exist, the convection currents must be very slow. This conclusion is justifiable on the grounds that the driving force for convection currents arises from density variations consequent on temperature differences; if the temperature differences are too small to be detected, the forces causing convection must be very small. The satisfactory response when 2-ton melts are subjected to the settling treatment is no doubt largely due to the limited convection which occurs, since the small-scale experiments had already shown that, unless in this case precautions were taken to avoid convection, the settling process was not efficient.

Modifications were gradually introduced into the melting procedure

Melt No.:	5933	6149	6289	6332	6369	6159
Alloy (Elektron Designation):	A8.	A8,	AZ91	AZ91.	AZM.	AZM.
lloying temp., ° C uperheating time uperheating temp., ° C	740 1 hr. 35 min. 900	740 1 hr. 35 min. 900	760 1 hr. 30 min. 900	760 1 hr. 35 min. 900 (kept 750–900 45 min.)	750 I hr. 40 min. 900 (kept 900) 15 min.)	740 2 hr. 920 (cooled in the furnace for 4 hr. at an irregular rate. Taken to cooler at 750° C 1
ooling time	1 hr. 40 min.	1 hr. 50 min.	1 hr. 50 min.	1 hr. 30 min.	1 hr. 50 min.	
emp. of transfer to tilter, °C emp. at beginning of pour, °C. emp. at end of pour, °C.	695 655 620	690 650 610	(15 mm. <700) 680 645 605 (cooling slowed down)	685 650 600	680 645 610	680 650 610
$\begin{array}{c} \text{nalysis, } \%: \\ \text{Mean iron content} & . & . \\ \text{Fe. Sample No. 1} & . & . \\ 2 & . & . \\ 3 & . & . \\ 4 & . & . \\ 5 & . & . \\ 6 & . & . \\ 7 & . & . \\ 8 & . & . \\ 9 & . & . \\ 10 & . & . \\ 11 & . & . \end{array}$	$\begin{array}{c} 0.005\\ 0.016\\ 0.009\\ 0.009\\ 0.006\\ 0.003\\ 0.003\\ 0.002\\ 0.001\\ < 0.001\\ 0.001\\ < 0.001\\ < 0.001\\ < 0.001 \end{array}$	$\begin{array}{c} 0.0035\\ 0.012\\ 0.005\\ 0.003\\ 0.005\\ 0.002\\ 0.002\\ 0.002\\ 0.002\\ 0.001\\ 0.005\\ 0.001\\ 0$	$\begin{array}{c} 0.003\\ 0.007\\ 0.004\\ 0.006\\ 0.003\\ 0.003\\ 0.002\\ <0.001\\ <0.001\\ <0.001\\ 0.001\\ 0.002\\ <0.001\\ 0.002\\ \end{array}$	$\begin{array}{c} 0.0025\\ 0.005\\ 0.002\\ 0.001\\ 0.002\\ 0.002\\ 0.003\\ 0.003\\ 0.002\\ 0.001\\ 0.001\\ 0.001\\ 0.002\\ \end{array}$	$\begin{array}{c} 0.0025\\ 0.005\\ 0.004\\ 0.003\\ 0.003\\ 0.003\\ 0.002\\ < 0.002\\ < 0.002\\ < 0.002\\ < 0.002\\ < 0.002\\ < 0.002\\ \end{array}$	$\begin{array}{c} 0.0035\\ 0.008\\ 0.006\\ 0.004\\ 0.003\\ 0.002\\ 0.002\\ 0.002\\ 0.003\\ 0.003\\ 0.004\\ 0.004\\ 0.003\\ \end{array}$

VOL. LXXIII.

Mn. Sample No. 1	$\begin{array}{c} 0.52\\ 0.36\\ 0.31\\ 0.33\\ 0.29\\ 0.29\\ 0.25\\ 0.26\\ 0.23\\ 0.20\\ 0.20\\ 0.20\\ 0.20\\ 0.20\\ 0.20\\ 0.20\\ 0.60\\ 8.1\end{array}$	$\begin{array}{c} 0.29\\ 0.27\\ 0.26\\ 0.26\\ 0.22\\ 0.22\\ 0.22\\ 0.20\\ 0.18\\ 0.20\\ 0.20\\ 0.21\\ 4321\\ 371\\ 22\\ 65\\ 7.9\end{array}$	$\left \begin{array}{c} 0.29\\ 0.28\\ 0.21\\ 0.22\\ 0.21\\ 0.20\\ 0.18\\ 0.19\\ 0.18\\ 0.19\\ 0.18\\ 0.18\\ 0.18\\ 0.18\\ 0.18\\ 0.13\\ 445\\ 22\\ 70\\ 9.5\\ \end{array}\right.$	0.35 0.28 0.25 0.23 0.21 0.18 0.18 0.18 0.18 0.18 0.18 0.18 0.1	0.35 0.35 0.31 0.32 0.30 0.29 0.29 0.25 0.26 0.23 4276 276 276 48 70 6-1	$\begin{array}{c} 0.50\\ 0.49\\ 0.43\\ 0.36\\ 0.42\\ 0.33\\ 0.32\\ 0.32\\ 0.29\\ 0.25\\ 0.23\\ 4276\\ 276\\ 48\\ 90\\ 6.1\\ \end{array}$
Zinc Manganese chloride General alloy analysis, %. Al	22 60 8·1	22 65 7.9	22 70 9.5	22 70 9.6	48 70 6·1	48 90 6·1
(Dip sample.*) Zn . Mn . Si . Cu .	$ \begin{array}{c} 0.47 \\ 0.39 \\ 0.02 \\ < 0.01 \end{array} $	$ \begin{array}{c} 0.54 \\ 0.38 \\ < 0.01 \\ < 0.01 \end{array} $	0.53 0.29 0.03 0.01	0.56 0.28 0.01 0.02	$ \begin{array}{c c} 1.07 \\ 0.36 \\ 0.02 \\ < 0.01 \end{array} $	$ \begin{array}{c} 1.20 \\ 0.58 \\ 0.01 \\ < 0.01 \end{array} $

* This dip sample was taken before transferring the pot to the tilter; between this time and the actual pouring some further settling took place, which is shown by the discrepancy in manganese figures.

the Iron Content of Mg-Base Alloys

and were applied to further melts of magnesium-aluminium-containing alloys; these changes are detailed below:

- (a) Pouring temperatures were kept as low as possible, and, by suitable manipulation of burners, it was arranged that the
 - * temperature decreased continually throughout the pour.
- (b) Prolonging the superheating time to 45 min., or, alternatively, prolonging the cooling time, improved the efficiency of the process.
- (c) The efficiency of the removal of iron increased with increasing additions of manganese chloride up to an optimum value of 2%. Larger additions, however, did not reduce the iron content and, moreover, resulted in a final manganese content which was undesirably high.
- (d) Allowing the melt to cool in the furnace, instead of in the cooler, was found to impair the efficiency of the process.

The final procedure adopted, using the results quoted above, involved alloying at 760° C. with the addition of 2% manganese chloride, heating to 900° C. over a period of $1\frac{1}{2}$ hr. (this rate was found to give optimum manganese distribution), keeping at 900° C. for 15 min., cooling during a period of not less than 2 hr. (to assist settling as indicated in (b) above), and then pouring at the minimum temperature possible for the particular alloy in question, adjusting the heating in the tilter so as to avoid heating of the metal towards the end of the pour. Alloys were produced in this way so that the whole charge had an iron content < 0.005%. However, it was not possible by this procedure to produce the whole of a melt with an iron content < 0.002%, which, in the light of American investigations, may be a desirable upper limit for iron.⁶

2.-Simple Settling Experiments on Secondary Metals.

Because of the availability of secondary metal, and as it was desired to discover whether the same mechanism would operate with metal of lower general purity, it was decided to carry out settling experiments in which unusually large additions of secondary metal should be used. Two melts of Elektron A8 were made with secondary-metal additions of 60 and 90%, respectively. The melting conditions were otherwisc similar to those which gave the best results on the virgin melts. Analyses of the ingots (see Table IX) showed that the iron contents of these two melts were < 0.002 and 0.003%, respectively, and that the mean iron content of each melt was < 0.002%.

The excellent response of these secondary metal-rich melts to the

removal of iron by the manganese settling process is probably attributable to the initially low iron content of the secondary metal, which was only 0.015% (as compared to about 0.03% in electrolytic magnesium). This difference in iron content is caused by the settling which normally takes place in the alloying process undergone by the secondary metal at an earlier stage in its history.

Complete analyses for other impurities in this and other secondary melts showed, however, that the silicon and copper contents were greater than is regarded as desirable for "high-purity" material : they were not unduly unsatisfactory, however, as can be seen from Table IX.

3.-Remelting Experiments.

It was desired to produce high-purity magnesium-base alloys containing < 0.002% iron. In view of the results obtained with the melts rich in secondary metal, it was considered possible that this further reduction in iron content could be made, while maintaining low silicon and copper values, by remelting new ingot cast from melts which had already been given a settling treatment as described in (2) above.

Experiments were carried out on alloys containing aluminium as detailed below.

In the first melt, ingots of an alloy containing 5% aluminium, made from virgin metal using the best settling conditions, were remelted in a 2-ton pot. The procedure adopted in the initial alloying and settling of this alloy, and the analysis of the ingot first obtained, are given in Table X (Melt No. 6570). The analysis showed that the removal of iron had not been completely successful, and confirmed previous experience that it is more difficult to obtain even small quantities of material of low iron content when the aluminium content is low, than it is to obtain such metal from alloys which have greater percentages of aluminium.

After remelting the 5% aluminium alloy stock, a further 1% manganese chloride was added. The melt was then superheated and generally treated as a virgin melt, and poured into ingots after cooling in the usual way. The precise details of procedure, and the ingot analysis for this remelt, are given in Table X (Melt No. 6663), from which it will be seen that the method was very successful, the mean iron content of the melt being of the order of 0.001% or less.

In the second experiment, a melt of Elektron A8 was made using the best settling conditions. Instead of pouring into ingots, however, the alloy was decanted into a second crucible at 650° C., leaving a small residue in the first crucible. This metal was then subjected to a second cycle of operations, a further 0.75% manganese chloride being added

ä

at 760° C. After superheating, cooling, and pouring, the ingots were analysed, with the results shown in Table X. Again it will be seen that a mean iron content of as little as 0.001% or less was achieved.

 TABLE IX.—Results of Simple Settling Experiments on Two-Ton Elektron
 A8 Melts, Containing High Proportions of Secondary Metal.

Melt No. :	6410	6506
Alloy (Elektron Designation):	A8.	A8.
Alloying temp., °C	760 1 hr. 5 min. 900 2 hr. 660 645 610	760 1 hr. 15 min. 920 2 hr. 20 min. 680 650 610
Analysis, % : Mean iron content Fe. Sample No. 1	0-001 0.002 0.001 0.001	0.0019 0.0034 0.0018 0.0020
$ \begin{array}{ccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} 0.001 \\ 0.002 \\ 0.001 \\ < 0.001 \\ 0.001 \\ 0.001 \end{array} $	0.0016 0.0013 0.0011 0.0010
	$ \begin{array}{c} 0.001 \\ 0.001 \\ < 0.001 \\ 0.001 \\ 0.002 \end{array} $	$\begin{array}{c} 0.0014 \\ 0.0018 \\ 0.0023 \\ 0.0024 \\ 0.0025 \end{array}$
Mn. Sample No. 1	0·30 0·27 0·25 0·25	0·34 0·36 0·23 0·26
$5 \cdot \cdot$	0-24 0-20 0-20 0-21 0-22	0-23 0-23 0-24 0-23 0-24
10	0.21 0.23 0.22 1709	0.22 0.22 0.24 0.22 377
Secondary ingot Aluminium Manganese chloride General alloy analysis, %. Al	2880 111 51 8·1	4280 43 38 7·2
(Dip sample.*) Zn Mn Si Cu	$ \begin{array}{c} 0.52 \\ 0.33 \\ 0.11 \\ 0.06 \end{array} $	0·48 0·37 0·10 0·13

* This dip sample was taken before transferring the pot to the tilter; between this time and the actual pouring some further settling took place, which is shown by the discrepancy in manganese figures.

the Iron Content of Mg-Base Alloys

Previous experience with magnesium-aluminium alloys suggests that this process would be applicable to all commercial alloys of this type, having regard to the results obtained on the two alloys quoted.

In view of the success achieved with this recycling method in the case of alloys containing aluminium, and in view of indications in smallscale experiments regarding the possibility of removing iron from Elektron AM503 by settling, this same method was also applied to a 2-ton melt of Elektron AM503 (Melt No. 6818). As will be seen from Table X, this experiment was not successful. A double recycling technique was then tried in which 1% of extra manganese chloride was added before each settling operation (Melt No. 6932), but even in this case only a small amount of low-iron content Elektron AM503 was produced. The method was, therefore, abandoned as impracticable.

III.-DISCUSSION OF RESULTS AND CONCLUSIONS.

It has been shown that the iron content of magnesium-aluminium alloys can be reduced by means of settling with manganese, even when melting in iron-rich crucibles. The efficiency of the process depends on three main factors:

- (1) The addition of a sufficiency of manganese, in a suitable form.
- (2) The use of suitable settling conditions which, from a consideration of the small- and full-scale experiments, implies the use of crucibles of such depth to diameter ratios and heating conditions as are designed to reduce convection effects.
- (3) The use of crucibles having small wall-area to metal-volume ratios (*i.e.*, the use of large-capacity crucibles) to reduce iron pick-up.

It was found that the speed of pick-up of iron increases with increasing manganese content, but that the solubility of iron in the magnesiumaluminium alloys is decreased by an increase in manganese content; this is in agreement with the findings of Fahrenhorst and Bulian.⁷

The present authors consider that it is most probable that the iron is removed by manganese-rich particles in the melt which settle out together with iron. Three mechanisms which would possibly account for the observed results are:

- (a) Crystallization of the manganese-aluminium compound on iron nuclei or, alternatively (but much less likely), iron on the compound nuclei.
- (b) Co-precipitation of iron and manganese as their respective aluminium compounds or as a ternary or more complex compound.

TABLE X.-Results of Recycling Experiments of Two-Ton Virgin Melts of Elektron A8 and a 5% Aluminium Alloy.

6662

6818 •

	AIOA.	MoA.	A	5.	AM503.		AM503.		
Alloying temp., ° C.	760	760	760		740	740	710	740 Tet	740 2nd
Stage of process	initial	recycling	initial	recycling	initial	recycling	initial	recycling	recycling
Superheating time.	settling 1 hr. 40 min. 900	1 hr. 15 min.	settling 1 hr. 10 min. 900	1 hr. 15 min. 900	1 hr. 20 min. 850	1 br. 15 min. 850	1 hr. 5 min. S50	1 hr. 10 min. 850	1 hr. 10 min. 850
Cooling time	2 hr. 5 min.	(held 15 min.) 2 hr. 10 min.	(held 15 min.) 2 hr. 25 min.	(held 15 min.) 2 hr.	1 br. 40 min.	2 br. 5 min.	2 hr. 5 min.	1 br. 50 min.	2 hr. 10 min.
Temp. of transfer to tilter, °C.	680	680	650	680 650	670	6S0 675	670	670	680 675
Temp. at end of pour, °C.	620	625		610		660	•••		660
Fe. Sample No. 1	0.0035	0.0031		0.0021		0.023			0.017
2 .	0.0037	0.0015		0.0019		0.023			0.027
4 · . 5 · .	0.0076 0.0064	<0.0012		<0.0012		0.019			0.012
67;	0.0062	<0.001 <0.001		< 0.001 < 0.001		0-017 0-013			0.013 0.017
8.9.	0.0053	<0.001 <0.001		<0.001 0.001		0.012 0.010			0.010
10 :	0.0047 0.0044	<0.001 <0.001		<0.001 <0.001		0.000	•••		0.005
12 .		***		<0.001					
									2:31 2
States and									
									-
			-,	1	New York		1977-		-
		1	-,						-
			-,				17		-
1				ere.			7		-
			-						
			7						
Mn. Sample No. 1	- 0.26	1 0.47		0.42		1.0			1.65
Mn. Sample No. 1	0.26	0-47 0-43		0.42 0.37		1-68 1-58			1-88 1-72
Mn. Sample No. 1	0.26 0.25 0.28 0.26 0.28	0-47 0-43 0-41 0-40		0.42 0.37 0.30 0.28		1-68 1-58 1-64 1-59			1-88 1-72 1-64 1-83
Mn. Sample No. 1	0.26 0.25 0.28 0.26 0.26 0.28	0-47 0-43 0-41 0-40 0-36 0-36		0.42 0.37 0.30 0.28 0.27 0.27		1-68 1-58 1-64 1-59 1-60 1-70			1-88 1-72 1-64 1-83 1-90 1-90
Mn. Sample No. 1 3 4 5 6 7 8	0.26 0.25 0.28 0.26 0.26 0.27 0.28	$\begin{array}{c} 0.47\\ 0.43\\ 0.41\\ 0.40\\ 0.36\\ 0.36\\ 0.38\\ 0.35\end{array}$		0.42 0.37 0.30 0.28 0.27 0.27 0.25 0.24		1-68 1-58 1-64 1-59 1-60 1-60 1-60 1-63 1-67			1-88 1-72 1-64 1-83 1-90 1-90 1-85 1-85
Mn. Sample No. 1 2 3 4 5 6 7 7 8 9 10	0.26 0.25 0.28 0.26 0.26 0.28 0.27 0.28 0.27 0.28 0.25 0.26	$\begin{array}{c} 0.47\\ 0.43\\ 0.41\\ 0.40\\ 0.36\\ 0.36\\ 0.36\\ 0.35\\ 0.33\\ 0.35\end{array}$		0.42 0.37 0.30 0.28 0.27 0.27 0.27 0.26 0.24 0.24 0.23		1-68 1-58 1-64 1-59 1-60 1-70 1-63 1-67 1-72 1-67			1-88 1-72 1-64 1-83 1-90 1-90 1-90 1-90 1-85 1-85 1-93 1-93
Mn. Sample No. 1 2 3 4 5 6 7 7 8 9 9 10 11	0.26 0.25 0.28 0.26 0.26 0.26 0.27 0.28 0.27 0.28 0.25 0.26 0.26 0.26	$\begin{array}{c} 0.47\\ 0.43\\ 0.41\\ 0.40\\ 0.36\\ 0.36\\ 0.36\\ 0.38\\ 0.35\\ 0.33\\ 0.33\\ 0.33\\ \end{array}$		0.42 0.37 0.50 0.28 0.27 0.27 0.25 0.24 0.24 0.24 0.24 0.23 0.21 0.21		1-68 1-58 1-64 1-59 1-60 1-70 1-63 1-67 1-72 1-67			1-88 1-72 1-64 1-83 1-90 1-90 1-90 1-85 1-85 1-85 1-93 1-87
Mn. Sample No. 1 2 3 4 5 6 7 7 8 9 9 10 10 11 12 Charge, b. cell metal 12	0.26 0.25 0.28 0.26 0.26 0.26 0.27 0.28 0.27 0.28 0.25 0.26 0.26 0.26 0.26 0.25 0.26 0.27 0.28	0-47 0-43 0-41 0-36 0-36 0-36 0-38 0-35 0-33 0-35 0-33 0-35 0-33 0-35		0.42 0.37 0.30 0.28 0.27 0.27 0.27 0.24 0.24 0.24 0.23 0.21 0.21 0.21		1-68 1-58 1-64 1-59 1-60 1-70 1-63 1-67 1-72 1-67 			1-88 1-72 1-64 1-83 1-90 1-85 1-85 1-93 1-85 1-93 1-87
Mn. Sample No. 1 2 3 4 5 6 7 7 8 9 10 11 12 Charge, Ib. cell metal Secondary ingot	0.26 0.25 0.28 0.26 0.26 0.26 0.28 0.27 0.28 0.27 0.25 0.26 0.26 0.26 0.26 0.26 0.26 0.27 0.28 0.27 0.25 0.25 0.28 0.27 0.28 0.26 0.25 0.28 0.26 0.25 0.28 0.26 0.25 0.28 0.26 0.25 0.28 0.26 0.25 0.28 0.26 0.25 0.28 0.26 0.26 0.26 0.26 0.26 0.26 0.26 0.26	0-47 0-43 0-41 0-40 0-36 0-36 0-38 0-35 0-33 0-35 0-33 0-35 0-33 0-33 0-33	4308	0.42 0.37 0.37 0.30 0.28 0.27 0.27 0.27 0.24 0.24 0.24 0.23 0.21 0.31		1-68 1-58 1-64 1-59 1-60 1-70 1-63 1-67 1-72 1-67 			1-88 1-72 1-64 1-83 1-90 1-90 1-90 1-90 1-95 1-85 1-85 1-93 1-93 1-93 1-93 1-93 1-93 1-93
Mn. Sample No. 1 2 3 4 5 6 6 7 7 8 9 10 11 11 12 Charge, lb. cell metal Secondary ingot Aluminium Zinc	0.26 0.25 0.28 0.26 0.26 0.26 0.28 0.27 0.28 0.27 0.28 0.26 0.26 0.26 0.26 0.26 0.26 0.26 0.26	0-47 0-43 0-41 0-40 0-36 0-36 0-36 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-35		0.42 0.37 0.30 0.28 0.27 0.27 0.27 0.24 0.24 0.24 0.23 0.21 0.21 0.21 0.21	4606	1-68 1-58 1-64 1-59 1-60 1-70 1-63 1-67 1-72 1-67 			1-88 1-72 1-64 1-83 1-90 1-90 1-90 1-90 1-90 1-93 1-85 1-85 1-85 1-83 1-93 1-93 1-93 1-93 1-93 1-93 1-94 1-94 1-94 1-94 1-94 1-94 1-94 1-94
Mn. Sample No. 1 2 3 4 5 6 7 8 9 10 11 12 Charge, lb. cell metal Secondary ingot Alaminium Zinc Marganese chloride General alloy analysis, %. Al	0.26 0.25 0.28 0.26 0.26 0.28 0.27 0.28 0.27 0.28 0.25 0.26 0.26 0.26 0.26 0.25 0.26 0.25 0.26 0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.28 0.28 0.28 0.28 0.28 0.28 0.28 0.28	0-47 0-43 0-41 0-40 0-36 0-36 0-35 0-33 0-35 0-33 0-35 0-33 0-33 		0.42 0.37 0.30 0.28 0.27 0.27 0.24 0.24 0.24 0.24 0.23 0.21 0.21 0.21 0.21 0.21 0.21 0.21 0.23 0.21 0.23 0.21 0.23 0.21 0.23 0.23 0.21 0.23 0.24 0.25 0.26 0.27 0.26 0.27 0.26 0.27 0.26 0.27 0.26 0.27 0.26 0.27 0.26 0.27 0.27 0.26 0.27 0.27 0.26 0.27 0.27 0.27 0.26 0.27 0.27 0.26 0.27 0.27 0.27 0.27 0.27 0.27 0.27 0.27	4606	1.68 1.58 1.64 1.59 1.60 1.60 1.60 1.63 1.67 1.72 1.72 1.67 81 ≤ 0.05	4600		1-88 1-72 1-64 1-83 1-90 1-90 1-85 1-85 1-93 1-93 1-93 1-93 1-93 1-93 1-93 1-93
Mn. Sample No. 1 2 3 4 5 6 7 8 9 10 11 12 Charge, lb. cell metal Secondary ingot Aluminium Zinc Manganese chloride General alloy analysis, %. Al (Dip sample.1) Mn	0.26 0.25 0.28 0.26 0.26 0.26 0.28 0.27 0.28 0.25 0.26 0.26 0.26 0.26 0.26 0.26 0.26 0.26	0-47 0-43 0-41 0-40 0-36 0-36 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-35 0-35 0-35 0-55 0-55		0.42 0.37 0.30 0.28 0.27 0.25 0.24 0.24 0.24 0.23 0.21 0.21 0.21 0.21	4606	1-68 1-58 1-54 1-59 1-64 1-59 1-60 1-60 1-70 1-63 1-67 1-72 1-67 	4600		1-88 1-72 1-64 1-83 1-90 1-90 1-90 1-85 1-85 1-93 1-93 1-93 1-93 1-93 1-93 1-93 1-93
Mn. Sample No. 1 2 3 4 5 6 7 8 9 10 11 12 Charge, lb. cell metal Secondary ingot Aluminium Zinc Manganese chloride General alloy analysis, %. Al (Dip sample.1) Mn St	0.26 0.25 0.28 0.26 0.26 0.26 0.28 0.27 0.28 0.25 0.26 0.26 0.26 0.26 0.26 0.26 0.26 0.26	0-47 0-43 0-41 0-40 0-36 0-36 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-33 0-35 0-32 0-32 0-41 0-40 0-40 0-40 0-40 0-36 0-36 0-36 0-35 0-55 0		0.42 0.37 0.30 0.28 0.27 0.27 0.24 0.24 0.24 0.23 0.21 0.21 0.21 0.21 0.21 0.21 0.21 0.21	4606 	1-68 1-58 1-54 1-59 1-64 1-60 1-70 1-63 1-67 1-72 1-67 81 <0-05 <0-05 1-66 <0-01	4600		1-88 1-72 1-64 1-83 1-90 1-90 1-85 1-85 1-93 1-93 1-93 1-93 1-93 1-93 1-93 1-93
Mn. Sample No. 1 2 3 4 5 6 7 7 8 9 10 11 12 Charge, lb. cell metal 5 Secondary ingot 10 11 12 Charge, lb. cell metal 12 Charge, lb. cell metal 12 Secondary ingot 10 11 12 Charge, lb. cell metal 12 Charge, lb. cell metal 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 11 12 Secondary ingot 10 10 11 12 Secondary ingot 10 11 12 Secondary ingot 10 Secondary ingot 10 Secondary ingot 10 Secondary ingot 10 Secondary ingot 10 Secondary ingot 10 Secondary ingot 10 10 10 10 10 10 10 10 10 10 10 10 10	$\left \begin{array}{c} 0.26\\ 0.25\\ 0.28\\ 0.26\\ 0.28\\ 0.26\\ 0.28\\ 0.27\\ 0.28\\ 0.25\\ 0.26\\ 0.2$	$\begin{array}{c} 0.47\\ 0.43\\ 0.41\\ 0.40\\ 0.36\\ 0.36\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.33\\ 0.35\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ <0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.53\\ 0.02\\ 0.01\\ 0.02\\ 0.01\\ 0.02\\ 0.01\\ 0.02\\ 0.02\\ 0.01\\ 0.02\\ 0.$	4308 	0-42 0-37 0-30 0-28 0-27 0-27 0-27 0-24 0-24 0-24 0-24 0-24 0-23 0-21 0-21 0-21 0-21 0-21 0-21 0-21 0-21	4606 	1.68 1.58 1.64 1.59 1.60 1.70 1.63 1.67 1.72 1.72 1.67 81 <0.05 <0.05 1.66 <0.01 0.01	4600		$\begin{array}{c} 1.88\\ 1.72\\ 1.64\\ 1.83\\ 1.90\\ 1.90\\ 1.85\\ 1.93\\$

• The heating to 850° in these cases is not a superheating treatment for grain refinement, but only a preheating for the settling treatment. † This dip sample was taken before transferring the pot to the tilter; between this time and the actual pouring some further settling took place, which is shown by the discrepancy in manganese figures.

Melt No. :

6570

6663

6932 •

77

the Iron Content of Mg-Base Alloys

(c) Partition of iron between the magnesium-rich phase and the manganese-rich phase.

The possibility that simple manganese-magnesium compounds might be formed has not been considered, as Bulian and Fahrenhorst⁸ have produced evidence that no compounds of this type are formed in the magnesium-aluminium-manganese * system.

The association of high iron contents with high manganese contents would be expected if any of the above mechanisms were operative, so that this observation does not assist in discriminating between them. The solubility of iron in manganese at temperatures less than 850° C. is about 30%, so that the process (c) might proceed by adsorption of iron on the manganese particles or by true solution of iron in the manganese.

A melting cycle has been developed which was found successful for the alloys containing aluminium, with which it has been tried in the consistent production of ingot containing < 0.002% iron. It was found, however, that the binary magnesium-manganese alloy (Elektron AM503) could not be produced in this way with a low iron content.

It is probable that, as manganese particles settle through the melt, the rate of removal of iron depends on the number of the particles and also on the concentration of iron in the metal. However, as the manganese particles pick up iron they will probably show less tendency to pick up more iron, and if this is so, it would be expected that greater efficiency in removal of iron could be achieved by adding a given quantity of manganese in two portions, in successive settling operations, rather than making the addition in one operation. This possible "loading" effect of the manganese particles is amply supported by results which have been obtained in settling experiments using a simple recycling process.

It was thought that manganese particles in metal taken from the bottom of settled melts might differ in structure from those in metal taken from the top of the melt, on account of the iron associated with the settled manganese. On examining suitable specimens at magnifications up to 1000 dia., however, no structural differences could be detected; this suggests that a mechanism of true solution of ironin manganese operates.

The authors have concluded that economical production of Elektron AM503 of low iron content is impracticable by any manganese settling process, and that other iron-precipitating agents would have to be

^{*} The present authors' X-ray examination of residues from Elektron AM503 melts has given no indication that iron is present in any form other than that of alpha iron.

PLATE III.



Fig. 3.—Duplex Decarburized Zone in a 13% Manganese, 1.3% Carbon Steel After Prolonged Contact with Molten Elektron A8 and Flux. \times 500.



Fig. 4.—Decarburized Zone in a 0.4% Carbon Steel After Prolonged Contact with Elektron A8 and Flux. × 300.

the Iron Content of Mg-Base Alloys

used. As can be seen from Appendix I, the use of the manganese as metal rather than as manganese chloride for alloying is desirable for maximum corrosion-resistance, as in the former case very many fewer manganese-rich particles are produced.

It appears that when melting in ferrous pots less pick-up of iron is to be expected from contact of the melt with decarburized surfaces than from contact with those containing carbon.

It has been found that this decarburization is accompanied by some pick-up of aluminium and magnesium in the melting of the magnesium alloys containing aluminium, and that this pick-up is quite pronounced in the case of high-manganese steels. It is suggested that either (a) this pick-up, owing to its "sealing" effect on the steel surface, greatly retards dissolution of iron in the molten magnesium alloy, or that (b) such dissolution is also accompanied by a dissolution of manganese from the crucible wall, which will provide a local supply of precipitant for this iron as quickly as it is dissolved. If the former mechanism holds, definite advantages can be expected from the use of manganese steels in all conditions; if the latter, there will be an advantage only above a certain limiting temperature, since it has been found that the presence of high concentrations of manganese in the magnesium also promotes dissolution of iron, and that at lower temperatures this effect more than outweighs the accelerated iron-precipitating tendency associated with the presence of the higher manganese concentration.

ACKNOWLEDGEMENTS.

The greater part of this investigation was carried out under a Ministry of Aircraft Production research contract. The authors' thanks are due to the Ministry, as well as to the Directors of Magnesium Elektron, Ltd., for permission to publish this paper.

REFERENCES.

1. F. A. Fox and C. J. Bushrod, J. Inst. Metals, 1944, 70, 325.

- F. A. Fox and C. J. Bushrod, J. Inst. Metals, 1947, 70, 255.
 F. A. Fox and C. J. Bushrod, J. Inst. Metals, 1946, 72, 51.
 A. Bock, "The Technology of Magnesium and its Alloys," London: 1940, p. 281.
 W. R. D. Jones, J. Inst. Metals, 1931, 46, 398.
 J. D. Hanawalt, C. E. Nelson, and J. A. Peloubet, Trans. Amer. Inst. Min. Met.
- Eng., 1942, 147, 273.
- E. Fahrenhorst and W. Bulian, Z. Metallkunde, 1941, 33, 31; 1942, 34, 166.
 W. Bulian and E. Fahrenhorst, "Metallography of Magnesium and its Alloys,"
- London: 1944, p. 27. 9. J. D. Grogan and J. L. Haughton, J. Inst. Metals, 1943, 69, 241. 10. "The Analysis of Magnesium and its Alloys," London: F. A. Hughes and
- Co., Ltd., 1946.

APPENDIX I.

In connection with work on the development of Elektron AM503type alloy of maximum corrosion-resistance, seven water-cooled slabs were cast as described below, the technique of which is closely similar to that of the experiments described in the main body of this paper.

The metal was poured at 720° C. into a tapered, thin sheet-metal mould. The bottom of the mould was kept in contact with running water while the top was covered with an electrically heated hood, kept sufficiently hot to retard solidification and to maintain a temperature-gradient up the mould. In these conditions, solidification takes a considerable time, during which most of the manganese particles settle to the bottom of the slab, taking with them a large proportion of the iron.

Standard corrosion specimens, previously described,^{1,2,3} were machined from 12 different levels of the slabs and then immersed for 7 days in the authors' standard 3% sodium chloride solution, and the corrosion rates were recorded. All the specimens were then analysed for iron and manganese. Data for a typical slab are given in Table XI.

TABLE VI'-	-1701	ana	munyar	nese C	onients	unu	Corroston	nuces	ui
Different	Levels	of a	Typical	Water	-Cooled	Slab	of Elektron	AM50	3.
									-

1 0 1

Level.	Mean Iron Content, %.	Mean Manganese Content, %.	Mean Corrosion Rate, Mg./sq. cm./day.
1 top	0.007	1.17	0.76
2	0.007	1.22	0.80
3	0.008	1.15	0.55
4	0.007	1.21	0.61
5	0.009	1.25	0.65
6	0.007	1.24	0.80
7	0.011	1.24	1.29
8	0.008	1.22	1.83
9	0.014	1.19	0.55
10	0.025	1.40	3.01
11	0.054	1.44	3.61
12 bottom	0.023	1.47	2.60

The statistical correlations between manganese and iron contents, between iron content and corrosion rate, and manganese content and corrosion rate was then investigated. The correlation coefficients obtained are given in Table XII. Before discussing these results it should be observed that the manganese content at the top of the slab, which, as seen under the microscope, is substantially free from manganese particles, can be taken as being that quantity which is in solid solution throughout the slab at all levels. Although this statement is probably only an approximation, it is likely to be reasonably accurate, as the total manganese content is well below the solid solubility at the freezing point.⁹ Difference in manganese content between the top level and lower levels can, therefore, be attributed to the presence of manganese particles. The conclusion to be reached, that free manganese particles have a bad effect on the rate of corrosion, is, therefore, reflected in this table by the result that the rate of corrosion increases with increasing manganese content. This, however, was not to be expected if the increases in manganese content were due to the presence of a larger quantity of manganese in solution.

TABLE XII.—Values of Correlation Coefficients of Data Such as Those Given in Table XI.

Correlation Between :	Correlation Coefficient.	Correlation Coefficient after Elimination of the Effect of the Third Variable.
Manganese and iron contents	0-891	0-463
Manganese content and corrosion rate .	0-781	0-052
Iron content and corrosion rate .	0-711	(insignificant)

These corrosion specimens were prepared according to a technique previously described,^{1, 2} using "IF" emery paper as the abrasive. This method of preparation has now been shown ³ to mask, at least in part, the difference in rate of corrosion between magnesium-aluminium alloys of differing iron content. However, four experiments were carried out in which specimens of Elektron AM503 sheet, prepared with "IF" paper or pumice powder, were immersed in 3% sodium chloride solution for varying periods up to 30 days. In all cases it was found that the method of preparation had no significant effect on the rate of corrosion of this alloy, and it is of interest that the rates of corrosion decreased with time. The adverse effect of the emery preparation is, therefore, not present with the magnesium-manganese binary alloy.

The results of this statistical examination may be summarized as detailed below :

- (1) There is a strong correlation between iron content and manganese content, which is an additional proof that precipitating iron is associated with the manganese out of solution.
- (2) There is a correlation between manganese content and rate of corrosion and also between iron content and rate of corrosion.
- (3) If the correlations between manganese content and iron content and rate of corrosion are examined, having regard to the correlation existing between iron content and manganese content; it is found that the correlation between manganese content and

82 The Reduction of Fe Content of Mg-Base Alloys

rate of corrosion rate remains significant, whereas that between iron and rate of corrosion rate does not.

As differences in manganese content are due almost entirely to the number of manganese particles in suspension, it can be concluded from the results given above that improved corrosion-resistance of Elektron AM503-type alloys can be obtained by eliminating manganese particles (while maintaining a sufficient manganese content in the alloy).

It is a matter of general experience that the corrosion-resistance of Elektron AM503 is somewhat variable, and the conclusion stated above indicates one of the reasons why this should be so (the ratio of manganese in, to manganese out, of solution not being at present controlled). However, it is probable that in the alloys containing aluminium the presence of the manganese-aluminium compound particles does not adversely affect corrosion-resistance, at least within normal ranges of composition, since most of the manganese is probably present in the form of the corrosion performance. Further, there seems to be little variability in the corrosion behaviour (provided that other impurity levels are properly controlled) which could be attributed to differences in the form of the beneficial manganese, whether in solution or in particle form.

Experiments to produce such alloys on the large scale by the use of electrolytic manganese metal and to remove iron at the same time by using precipitating agents, other than manganese, are now progressing.

APPENDIX II.—COLORIMETRIC DETERMINATION OF IRON IN HIGH-PURITY MAGNESIUM ALLOYS.

In view of the importance of the accuracy of iron analysis figures obtained on high purity metal on the conclusions that can be reached from the research described in this paper, a brief outline is given below of the method developed by the analytical laboratories of Magnesium Elektron, Ltd., for the colorimetric determination of iron in high-purity magnesium alloys, and fully described elsewhere.¹⁰

The sample is dissolved in 50% hydrochloric acid, and hydroxylamine-hydrochloride is added in order to reduce the iron to the ferrous state. Ammonium tartrate is then added to keep the iron and aluminium in solution during subsequent operations. The required amount of o-phenanthroline is next added, and the pH adjusted to 4.0with ammonia and hydrochloric acid. The solution is then made up to standard volume, allowed to stand for 1 hr., and then transferred to the measuring cell of a "Spekker" photoelectric absorptiometer fitted with an Ilford spectrum filter.

A NEW ALUMINIUM-RICH PHASE IN THE 1037 ALLOYS OF ALUMINIUM AND MANGANESE.*

By (MISS) K. LITTLE,[†] B.A., B.Sc., STUDENT MEMBER, G. V. RAYNOR,[‡] M.A., D.Phil., MEMBER, and W. HUME-ROTHERY,[§] M.A., D.Sc., F.R.S., MEMBER.

SYNOPSIS.

Chill castings of aluminium-manganese alloys containing a few per cent. of manganese were prepared from high-purity metals, and were annealed at different temperatures. When annealed at or above 600° C., the two-phase alloys obtained were of the $(a + MnAl_{6})$ type, in agreement with the usually accepted equilibrium diagram. Castings annealed at lower temperatures showed three-phase structures, the phases being a, MnAl₆, and a new phase denoted "G." X-ray diffraction photographs showed the "G" phase to have the same structure as the "G" ternary phase in the system aluminium-chromium-manganese. On annealing these three-phase alloys at high temperatures, the "G" phase disappeared and alloys of the $(a + MnAl_{6})$ type were obtained; this indicates that the "G" phase is unstable at high temperatures. At lower temperatures, three-phase alloys persisted after very long periods of annealing, and it seems probable that "G" is a metastable, rather than a stable, constituent of the pure binary aluminium-manganese system.

I.-INTRODUCTION.

THE constitutional diagram of the aluminium-rich alloys of manganese and aluminium has been investigated most recently by Phillips ¹ who, however, used no alloys annealed below 600° C.; by Dix, Fink, and Willey,² and by Butchers and Hume-Rothery,³ the latter confining their attention to the accurate determination of the solid-solubility curve. These investigators were in agreement that the phases encountered are the α solid solution of manganese in aluminium, and two intermetallic compounds MnAl₆ and MnAl₄. The compositions of these compounds were confirmed by Raynor,⁴ who separated primary crystals from ingots quenched from the semi-liquid region. The usually accepted diagram is reproduced in Fig. 1.

In the course of a recent study of the structure of aluminium alloys, the present authors observed that when chill-cast binary aluminiummanganese alloys containing from 1 to 3% manganese were annealed at temperatures below 600° C., the resulting microstructures indicated the presence of the α -phase, MnAl_e, and of a new phase, which is denoted

‡ I.C.I. Research Fellow in Theoretical Metallurgy, University of Birmingham; formerly Inorganic Chemistry Laboratory, Oxford.

§ Royal Society Warren Research Fellow, Oxford.

^{*} Manuscript received April 29, 1946.

[†] Formerly Inorganic Chemistry Laboratory, Oxford.

84 Little, Raynor, and Hume-Rothery: A New

"G." Fig. 2 (Plate IV) shows the microstructure of one of these alloys after annealing at 550° C., and the presence of three phases is apparent. This section was etched with a permanganate-caustic soda mixture. An X-ray-diffraction photograph showed that the "G" phase had a crystal structure identical with that of the "G" ternary



FIG. 1.-Constitutional Diagram of the Aluminium-Manganese System.

phase discovered by Raynor and Little ⁵ in the system aluminiumchromium-manganese. Its appearance in binary aluminium-manganese alloys made from the purest metals was quite unexpected.

• Experiments have shown that the relative stability of the "G" phase is greatly affected by the presence of different elements, and it is hoped to publish an account of these effects later. Correspondence with Mr. H. W. L. Phillips, of The British Aluminium Company, Ltd.,

Al-Rich Phase in the Alloys of Al and Mn 85

suggested that the existence of the "G" phase might be of interest in connection with the effects of heat-treatment on the mechanical properties of aluminium-manganese alloys, and the authors therefore present this short paper in order to describe the main characteristics of the new phase.*

II.—THE CHARACTERISTICS OF THE "G" PHASE. 1.—Microstructure.

The failure of previous investigators to distinguish the "G" phase has probably been due to the small size of the crystals in the alloys examined, but with careful preparation there is no difficulty in detecting the presence of both "G" and MnAl, when they exist together in the same alloy. Familiarity with both phases is necessary before an isolated particle can be identified with certainty. The authors have obtained the most satisfactory results by careful hand-grinding of the alloys on graded emery papers moistened with paraffin, followed by hand-polishing with a liquid metal-polish of the "Brasso" type. Under these conditions, the unctched section of the alloy shows MnAl, to be a hard phase of pale-lavender colour, standing out in considerable relief, whereas the "G" phase is softer, lighter in colour, and shows little or no relief. The crystals of MnAle are normally of a comparatively regular geometrical form, while those of "G" have irregular shapes, although tending to be round. In Fig. 2 (Plate IV) it will be seen that a number of the "G" crystals have a hexagonal form with sharp corners and edges, but this characteristic is not usually observed. In general, when both types of crystal are present in an alloy the MnAl, crystals are found in grain boundaries, and "G" crystals within the grains. When both types of crystal are present, the MnAle crystals tend to occur in the grain boundaries, although, if the amount is large, they may be found in the body of the grains also. "G," on the other hand, tends to occur within the grains, although it may be found in the boundaries if the total amount present is large. The authors have never observed crystals of "G" in a Widmanstätten type of structure. although MnAl, does form this structure in some conditions.

The etching characteristics of the $MnAl_6$ and "G" phases arc summarized in Table I. It is to be noted that the effects observed for $MnAl_6$ agree with those given on pp. 1292-93 of the 1939 issue of the "Metals Handbook." The greatest contrast between the two

^{*} The correspondence with Mr. H. W. L. Phillips has made it clear that the "G" phase has been present in alloys prepared in other laboratories, but has escaped detection until recently.

86 Little, Raynor, and Hume-Rothery : A New

phases is obtained by etching with caustic soda and alkaline permanganate,* but considerable difficulties are encountered owing to uneven staining, particularly of the α . On the whole the most satisfactory distinction is made by the examination of the unetched specimens (or occasionally specimens etched with dilute HF), and it is to be noted that by lengthening the time of polishing the difference in the relief effects can be increased.

Etching Reagent.	MnAl _e .	"G" Phase,
0.5% HF, cold, 30 sec.	Outlined; slightly	No effect.
2N-NaOH, cold.	Attacked; uneven blue or brown stain.	30 sec.; becomes almost indistinguishable from
a sea a grant and the	T1. 03. 100 T.	a. 60 sec.; outlined.
Nitrie and sulphuric acids;	No effect.	No effect.
torners conditions: cold, 5 min.	Outlined; slightly	No effect.
Alk. permanganate.	Stained yellow to dark brown.	Unstained to pale yellow.

m		- Y
11 3 1	DIT	
TUI	DLC	- T •

2.-X-Ray Diffraction Patterns.

The X-ray diffraction patterns of the MnAl, and "G" phases are totally different, that of the "G" phase containing a relatively small number of lines. Fig. 3 shows the position of the lines on films obtained from alloys of the $(\alpha + MnAl_s)$ and $(\alpha + "G")$ types, † details of the latter being given in Table II. Specimens used were rods turned from previously annealed ingots. Although the aluminium lines were not always clearly defined, the compound lines were satisfactory. The $(\alpha + MnAl_s)$ specimen was obtained from a 5% manganese alloy annealed at 600° C.. and the $(\alpha + "G")$ specimen from a 3% manganese alloy annealed at 460° C. Results for copper Ka radiation have been given, since this is in such general use and is very suitable for the study of the lattice spacings of the α solid solution. The absorption edges of chromium and manganese are such that the use of copper radiation produces marked general scattering, and the films are not suitable for photographic reproduction, although the distinction between the two phases is quite easy. The general scattering can be reduced by the use of chromium radiation.

* This etching reagent consists of freshly mixed solutions of 2N-caustic soda and N/10-potassium permanganate in the ratio 1:10, and heated to $60^{\circ}-70^{\circ}$ C.

† As explained later, it was not possible to obtain an (a + "G") alloy completely free from MnAl_s.



FIG. 2 (a).—MnAl₄ (dark) and "G" in Alloy Containing 2.72% of Manganese. Etched with permanganate-caustic soda mixture. × 1000.



Fig. 2 (b).—As Fig. 2 (a). Showing $MnAl_6$ in grain boundaries and "G" within grains. \times 500.

[To face p. 80.





In each case the aluminium lines are given above, and the compound lines below. The lengths of lines are not proportional to the intensities, but class them as strong, medium, or weak. The ends of the diagrams represent Bragg angles of 0° and 90°.

87

VOL. LXXIII.

3.—The Composition of "G."

It has not yet been found possible to determine the composition of "G" directly, since the phase has been encountered only in conjunction with α and MnAl₈. The relative areas occupied by the two kinds of crystal make it clear that "G" contains more aluminium than MnAl₆. In the system aluminium-chromium-manganese, in

TABLE II.—Table of Angles for Some of the Strongest Lines of the Powder Diffraction Pattern of "G."

Line.*	Angle, °.	Line.*	Angle, °.
1 4 8 11 12 15 16	8.63 19.29 21.15 22.93 24.56 30.48 31.84	$ \begin{array}{c} 33 a_1 \\ a_2 \\ 34 a_1 \\ a_2 \\ 35 a_1 \\ a_2 \\ 35 a_1 \\ a_3 \\ 36 a_1 \end{array} $	60.74 60.99 62.17 62.44 65.19 65.48 70.35
19 21 24 27 32 a ₁ a ₂	$\begin{array}{c} 37.05\\ 38.27\\ 44.36\\ 46.78\\ 59.36\\ 59.59\end{array}$	$ \begin{array}{c} a_{2} \\ 37 \ a_{1} \\ a_{2} \\ 38 \ a_{1} \\ a_{3} \\ 39 \ a_{1} \\ a_{2} \\ \end{array} $	70.69 72.31 72.69 74.48 74.92 76.98 77.61

* See Fig. 3. The numbers of the lines are those marked in the figure.

which the "G" phase is stable, the preparation of a homogeneous specimen indicated a composition of $CrMn_4Al_{65}$ or $(CrMn)Al_{13}$. If it be assumed that one atom of chromium is equivalent to one of manganese, the formula of "G" will be $MnAl_{13}$. If it be assumed that the electron concentration in the sense used by Raynor and Little ⁵ remains constant, the composition of "G" will be $MnAl_{12\cdot6}$, whereas if 3 atoms of manganese were equivalent to 2 atoms of chromium as in the case of the ternary solid solution in $CrAl_{7}$, ⁵ the formula of "G" would be $MnAl_{11\cdot6}$, which may be compared with the compound WAl_{12} in the system aluminium-tungsten.⁶

III.—THE FORMATION OF THE "G" PHASE IN BINARY Aluminium-Manganese Alloys.

As stated in the introduction, the "G" phase was first observed when chill-cast alloys were annealed at not too high temperatures. These alloys were prepared from super-purity aluminium, kindly presented by The British Aluminium Company, Ltd., and from the purest electrolytic manganese, the latter being added in the form of a master alloy containing 5.6% manganese * The alloys were melted in crucibles lined with alumina-fluorspar mixture, using a standard flux mixture.† After thorough stirring with a sintered-alumina rod, the alloys were cast into heavy copper moulds giving cylindrical ingots of 1-in. dia. For heat-treatment, the alloys were sealed in evacuated glass tubes, and annealed in electric-resistance furnaces controlled by temperature regulators made by the Foster Instrument Company, Ltd.

When cast alloys containing 1-4% manganese, whose compositions were outside the limits of the α solid solution, were annealed at 600° C. for periods of 8 days or less, the microstructures showed them to consist mainly of $(\alpha + MnAl_{\theta})$ with a few crystals of "G." On increasing the time of annealing to 24 days or longer, the crystals of

"G" disappeared, and a number of experiments with alloys in different conditions indicated that the "G" phase was unstable at 600° C. or at higher temperatures.

When cast alloys were annealed at 550° C. for 8 days, the quantities of the "G" and MnAl, phases were about equal. On extending the time of annealing, the proportion of the "G" phase diminished very slowly with time, but even after 40 days the alloys still

REE ENERGY LIMIT OF MnAl G COMPOSITION + Mn



contained a considerable amount of "G." When cast alloys were annealed at 460° C. for 8 days, the microstructures showed mainly $(\alpha + "G")$ with a few crystals of MnAl_s in the grain boundaries, but annealing for 40 days produced no apparent difference in the proportion of the MnAl.

Apart from the above experiments with cast alloys, an alloy containing 1% manganese was annealed at 640° C. and quenched, in order to produce a homogeneous a solid solution. On re-annealing a specimen of this alloy at 600° C., the structure was ($\alpha + MnAl_{e}$), but when other specimens of the same alloy were re-annealed at temperatures between 550° and 350° C. the resulting alloys were all of the three-phase

^{*} The master alloy was kindly presented by The British Aluminium Company, Ltd., and contained as impurities silicon 0.0085, iron 0.0045, and copper 0.0040%. † The flux contained 224 parts by weight of anhydrous magnesium chloride, 80 parts potassium chloride, 15 parts sodium chloride, and 10 parts calcium fluoride.

92 Forrester and Greenfield : The Adhesion of

The factors influencing adhesion of white-metal to various backing materials were considered in detail by Pell-Walpole² and by Prytherch³ from a theoretical point of view and on the basis of numerous laboratory tests. An extensive bibliography accompanies their papers. Their laboratory adhesion tests, in which a large number of variables were studied, were made on small plugs of white-metal bonded to steel or other basis material. From the results obtained it was concluded that with test-pieces of this kind, properly tinned and with suitable choice of cooling conditions, a bond equal to, or exceeding, the strength of the white-metal is,obtainable between all the alloys and basis materials tested.

The intention of the present investigation was to examine whether such high bond strengths are obtainable in conditions analogous to those of practice, using the range of tin-base alloys in commercial use.

II.-EXPERIMENTAL PROCEDURE.

In hand-lining bearing half-shells it is usual to clamp the tinned shell vertically in a heated jig, cast in white-metal, and cool the shell by water or air blast. This was, essentially, the method adopted in this investigation except that, in the majority of cases, a flat plate was used in place of a semi-circular shell. Half-shells were also lined to check the results obtained on flat plates. Little difference was found in bond strengths, though, as will be shown later, an interesting difference in microstructure was observed.

The white-metal alloys were made from commercially pure metals and check analyses disclosed no significant departure from nominal composition.

After some preliminary work on tinning and lining the steel plates and shells, the procedure detailed below was adopted as giving the most consistent results :

(a) Pre-lining Treatment of the Steel.

- (i) Vapour-degreased with trichlorethylene.
- (ii) Pickled for 3 min. in cold 50% hydrochloric acid to remove all scale.
- (iii) Fluxed by scrubbing the steel briskly in a saturated solution of zinc chloride in water.
- (iv) Tinned, immediately after fluxing, by hot dipping (for 15 sec.) in pure tin at 280° C. with a zinc chloride cover. Parts not required to be tinned were stopped off with a mixture of 12 parts magnesia or alumina, 12 parts water glass, and 76 parts water.
- (b) Lining the Plate or Shell.
 - (i) The jig was heated to 320° C. in a thermostatically controlled oven; the types of jig used for shells and plates, respectively, are shown in Fig. 1 (a) and (b):



FIG. 1.-Jigs Used for Lining (a) Half-Shells and (b) Flat Plates.

- (ii) The tinned specimen was heated to 280° C. by immersion in a tin-pot; to prevent flux being trapped on the bond no cover was used on this tin-pot, oxidation of the tin being relatively slight at 280° C.
- (iii) The specimen was clamped in the jig as quickly as possible and all joints luted with a solution of alumina cement in water; jig and specimen were then placed in an empty water tank.
- (iv) White-metal was poured into the jig, about 15 sec. being required to fill it; the standard temperature of the white-metal was 50° C. above the liquidus of the alloy, though experiments were made with other casting temperatures.
- (v) The jig and specimen were then cooled, usually by quenching with water introduced into the bottom of the tank. The standard cooling rate was obtained by allowing water to flow into the tank at the rate of 3000 c.c./min.

Adhesion tests were carried out by the method described by Chalmers.⁴ This consists of isolating a plug of white-metal by means of a trepanning drill and then drilling a co-axial hole through the steel with a flat-ended drill. By forcing the plug of white-metal off the steel by means of a ram in a compression rig, the bond is fractured over an area of annular shape. Fracture takes place partly in tension and partly by tearing.

Micro-examination was carried out in conjunction with the bond testing, a micro-section being taken from one plate or shell for each alloy composition and for each variation in lining technique. The specimens were prepared in the usual way, particular care being taken

94 Forrester and Greenfield: The Adhesion of

with a 0000 final paper. Polishing on the wheel was omitted. They were polished for a very short time on a hand pad, using diamantine as abrasive, and were first briefly etched in a 4% solution of picric acid in alcohol, to attack the steel, and then finally etched in alcoholic acid ferric chloride (5 c.c. HCl, 2 g. FeCl₃, 30 c.c. water, and 60 c.c. absolute alcohol) for the white-metal.

III.-TIN-ANTIMONY-COPPER ALLOYS.

1.—Influence of Composition.

Steel plates were lined under standard conditions with twelve tinantimony-copper alloys containing 3, 7, 10, and 14% antimony and 1, 3.5, and 7% copper. Throughout this paper, these alloys are referred to by their antimony and copper percentages, the balance being understood to be tin. Four plates were lined with each alloy and four





adhesion tests were carried out on each plate, giving a total of 16 tests on each alloy. Adhesion tests were made some distance from the edges of the plate, for, as noted later, the edges showed structural differences. The results are shown in Fig. 2, in which average bond strength is plotted against antimony content for different copper contents, and the standard deviation for results on each alloy is given. Four bearing half-shells were also lined in standard conditions, two with 7 Sb/3 $\frac{1}{2}$ Cu and two with 7 Sb/7 Cu. The average bond strengths were 4.8 tons/sq. in. for the 7 Sb/3 $\frac{1}{2}$ Cu and 2.75 for the 7 Sb/7 Cu, showing good agreement with the results on flat plates.

With 1 and $3\frac{1}{2}\%$ copper, bond strengths are high and, as the figures for standard deviation indicate, consistent. In some cases fracture occurred partly in the white-metal so that the true bond strength would be rather higher than that recorded. Within the range of solid solubility antimony increases the bond strength, but when SbSn crystals appear further antimony has little effect with 1% copper, and reduces bond strength with $3\frac{1}{2}\%$ copper. With 7% copper, bond-strength values are much lower and much less consistent. Increase of antimony reduces the bond strength continuously. (In view of the high standard deviation for 7 Sb/7 Cu the discontinuity in the curve for 7% copper is not significant.)

Micro-examination showed a marked difference between the bond with alloys containing 1 and $3\frac{1}{2}\%$ copper and that with those containing 7% copper. With the 1 and $3\frac{1}{2}\%$ copper contents the bond was almost entirely between steel and the matrix phase, apart from an occasional Cu_8Sn_5 crystal in contact with the steel. (Little trace of the iron-tin compound was visible with standard tinning and lining conditions.) With 7% copper, parts of the bond showed continuous chains of Cu_8Sn_5 crystals which were apparently in direct contact with the steel. There was a marked difference between the structure at the centre of a plate and that at the edge. In all cases the edges of the specimens were fairly free from Cu_8Sn_5 at the bond, but an increasing number of Cu_8Sn_5 crystals at the bond became evident towards the middle of the specimen. This is shown in Figs. 3 and 4 (Plate V).

Micro-sections from the curved bearing shells showed similar differences between alloys of different copper contents, but with the 7% copper alloys there was less tendency to form Cu_8Sn_5 on the bond than with the flat plates.

A micro-section of an alloy containing 7% copper and no antimony showed a structure at the bond very similar to that of the 7 Sb/7 Cu alloy, indicating that the formation of Cu_6Sn_5 crystals at the bond is little affected by the antimony content of the alloy.

The difference in the microstructures of alloys of different copper content strongly suggests that the low bond strength of the highantimony, high-copper alloys is due to the formation of a brittle layer of Cu_6Sn_5 on the bond. Wood ⁵ has previously shown the importance of Cu_6Sn_5 distribution on bond strength. The effect is most marked with the less ductile alloys; the alloys 0 Sb/7 Cu and 3 Sb/7 Cu had

96 Forrester and Greenfield: The Adhesion of

bond strengths of 3.6 and 3.5 tons/sq. in., respectively, as compared to 2.0 tons/sq. in. for the 14 Sb/7 Cu alloy.

2.-Influence of Lining Conditions.

The formation of Cu_6Sn_5 at the bond, shown to be associated with low bond strength, is basically a case of normal segregation, for Cu_6Sn_5 is the first constituent to solidify in the 7% copper alloys, and with the standard cooling method the metal in contact with the steel is at the lowest temperature. The extent to which normal segregation occurs can be modified considerably, however, by various factors, viz., casting and mould temperatures (both of which affect the rate of cooling), extent of stirring, regularity and position of isotherms, and extent of undercooling (affected by presence of nuclei). These factors were therefore investigated to find the conditions in which minimum deposition of Cu_6Sn_5 occurs on the bond.

(a) Rate of Cooling.

The influence of the rate of cooling on bond strength was studied by two methods: (a) by variation in the controlled rate of water flow into the quench tank, and (b) by variation in the casting temperature of the white-metal.

(i) Effect of rate of water flow. This was studied by casting the white-metal from 50° C. above its liquidus and then cooling the plate by introducing water into the quench tank at controlled rates of 3000, 2000, and 1000 c.c./min. Alternatively, plates were cooled by spraying the steel backing with a fine jet of water, or by cooling without disturbance in air. Results are given in Table I.

-	t-Lhintow-	Bond St.	Bond Strength, tons/sq.in.				
Alloy.	Rate of Wa	ter Flow into Qu	Water Spray.	Air-Cool			
A CONTRACT	3000 c.c./min.	2000 c.c./min.	1000 c.c./min.	nuoci opiajo	Constitution of the		
7 Sb/3·5 Cu. 7 Sb/7 Cu .	5·47 2·67	5.45	4.82	2.60	4·55 2·05		

TABLE I.—Influence of Cooling Conditions on Bond Strength.

(ii) Casting temperature. Plates were prepared by casting the white-metal from 5° and 100° C., respectively, above its liquidus and quenching with a standard water flow of 3000 c.c./min. Results are given in Table II.

Both series of results indicate that rapid cooling of the lined plate is conducive to high bond strength with these alloys. Casting temperature



Fig. 3.—7 Sb/7 Cu Alloy Bonded to Steel. Edge of Flat Plate. \times 400.



Fig. 4.—7 Sb/7 Cu Alloy Bonded to Steel. Middle of Flat Plate. \times 400.



Fro. 5.—7 Sb/7 Cu Alloy Bonded to Steel Previously Tinned at 450° C. for 1 hr. Showing Cu_8Sn_5 lying on $FeSn_2$. × 400.

[To face p. 96.

Tin-Base Bearing Alloys to Steel

TABLE II.—Effect of Casting Temperature on Bond Strength.

Bond Strength, tons/ sq.in.					
Alloy.	Casting Temperature above Liquidus.				
Adam (14) 15 Sty - 2 and	100° C.	50° C.	5° C.		
7 Sb/3·5 Cu 7 Sb/7 Cu .	4·51 2·15	5·47 2·67	4-84		

appears to be of particular importance and should be kept as low as is conveniently possible; this is in agreement with the findings of Prytherch.³

One micro-section was taken for each alloy for each different condition of preparation. In the case of the 7 Sb/3½ Cu alloy, no difference could be detected between a bond that gave 5.47 and one that gave 4.55 tons/sq.in. All the 7 Sb/7 Cu specimens showed Cu₈Sn₅ crystals on the bond in amounts varying from occasional single crystals, in the case of specimens cast from 5° C. above the liquidus, to a long continuous chain, in the case of specimens cast from 100° C. above the liquidus. In every case a reduced rate of cooling gave more Cu₈Sn₅ at the bond. Micro-sections from shells lined with 7 Sb/7 Cu also showed more Cu₈Sn₅ at the bond with a reduced rate of cooling.

The fact that a high rate of cooling tends to prevent formation of Cu_8Sn_5 at the bond may explain to some extent the difference observed between the edge and the middle of flat plates, but it can scarcely be the only factor : the rate of cooling at the centre of a water-cooled plate is much greater than that at the edge of an air-cooled plate, yet the centre of the water-cooled plate shows much more bond Cu_8Sn_5 . Moreover, a different rate of cooling does not explain the difference between a flat plate and a curved shell, for, under the same conditions, the time taken for the white-metal to solidify was practically the same in both cases.

(b) Puddling.

In the production of commercial hand-cast bearings, it is usual to puddle the white-metal until it reaches a temperature about mid-way between its liquidus and solidus to obviate the entrapment of air at the bond. To study whether such puddling influences the formation of Cu_6Sn_5 crystals at the bond an experiment was carried out with 7 Sb/7 Cu alloy. The white-metal was cast from 495° C. (100° C. above its liquidus) and puddled vigorously until the temperature, measured

98 Forrester and Greenfield: The Adhesion of

by a thermocouple, had decreased to 350° C., at which point water was introduced into the quench tank at a rate of 3000 c.c./min.

Micro-examination of a horizontal section taken from the middle of the lined plate showed a continuous chain of Cu_6Sn_5 crystals at the bond, with a definite tendency for more crystals to occur at the centre of the plate than at the edges, *i.e.*, precisely the same as the distribution obtained without puddling.

(c) Direction of Cooling.

A jig was constructed to give cooling towards the bond, *i.e.*, in the opposite direction to that obtained in the standard lining procedure, but at the same rate. Two plates of 7 Sb/Cu alloy were cast into the new jig and water-cooled at the standard rate of 3000 c.c./min.

Four adhesion tests were carried out on each plate; the average of the eight results was 2.68 tons/sq.in. Micro-examination showed that the bond was practically free from Cu_6Sn_5 , thus confirming that cooling from the bond is an essential condition for Cu_6Sn_5 formation at the bond. The fairly low bond strength obtained in this case is almost certainly due to shrinkage cavities, as suggested by Pell-Walpole.²

The possibility remains that if conditions could be so arranged as to give a compromise between these two types of cooling (normally from bond and normally from mandrel) rather better adhesion might be obtainable.

(d) The Part Played by Nuclei.

It has been noted above that some segregation of Cu_6Sn_5 at the bond is to be expected with cooling from the bond. The continuity of the Cu_6Sn_5 layer sometimes observed, however, suggested that some factor such as the existence of nuclei for crystallization at the bond might play some part.

To investigate this hypothesis a steel plate was prepared in the usual way, then lightly oxidized by heating, and left untinned. It was then set up in the jig and lined with white-metal in the usual way. The white-metal parted readily from the untinned steel plate, so, to preserve the "bond" surface for polishing, it was plated with copper. Examination showed no tendency to preferential segregation of Cu_6Sn_5 at the "bond" surface. A few needles were found growing normally to the surface but there was no continuous chain. It is clear therefore that the steel surface plays a part in the formation of Cu_6Sn_5 , probably by providing nuclei for crystallization. Such nuclei might be provided by the steel itself or by the FeSn₂ layer resulting from the tinning operation. If FeSn₂ be assumed to be responsible, it might be possible

Tin-Base Bearing Alloys to Steel

to obtain a better bond by casting white-metal on to an untinned steel plate cleaned in a molten salt bath of the type developed for tinning cast iron.⁶ This method was examined by cleaning an untinned steel plate by immersion in a molten salt bath (75% ZnCl₂ + 11% NaCl + 14% KCl) at 180° C. for 8 min. and then lining it with 7 Sb/7 Cu alloy, using the standard procedure. The average bond strength of this plate was 1.31 tons/sq.in.-considerably less than that obtained on a plate lined after tinning. Micro-examination showed a continuous layer of Cu.Sn. on the bond except at the outside, at which the laver was intermittent. This method, therefore, accentuated rather than reduced the tendency to precipitation of Cu_sSn₅ on the bond. The experiment showed that with the fused-salt method of cleaning the formation of Cu_eSn₅ at the bond is not avoided; it leaves in doubt the question whether steel or FeSn, crystals act as nuclei, for some FeSn, may be expected to form immediately the white-metal touches the steel, although insufficient in amount to be resolvable under the microscope.

On the alternative hypothesis, viz., that the nuclei are provided by the steel itself, a continuous layer of FeSn_2 might be beneficial. A steel plate was therefore tinned at 450° C. for 1 hr. to build up a thick layer of FeSn_2 . It was then lined with 7 Sb/7 Cu alloy under standard conditions. Micro-examination showed a continuous chain of Cu_8Sn_5 crystals along the thick FeSn_2 layer (Fig. 5, Plate V).

A third possibility was examined, namely that of providing alternative nuclei by adding 0.2% of tellurium so that SnTe becomes the primary phase. Two plates were lined under the standard conditions with the 7 Sb/7 Cu alloy containing an addition of 0.2% tellurium. Sections were taken for micro-examination and bond tests carried out on the remaining portions of the plates. Eight bond tests were made; the average result was 2.2 tons/sq.in. The micro-sections showed that there was rather less Cu_6Sn_5 at the bond than with the tellurium-free specimens, but the difference was not very marked.

As might be expected, copper also provides nuclei for Cu_6Sn_5 formation, as was shown by lining a $\frac{1}{4}$ -in. copper plate with 7 Sb/7 Cu alloy; a string of Cu_6Sn_5 crystals could be seen at the bond. The effect on bond strength, however, was less than with steel, the fairly high value of 3.6 tons/sq.in. being obtained. This is perhaps attributable to the greater ductility of the copper which results in better spreading of the load.

3.-Mechanism of Cu₆Sn₅ Formation at the Bond.

It has been shown that there are three requirements for formation of Cu_8Sn_5 at the bond :

100 Forrester and Greenfield: The Adhesion of

- (i) high copper content;
- (ii) slow cooling from the bond surface inwards; and
- (iii) a clean, or tinned steel surface.

To explain these facts the following hypothesis is put forward. The part of the liquid bearing metal which reaches its liquidus temperature first is, in theory, that adjacent to the bond surface. In practice it is probable that, owing to disturbing influences such as convection currents, the temperature close to the bond surface varies irregularly and a number of points at or near to the bond reach the liquidus temperature almost simultaneously. Supercooling, however, is known to be quite usual in this system, so primary separation of CueSn, will only occur at the liquidus temperature when nuclei are present. Such nuclei are provided at the steel surface either by the steel itself or by FeSn₂. Crystals of Cu_eSn₅, therefore, form first at the bond, impoverishing the liquid locally in copper. (Such local impoverishment has been observed in some micro-sections.) If this impoverishment in copper is maintained, these first-formed crystals will be restricted in size and more crystals will form farther from the bond in areas of higher copper content. On the other hand, if diffusion can occur copper will diffuse into the metal near the bond, allowing the first-formed crystals to grow and new crystals to form on more bond nuclei. The extent of Cu_cSn₅ formation at the bond is thus controlled by the copper content near the bond surface, which is, in turn, controlled by the original copper content of the metal and by the extent of diffusion. High rates of cooling tend to inhibit diffusion and so restrict Cu_sSn₅ formation at the bond.

This hypothesis does not account for the curious difference observed between the centre and the edge of a flat plate, and the less marked difference between a flat plate and a curved shell. As has been noted on p. 97, these differences cannot be attributed directly to different rates of cooling. It is quite possible, however, that diffusion of copper, which controls the rate of Cu_6Sn_5 formation, may be influenced by temperature gradients consequent on differential cooling.

4.-Nature of the Bond Weakness Caused by Cu₆Sn₅.

The conclusion reached as a result of the present investigation, that alloys of high copper content may have a low bond strength in consequence of Cu_8Sn_5 at the bond, is apparently contradictory to the findings of Prytherch,³ whose results indicated little change in bond strength with copper contents from 1.5 to 7%. Prytherch used a test in which the bond is tested in pure tension, whereas the present series of tests was carried out by Chalmers' method, which imposes, as noted earlier, a tearing stress. To investigate whether the test method has any influence some tests were carried out in which the bond was fractured by simple shear.

Steel plates were lined with white-metal in the way already described and then cut into strips, each 2 in. long by 0.5 in.

wide, four specimens being obtained from each plate. Holes, counter-sunk to the bond and of a size suitable to fit self-aligning grips in a tensile-testing machine, were drilled at each end of the specimens, as shown in Fig. 6. Slots were cut completely across and through the steel and the white-metal, thus isolating an area of the bond of about 0.075 sq.in. The specimens were then pulled in the tensile machine. Results are given in Table III, which also includes results obtained with similar specimens tested by



FIG. 6.—Specimen Used for Shear Test.

Chalmers' method and by the chisel test, in which a chisel is placed at the bond and hammered.

TABLE III.—Comparison of Results of Different Bond-Strength Te	ests.
--	-------

Alloy.	Lining Conditions.	Bond Strength in Shear, tons/sq.in.	Bond Strength by Chalmers' Method, tons/sq.in.	Result of Chisel Test.
7 Sb/3½ Cu.	Standard water- cool.	3.43	5-47	Good adhesion. Much force re- quired to sep- arate.
7 Sb/7 Cu .	Air-cool.	3-08 3-14	2.67 2.05	Bond fractured by light tap.

Micro-examination showed the usual Cu_8Sn_5 layer at the bond of all the 7 Sb/7 Cu specimens.

These results show clearly that the effect of Cu_6Sn_5 is to reduce the ductility of the bond rather than to reduce its ultimate strength in tension or shear, for the influence of Cu_6Sn_5 is only shown by a test which affords a measure of ductility. This raises two more questions: (a) if tinning conditions are such as to allow a thick layer of FeSn₂ to form, does this have a similar effect?; and (b) is the type of weakness conferred by Cu_6Sn_5 a potential source of trouble in a bearing?

To decide the first question, a steel plate was immersed in the tinpot for 1 hr. at 450° C., then lined with 7 Sb/3½ Cu alloy in standard conditions. Tested by Chalmers' method, this specimen gave an

102 Forrester and Greenfield: The Adhesion of

average bond strength of 0.17 tons/sq.in., while a micro-section showed a thick continuous layer of FeSn_2 but practically no Cu_6Sn_5 on the bond. The very low bond strength must therefore be attributed to the thick layer of FeSn_2 .

The second question, whether embrittlement of the bond by Cu_8Sn_5 impairs the serviceability of a bearing, can only be answered conclusively after comparative bearing tests. There is at least a strong probability that, where a bearing is subjected to pounding, such embrittlement will result in failure. It may well be that the reputedly unsatisfactory service of alloys with high proportions of antimony and copper in conditions of alternating load is due more to bond brittleness than to the properties of the alloys themselves. In view of this, it is highly desirable that the adhesion of bearings should always be tested by a method which involves a tearing action (as does Chalmers' method) or, alternatively, measures resistance to shock (as does the method described by Bradley and O'Neill, ' using an Izod machine). Methods involving static tension or shear are likely to give misleading results.

IV .--- TIN-ANTIMONY-COPPER-CADMIUM ALLOYS.

The addition of cadmium to tin-antimony-copper alloys has been shown to increase their hardness,^{8, 11} tensile strength,^{8, 9} fatigue strength,^{10, 11} and resistance to pounding.¹² It has been suggested, however, that cadmium may impair bonding qualities. To study the effect of cadmium on the adhesion of tin-base white-metals to steel, several flat plates were lined with an alloy containing 9% antimony and 2% copper with additions of 1, 2, and 3% cadmium, using different rates of cooling. The results are given in Table IV.

TABLE IV.—Influence of	f Cooling	Rate of	n Adhesion	of	Alloys	Containing
Cadmium.						

	Bond Strength, tons/sq.in.						
Alley,	Rate of Water Flow into Quench Tank.						
and a get or motion	3000 c.c./min.	2000 c.c./min.	1000 c.c./min.	All-Cool.			
9 Sb/2 Cu/1 Cd . 9 Sb/2 Cu/2 Cd . 9 Sb/2 Cu/3 Cd .	2·43 1·61	2.55	4·37	6·21 6·08 4·26			

These results indicate that a good bond can be obtained with tinbase alloys containing up to 3% cadmium provided that slow cooling is employed. Rapid cooling gives low bond strength in the cadmium-

Tin-Base Bearing Alloys to Steel

containing alloys, in contrast to its favourable effect on the adhesion of the cadmium-free alloys. In the latter, rapid cooling is favourable to adhesion because it suppresses Cu_6Sn_5 formation at the bond and tends to prevent the formation of shrinkage cavities. In the cadmiumcontaining alloys these favourable tendencies are probably nullified, as Pell-Walpole² suggests, by the effect of differential contraction. Having a much higher creep strength than the cadmium-free alloys, those containing cadmium cannot absorb this contraction so readily by rapid creep and cracks form with high rates of cooling.

V.-CONCLUSIONS.

(1) Using ordinary hand-lining methods, bonds as strong as the white-metal itself can be obtained with tin-antimony-copper alloys with up to $3\frac{1}{2}$ % of copper. The rate of cooling is not critical, but rather higher bond strengths are obtained with rapid cooling.

(2) With alloys containing 7% copper a layer of Cu_6Sn_5 may form at the bond and reduce its ductility and resistance to shock. The formation of such a layer takes place only when cooling is from the bond and the steel is wetted by the metal, but both these conditions are, for other reasons, essential to continuous bonding. The only practicable method found to avoid Cu_6Sn_5 on the bond and to obtain good adhesion with 7% copper alloys is to use a low casting temperature and very rapid cooling.

(3) The chisel test and Chalmers' test both demonstrate the existence of this type of bond weakness, but a plain static-shear test does not do so.

(4) Tin-antimony-copper-cadmium alloys give a good bond strength when slow cooling is used. Rapid cooling has a detrimental effect on the bond.

ACKNOWLEDGEMENTS.

The investigation described in this paper was carried out in the laboratories of the Tin Research Institute, to which the authors are indebted for permission to publish the results.

For references, see p. 104.

REFERENCES.

- 1. S. A. McKee, Inst. Mech. Eng., General Discussion on Lubrication, 1937, p. 179.
- W. T. Pell-Walpole, J. Inst. Metals, 1942, 68, 217.
 J. C. Prytherch, J. Inst. Metals, 1942, 68, 230.
 B. Chalmers, J. Inst. Metals, 1942, 68, 253.

- E. Wood, Metal Ind., 1938, 52, 569.
 R. A. Cresswell, Iron Steel Inst. Preprint, 1946, (Feb.).
- 7. J. N. Bradley and H. O'Neill, J. Inst. Metals, 1942, 68, 259.
- 8. C. E. Homer and H. Plummer, Tech. Publ. Internat. Tin Research Develop. Council, 1937, [A], (57). 9. H. Greenwood, Tech. Publ. Internat. Tin Research Develop. Council, 1937, [A],
- (58).
- 10. D. J. Macnaughtan, J. Inst. Metals, 1934, 55, 33.
- 11. F. K. v. Goler and G. Sachs, Mitt. Arbeitsbereich Metallges., Frankfurt, 1935, (10), 3.
- 12. H. Greenwood, J. Inst. Metals, 1934, 55, 77.

METALLURGICAL ABSTRACTS

		PAGE
I.	Properties of Metals	345
II.	Properties of Allovs	347
III.	Structure (Metallography; Macrography; Crystal Structure).	352
IV.	Dental Metallurgy	1 -
V .	Powder Metallurgy	353
VI.	Corrosion and Related Phenomena	354
VII.	Protection (Other than by Electrodeposition)	355
VIII.	Electrodeposition	355
IX.	Electrometallurgy and Electrochemistry (Other than Electro-	
	deposition)	
Х.	Refining	
XI.	Analysis	355
XII.	Laboratory Apparatus, Instruments, &c.	364
XIII.	Physical and Mechanical Testing, Inspection, and Radiology.	365
XIV.	Temperature Measurement and Control	366
XV.	Foundry Practice and Appliances	366
XVI.	Secondary Metals : Scrap, Residues, &c	
XVII.	Furnaces, Fuels, and Refractories	370
XVIII.	Heat-Treatment	
XIX.	Working	371
XX.	Cleaning and Finishing	0.71
XXI.	Joining	371
XXII.	Industrial Uses and Applications	372
XXIII.	Miscellaneous	070
AAIV.	Bibliography	313
AAV.	DOOK NOVIOWS	

AUTHOR INDEX TO ABSTRACTS

AGEEV, N. V., 351. Akimova, K. I., 368. Aksenov, G. I., 366. Al'tschuller, L. V., 353. Andon'eva, A. K., 362. Andrade, E. N. da C., 374. Aref eva, T. V., 360. Arend, A. G., 345. Ashkinadzi, M. S., 361. Ashworth, F., 346. Baird, J., 372. Bastien, P., 352, 368. Bastings, L., 366. Bates, R. S., 374. Baum, H., 373. Beck, G., 355, 356. Beerwald, E., 350. Beltaky, M. S., 359. Beltaky, W. S., 359. Bel'masov, V. E., 365. Beunderman, W. F., 373. Bjerre, E., 373. Blinov, V. L., 365. Blok, I. I., 358. Blot, M., 373. Bochvar, A. A., 347, 351, 367, 368. Bornand, R., 371. Boutin, P., 368. Brekhovskikh, L. M., 353. Bungardt, W., 347. Burton, E. F., 375. Busk, R. S., 350. Cambier, E., 369. Carslaw, H. S., 375. Chernikhov, Y. A., 357. ^{357.} Colton, R. A., 348. Contractor, G. P., 371. Converse, C. J., 369. Cooper, H. J., 375. Courard, T., 372. Dauxois, P., 369, Davies, W. O., 362, Davids, J. A., 367, Davydov, A. L., 355, Dawson, J. A. T., 366, Dennery, C., 368, Desch, O. H., 375, Devekki, V. S., 355, Domony, A. 345

Domony, A., 345. Dubovitskaya, E. I., 360 Dudley, L. P., 366.

Eastwood, L. W., 367. Ebert, H., 349. Edwards, F. H., 360. Eeckhout, I. J., 358. Evans, B. S., 359, 364.

Finckh, B., 357. Forsyth, P. E. J., 351. Frear, C. L., 365. Fridman, Y. B., 346.

Gabor, D., 375. Galko, A. I., 366, Galko, A. I., 366, Galler, B. A., 357. Gelylikman, B. T., 347. Gentry, O. H. R., 356. Gibbs, L. E., 376. Gibbs, L. E., 370. Gibson, J., 364. Giffen, E., 375. Ginzburg, V., 346, 347. Glukhov, A. D., 359. Gorman, L. J., 354. Gorskaya, N. F., 358. Grober, H., 347. Gubkin, S. I., 371. Guérin, R., 369. Gulbransen, E. A., 364. Gurevich, L., 347. Hadley, W. H., 358. Hägg, G., 365. Hanawalt, J. D., 372. Happey, F., 364. Haughton, J. L., 351. Haughion, J. L., 351. Haynes, H. G., 356. Hedley, W. H., 375. Heitler, W., 376. Heiz, W., 371. Higgs, D. G., 359, 364. High, J. H., 360. Holness, H., 356, 357. Hotop, W., 353, 354. Hudson, F., 368. Hull, A. W., 365. Il'in, D. I., 365. Irmann, R., 371. Ivantsov, L. M., 363. Izgaryschev, N. A., 355. Johnson, W. A., 345.

Kenner, R., 370. Key, C., 362. Khakimdzhanova, M. K., 347. Khrashanovsky, S. A., 363. 363.
 Kiefter, R., 353, 354.
 Kistler, W., 345.
 Kobl, W. H., 375.
 Koblmeyer, E. J., 371.
 Kolthoff, I. M., 358.
 Komar, A., 349.
 Kortlum, G., 357.
 Kostarev, A. I., 353. Kostarev, A. I., 353. Kubaschewski, O., 349. Kurakin, K. D., 371. Kuznetsov, V. A., 359.

Lambie, D. A., 357. Lambie, D. A., 357. Landau, L., 346, 347. Landberg, G. S., 363. Laurent, T., 365. Laurs, L., 348. Ichmann, H. L., 361. Lennox, J. W., 354. Leontis, T. E., 350. Lifsbits, E. M., 352. Lingane, J. J., 360. Linsley, H. E., 370.

Lobrushkin, S. L., 352. Loring, B. M., 348. Lukens, B. L., 376. Lyons, R. E., 365. Macgillivray, L. L., 366. Macnner, R. J., 367. Maillard, L., 369. Marande, R. F., 350. Marquardt, K., 353. Marshall, W. K. B., 372. 372. Matsuyama, G., 358. Mayants, A. D., 363. Meyer-Rässler, E., 348. Mikheeva, V. I., 350. Mikul'chik, F. A., 352. Missia, J. D. 269. Minster, J. D., 362. Minz, I. M., 359. Mironenko, M. L., 360. Montupet, J., 370. Motock, G. T., 376. Mukhina, Z. S., 360. Nakhimovich, N. M., 346. Nemilov, V. A., 372. Nevsky, B. V., 372. Nicola, A., 355. Nicolas, P., 369. Nikitin, A. D., 357. Nikitin, V. N., 363. Orowan, E., 346. Perrault, R., 376. Picard, R. G., 364. Pinenne, M. H., 376. Pietenev, S. A., 360. Portrey, A. W., 364. Portnoy, K. I., 365. Prater, J. D., 376. Price, J. W., 362. Prokolev, V. K., 361. Pshenitsyn, N. K., 360. Rakov, V. I., 366. Reimann, A. L., 349. Rhines, F. N., 350. Rice-Oxley, F. B., 370 Rivelin, R. S., 364. Rogozbin, V. V., 366. Ronceray, R., 370. Rocksby, H. P., 364. B., 376. Rubinshtein, A. М., 372, 378, V., Rudnitsky, 316, 351, 352. Russell, A. E., 365. Rysanov, A. K., 359. de Saint-Andriev, A., 370. Sanoylovich, A., 348. Sanitsky, E. M., 371. Schlain, D., 376. Schlatter, H. A., 371. Schleicher, A., 362. Schmidt, H. W., 372.

Schneider, A., 345. Schoeller, W. R., 356, 357. Schoofs, J., 373. Schrödinger, E., 376. Schupp, K., 345. Schupp, K., 345. Scdlon, V. J., 369. Seemann, H. E., 366. Shanahan, O. E. A., 362 362. SheIntsis, O. G., 356. Sherrington, L. G., 356. Shipkina, L. A., 319. Shumilova, N. A., 358. Simanosvky, P. V., 360. Simon, W. H., 376. Smith, O. J., 376. Smith, W. R., 351. Sokolov, N. A., 358. Sokolov, N. N., 373. Solodovnik, S. M., 359. Spassky, A. G., 366, 367. Stepanov, P. E., 348. Stricter, F. P., 367. Striganov, A. R., 361. Sukhenko, K. A., 358. Taylor, E. D., 346. Taylor, H. F., 367. Teece, J. H. H., 370. Todoroff, T., 362. Tooley, D. A., 372. Trapeznikov, A. К., 366. Tripol'skaya, R. S., 361. Trismakov, P. M., 352. Tsukerman, V. A., 353. Umansky, M. M., 353. Uspensknya, T. A., 357. Van der Voort, P., 362. Van Pee, P., 363. S., Vasileyskaya, N. 363. Velichko, I. P., 349. Viswanathan, S., 371. Vvedensky, L. E., 362, 364. Wassermann, G., 347. West, P. W., 355. Weyn, O., 363. Wick, W. C., 367. Yavnel, A. A., 358. Zakhariya, N. F., 361. Zakharov, M. V., 353. Zan'ko, A. M., 357. Zan'ko, A. al., 357. Zel'dovich, Y., 346. Zhadaeva, O. S., 351. Zheldak, M. P., 366. Zbeleztsov, N. A., 359. Zhmudsky, A. Z., 349.

Zvyagintsev, O.

353.

E.,

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 13

OCTOBER 1946

Part 10

I.—PROPERTIES OF METALS

*Investigations Into the Rapid Deformation of Aluminium. W. Kistler (Schweiz. Arch. angew. Wiss. Techn., 1946, 12, (6), 169–176).—[In German]. X-ray examination of aluminium tubes produced by impact extrusion failed to provide evidence that the type of deformation taking place as the result of a sudden blow is in any way different in kind from that obtaining in slow methods of working. The deformation is by slip along the same planes and in the same directions in both cases. A large part of the paper is devoted to a mathematical consideration of the process of deformation in impact extrusion, based mainly on Kochendörfer's theories of plasticity. This showed that any difference in the plastic behaviour of aluminium in slow and in rapid deformation can be adequately explained by the temp. increase which occurs in the latter case.—N. B. V.

*Blister Formation in Semi-Fabricated Parts of Aluminium or Aluminium Alloys. András Domony (Bányászati és Kohászati Lapok, 1941, 74, 455–460; Chem. Zentr., 1942, 113, (II), 453; C. Abs., 1943, 37, 6230).—It is shown by experiment that the cause of surface blisters, apart from such well known factors as insufficient deoxidation or faulty casting and fabricating procedures, can be segregation in the casting. To obtain a sound structure, the castings should be cooled quickly and uniformly.

*Diffusion of the Stable Isotopes of Nickel in Copper. William A. Johnson (Metals Technol., 1946, 13, (4); A.I.M.M.E. Tech. Publ. No. 2007, 13 pp.).—A layer of nickel was plated on to a copper cylinder and diffusion was made to occur by annealing for 3–4 days at 1053° C. in "Ammogas." Successive layers were then turned off and were analysed for copper. The residue of nickel sulphate was then converted into nickel carbonyl which was examined in a mass spectrometer. The relative abundance of the different isotopes is altered by diffusion, and the results are best explained by assuming that the isotopes diffuse at rates inversely proportional to the square roots of their masses.—W. H.-R.

Lithium: Extraction, Recovery, and Industrial Uses. A. G. Arend (Indust. Chemist, 1944, 20, (235), 423-426).—A short account is given of the occurrence and extraction of lithium. The uses of the metal have developed greatly since 1939: it is now added to lead (with calcium) to produce a bearing metal, and (usually with beryllium) to aluminium as a hardening and strengthening ingredient. It is also used in the deoxidation of copper and for the removal of such impurities as phosphorus, sulphur, and carbon from other metals; its ready combination with occluded gases suggests a use in the fixation of nitrogen.—P. R.

*Rates of High-Temperature Oxidation of Magnesium and Magnesium Alloys. (Leontis and Rhines). See p. 350.

*The Vapour Pressure of Tellurium. A. Schneider and K. Schupp (Z. Elektrochem., 1944, 50, (6/7), 163-167).—The vapour pressure of molten tellurium was determined and found to obey the law :

$$\log p_{(600^{\circ}-750^{\circ}\text{ C.})} = -\frac{5130}{T} + 6.78,$$

- * Denotes a paper describing the results of original research.
- † Denotes a first-class critical review.

CC

where p is the pressure in c.g.s. units and T is the temp. in ° abs. The latent heat of vaporization per mol. Te₂ at 900° abs. was found to be $23\cdot8\pm0\cdot3$ kg.-cal. From this value and that of the critical temp., 2260° abs., the calculated latent heat of vaporization λ_{1} at the b.p. is approx. 18-22 kg.-cal., and Trouton's const. lies between 11 and 13.—E. N.

*Anomalous Dependence of the Resistance of Zinc on the Magnetic Field. N. M. Nakhimovich (Zhur. Eksper. Teoret. Fiziki, 1942, 12, (11/12), 539– 541).—[In Russian]. N. measured the electrical resistance of a single crystal of zinc at the temp. of liquid helium in an alternating transverse magnetic field (up to 22.7×10^3 oersteds).—D. A.

Notch Brittleness and the Strength of Metals. E. Orowan (Trans. Inst. Eng. Ship. Scotland, 1946, 89, 165–196; discussion, 196–215).—Present-day conceptions regarding the physical basis of the strength properties of metals are reviewed with regard to mechanical testing and engineering design and the types of fracture which occur in practice, particular attention being paid to brittle fracture and the fibrous type of ductile fracture. Brittle fracture is considered with reference to molecular and technical strength, the experimental verification of the crack theory of brittle strength, and the fracture condition for brittle fracture. The Ludwik theory of notch brittleness is dealt with, and the plastic-constraint factor of the ideal notch and elastic super-stressing discussed as a possible cause of brittle notch fracture. The relationships between notch brittleness and velocity of crack propagation, and between notch brittleness and low-temp. brittleness are also considered, and a criterion given for the mechanism of brittle fracture. Reference is also made to Kuntze's method of "cohesive strength" and to fatigue fracture.—J. W. D. Resistance-Temperature Coefficients of Metals and Semi-Conductors.

Resistance-Temperature Coefficients of Metals and Semi-Conductors. F. Ashworth and E. D. Taylor (J. Inst. Elect. Eng., 1945, 92, [I], (59), 412-413).—An elementary account of the subject is given.—E. V. W.

*The Mutual Displacement of Metals from Vapours of Their Salts and the Application of These Processes to the Protection of Metals. (Izgaryshev). See p. 355.

*On the Relation Between the Liquid and Gaseous States in Metals. Ya. Zcl'dovich and L. Landau (Zhur. Eksper. Teoret. Fiziki, 1944, 14, (1/2), 32-34).—[In Russian]. General considerations regarding the transition of a substance from the metallic to the dielectric state lead to the conclusion that such a transition takes place as an ordinary phase change up to very high temp. Consequently the existence may be expected, in a certain range, of two distinct transitions (at different temp. and pressures), from the metallic to the non-metallic state and from the liquid to the gaseous state.—N. A.

[†]The Physico-Chemical Problem of the State of Metallic Surfaces. (Bastien). See p. 352.

On the Evaluation of the Static Plasticity of Metals. Ya. B. Fridman (Zavod. Lab., 1940, 9, (7), 761–775).—[In Russian]. The fundamental characteristics of static plasticity (elongation and reduction of area) are reviewed, and the significance of these properties in the practical testing of materials is discussed. —N. A.

*Change in Thermal Conductivity of Metals in a Magnetic Field at Low Temperatures (T < 0). V. Rudnitsky (*Zhur. Eksper. Teoret. Fiziki*, 1941, 11, (4), 463-466).—[In Russian]. Mathematical treatment of the dependence of the change of thermal conductivity on the magnetic field and temp.—D. A.

On the Thermoelectric Phenomena in Supraconductors. \hat{V} . Ginzburg (*Zhur. Eksper. Teoret. Fiziki*, 1944, 14, (6), 175–183).—[In Russian]. Theoretical. In the presence of a temp. gradient the normal current in a supraconductor must increase; in an isotropic supraconductor, however, this current is compensated by the supraconducting current and hence is not detected. In supraconducting crystals the resulting c.d. is not zero and the

Observations on the Theory of Supraconductivity. V. Ginzburg (Zhur. Eksper. Teoret. Fiziki, 1944, 14, (5), 134-151).—[In Russian]. The general state of the theory of supraconductivity and a number of questions relating to it are discussed in the light of the latest experimental and theoretical investigations.—N. A.

On the Theory of the Intermediate State of Supraconductors. L. Landau (*Zhur. Eksper. Teoret. Fiziki*, 1943, 13, (11/12), 377-387).—[In Russian]. Theoretical. A quantitative theory of the layer structure of supraconductors in the intermediate state has been evolved. Cf. L. Landau, J. Physics (U.S.S.R.), 1943, 7, 99-107; Met. Abs., 1944, 11, 247.—N. A.

On the Theory of Ferromagnetism. B. T. Geylikman (Zhur. Eksper. Teoret. Fiziki, 1943, 13, (11/12), 399-410).-[In Russian]. Sce Met. Abs., 1945, 12, 76.-N. A.

Energy Levels of Strongly Bound Electrons in Metals. B. T. Geylikman (Zhur. Eksper. Teoret. Fiziki, 1943, 13, (5), 168–180).—[In Russian]. Theoretical calculation of energy levels.—D. A.

*The Absorption of High-Frequency Sound by Metals. L. Gurevich (Zhur. Eksper. Teoret. Fiziki, 1944, 14, (6), 202-204).—[In Russian]. It is shown that sound of high frequency (exceeding the inverse time of the free propagation of Debye waves) is absorbed by metals for a time of the order of the period of the sound, *i.e.*, it is impossible in practice for the sound to be propagated in metals.—N. A.

II.—**PROPERTIES OF ALLOYS**

[†]Results of Microscopic and X-Ray Investigations of the Process of Age-Hardening in Aluminium Alloys. G. Wassermann (*Metallwirtschaft*, 1944, 23, (44/47), 387-391).—A critical review, with references, of recent work on the phenomena associated with the age-hardening of aluminium alloys.—E. N.

*On the Tendency of Aluminium Alloys to Cracking Under Shrinkage Stresses. A. A. Bochvar and M. K. Khakimdzhanova (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota (Collected Scientific Works of the Moscow Institute for Non-Ferrous Metals and Gold), 1940, (8), 39-45).-[In Russian]. By a method developed by B. and K., aluminium-silicon alloys containing 2, 4, 6, 8, 10, and 12% silicon, and aluminium-copper alloys containing 4, 8, and 12% copper, and pure aluminium (99.5%) were investigated. The effect of the modification treatment of Silumin and the effect of iron on shrinkage cracking were also studied. The tendency of the aluminium-silicon alloys towards shrinkage cracking sharply decreases with an increasing silicon content. Modification by salts has no effect, while modification by sodium increases the tendency to shrinkage cracks. Iron markedly increases the tendency to shrinkage cracking in low-silicon alloys, has less effect on mediumsilicon alloys, and no effect on eutectic alloys. In aluminium-copper alloys, copper slightly reduces the tendency to shrinkage cracking .--- N. A.

*Blister Formation in Semi-Fabricated Parts of Aluminium or Aluminium Alloys. (Domony), See p. 345.

*On Press and Forging Alloys of the Aluminium-Zinc-Magnesium-Copper Type. W. Bungardt and H. Grober (*Metallwirtschaft*, 1944, 23, (44/47), 392-397).—A study was made of the mechanical and stress-corrosion properties of aluminium alloys containing zinc $4\cdot5$, magnesium $0\cdot5-3\cdot5$, copper $0\cdot5-2\cdot5$, manganese $0\cdot5-0\cdot7$, and silicon $0\cdot2-0\cdot8\%$; these alloys correspond to the R.R. 77 series. Samples were tested after solution-treatment and quenching, with and without cold and warm ageing for periods up to 6 months. The results show that: (i) there is an improvement in properties as the magnesium and copper contents increase, the effect of the magnesium being greater than that of the copper; (ii) cold ageing is only complete after about 6 months; (iii) for every temperature of warm ageing there is a critical time, after which reversion phenomena occur, and the time should not exceed 14 hr. at the maximum temperature of 150° C.; (iv) there is an increase in mechanical properties but a decrease in stress-corrosion-resistance on increasing the solution-treatment temperature from 470° to 500° C.; (v) increasing the silicon content to 0.8% causes a decrease in the properties, owing to the formation of Mg₂Si. The alloy containing 3.5% magnesium and 2.5% copper after solutiontreatment at 470° C., quenching, and cold ageing for 6 months had a 0.2% proof stress of 45 kg/sq. mm., a tensile strength of 60 kg./sq. mm., and an elongation of 8-9%. It is concluded that these alloys with their high tensile and corrosion-resistance properties are capable of replacing Duralumin in many press and forging applications.—E. N.

*Segregation of Iron, Manganese, and Titanium in Aluminium Piston Alloys. E. Meyer-Rassler and Lore Laurs (Metallwirtschaft, 1944, 23, (44/47), 398-404) .- A spectrographic investigation of the segregation of iron, manganese, and titanium in aluminium piston alloys is reported. Results are given for the following alloys : aluminium with 11.5-13% of silicon, 1% each of copper, nickel, and magnesium, and less than 0.8% of iron and titanium, with and without manganese ; alloys of the R.R. 53-59 series ; "Y" alloy ; and aluminium with 5-7% magnesium. Little difference was found between chill- and continuously cast billets, but casting in thick-walled moulds with slow rates of cooling led to the formation of a brittle, coarse macrostructure. There was a gradual increase of iron, manganese, and titanium from the top to the bottom of the ingots and the extreme butt often contained three to four times the specified content. "Y" alloy showed little segregation so long as the iron was kept below 0.5%, and segregation was greatest in the aluminium-magnesium alloys. Further additions of manganese caused a pronounced widening of the segregation range. It is concluded that for all alloys the alloying constituents must be kept within the specified range, the molten metal must not be overheated, and pouring must take place at the correct temp.-E. N.

*Aluminium Bronze Parts with High Mechanical Properties. — (Fonderie, 1946, 1, (4), 159-161; also (translation) Found. Trade J., 1946, 79, (1559), 245-246).—[In French]. An "aluminium bronze" containing copper 83, aluminium 10, and iron 7% has a tensile strength of 65.5 kg./sq. mm. (41.6 tons/sq. in.); an elongation of 19.5%, and a reduction of area of 21.2%. The function of each of the three main constituents is discussed. In addition, manganese up to 0.2-0.3% can be used as a deoxidizer. Tin increases the solidification interval and breaking stress, but appreciably decreases the elongation. The addition of 1-2% lead is recommended only if extra machinability is required; the addition of nickel is justified only if increased corrosionresistance is required, since, although it tends to increase the breaking stress, it considerably complicates the casting problems.—J. H. W.

On the Second-Order Transformation of β -Brass. P. E. Stepanov (Zhur. Eksper. Teoret. Fiziki, 1940, 10, (1), 103-114).—[In Russian]. Thermodynamic treatment of the ordering process.—D. A.

On the Influence of the State of Ordering on the Elastic Constants of β -Brass. A. Samoylovich (Zhur. Eksper. Teoret. Fiziki, 1944, 14, (6), 205–220).—[In Russian]. Electrostatic forces play practically no part in the increase in the elastic moduli of β -brass which occurs during disordering. The principal factors are apparently the overlapping electron envelopes of the ions and the relation between the oscillatory levels of the lattice and the state of ordering.—N. A.

*The Effect of Phosphorus on the Properties of Gun-Metal. Robert A. Colton and Blake M. Loring (Metals Technol., 1946, 13, (4); A.I.M.M.E. Tech. Publ. No. 1974, 13 pp.).—A study of the effect of phosphorus on the

properties of Navy G gun-metal (copper 88, tin 8, zinc 4%). Chemical analysis showed that under the melting conditions employed most of the phosphorus added was retained by the alloy. This makes it questionable whether the phosphorus really acts as a deoxidizer, particularly when it is remembered that zinc itself is a strong deoxidizer. Small amounts of residual phosphorus of the order 0.01-0.02% increase the sp. gr. of the alloys and improve the mechanical properties, but larger proportions are harmful. Phosphorus also improves the running qualities of the molten alloys.—W. H.-R.

*Study of the $K\alpha_1\alpha_2$ Spectrum Lines of Copper in Its Alloys. A. Z. Zhmudsky (Zhur. Eksper. Teoret. Fiziki, 1941, 11, (5), 565-572).—[In Russian]. Z. studied the wave lengths of the $K\alpha_1\alpha_2$ lines of copper in its binary alloys with zine, aluminium, magnesium, bismuth, tin, and silver; in its ternary alloys with antimony and bismuth; and in the quaternary alloys with aluminium, manganese, and iron, and silicon, manganese, and iron. It was found that in alloys consisting of solid solutions the wave lengths were displaced in the long-wave direction, while in alloys containing intermetallic compounds the wave lengths were displaced in the short-wave direction. The magnitude of the displacement was from 0.05 to 0.20 kX. In the copper–bismuth eutectic alloy no displacement was observed.—D. A.

*Coppered-Tungsten Seals Through Hard Glass. A. L. Reimann (J. Sci. Instruments, 1946, 23, (6), 121-124).—When tungsten leads are sealed through glass, slow leakage may occur in vacuum apparatus owing to fine, longitudinal cracks in the tungsten. This difficulty may be overcome by plating copper, or copper plus nickel, on to the tungsten. This first electroplated layer is then fused in hydrogen in order to fill the cracks, after which a second layer is deposited. Details of beading and sealing-in are given, and the optimum coeff. of expansion of the glass is discussed.—W. H.-R.

*On the Problem of Replacement of Scarce Non-Ferrous Metals in High-Strength [Copper] Alloys. I. P. Velichko and L. A. Shipkina (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 546-550).—[In Russian]. Equilibrium isotherms were determined for the beryllium-silicon-copper system at 400° and 800° C. and the beryllium-manganese-copper system at 800° C. Beneficial effects of adding silicon and manganese to the copper alloy containing 1% beryllium are indicated. The effect of a simultaneous addition of silicon and beryllium to copper containing 0.5% beryllium was investigated.—N. A.

*The Electrical Conductivity of the Alloy AuCu₃ in a Transverse Magnetic Field and [Its Relation to] the Ordered Distribution of the Atoms. A. Komar (*Zhur. Eksper. Teoret. Fiziki*, 1941, 11, (6), 717-722).---[In Russian]. K. investigated the electrical conductivity of the alloy AuCu₃ in a transverse magnetic field in relation to the degree of ordering in the alloy and the strength of the field at room temp. and at the temp. of boiling nitrogen.--D. A.

*Diffusion Measurements in Gold and Platinum Alloys. Oswald Kubaschewski and Hans Ebert (Z. Elektrochem., 1944, 50, (6/7), 138-144).—The rates of solid diffusion in alloys of gold and platinum were studied. A series of binary alloys of gold containing 5% by wt. of iron and nickel, and of platinum containing 5% by wt. of copper and nickel were prepared. Small buttons of these alloys were welded to similar buttons of gold and platinum and heated for known times between 750° and 1000° C. for gold and its alloys and 1040° and 1400° C. for platinum and its alloys, during which periods diffusion occurred. The depth-concentration limits in the diffusion zone were then determined by X-ray measurements of the alteration of lattice constants. The diffusion coeff. (D) at the different temperatures (T° abs.) were calculated from the slope of the lines obtained by plotting log D against 1/T and from the Arrhenius formula : $D = A \cdot e^{-Q/RT}$. The diffusion values were found to be : (i) for gold + 5% iron, $D = 10 \cdot e^{-24400/RT}$; (ii) for gold + 5% nickel, $D = 150 \cdot e^{-31200/RT}$; (iii) for platinum + 5% copper, $D = 4.2 \times 10^3 \cdot e^{-55700/RT}$; (iv) for platinum + 5% nickel, $D = 68 \cdot e^{-43100/RT}$. Further experiments are necessary to form a clear relationship between the diffusion rate and other properties such as m.p., atomic radius, electrovalent factor, &c.—E. N.

*On the Effect of Cerium on the Properties of Magnesium-Aluminium Alloys. V. I. Mikheeva (*Izvest. Akad. Nauk S.S.S.R.*, **1941**, [Khim.], (6), 661-667).— [In Russian]. An experimental study was made of the effect of small additions of cerium (0·2, 1·5%), manganese (0·2%), and titanium (0·2%) on the microstructure of magnesium-aluminium alloys. The effect of small quantities of cerium in refining the structure of these alloys during heat-treatment is explained by reference to the equilibrium diagram.—N. A.

*On the Solubility of Iron and Manganese in Magnesium and Magnesium-Aluminium Alloys. A. Beerwald (Metallwirtschaft, 1944, 23, (44/47), 404-407).-A new determination is reported of the constitution of the magnesiumrich alloys of magnesium and manganese and a partial diagram is given. The four methods used in the preparation of the various alloys are described. The liquidus is slightly to the left of that of Grogan and Haughton (J. Inst. Metals, 1943, 69, 241), the eutectic is at 2.1% manganese, the eutectic line is at 652° C., and at this temp. the solid solubility of the manganese is 3.5%. The solubility of iron in pure magnesium is 0.015% at 660° C. and 0.07% at 800° C., the solubility decreasing sharply as the manganese content increases, becoming 0.002% in magnesium saturated with manganese. Additions of aluminium decrease the solubility of manganese and iron in magnesium. Reactivity between the iron pot and the melt at their surface of contact is discussed.-E. N.

*Some Properties of Sand-Cast Alloys in the Magnesium-Rich Corner of the Magnesium-Aluminium-Zinc System. R. S. Busk and R. F. Marande (Metals Technol., 1946, 13, (4); A.I.M.M.E. Tech. Publ. No. 2009, 19 pp.).—Sand castings of numerous magnesium-aluminium-zinc alloys containing from 0-6% zinc and 0-10% aluminium were prepared and were examined in the as-cast, heat-treated, and heat-treated and aged conditions. Comprehensive tests were carried out and diagrams are given showing the effect of composition on liquidus temp., solidus temp., solvus temp., freezing range under equilibrium conditions, non-equilibrium solidus temp. (*i.e.* m.p. of alloys in the as-cast state), non-equilibrium freezing range, porosity, shrinkage, fluidity, maximum practical heat-treating temp., elongation in tensile test, yield strength, tensile strength, and Brinell hardness number. These diagrams enable the correct composition to be chosen for a particular combination of properties. Eight typical commercial alloys of this type are discussed and, in general, their compositions are among the more suitable possibilities.

-W. H.-R.

*Rates of High-Temperature Oxidation of Magnesium and Magnesium Alloys. T. E. Leontis and F. N. Rhines (Metals Technol., 1946, 13, (4); A.I.M.M.E. Tech. Publ. No. 2003, 28 pp.).-The high-temperature oxidation of magnesium and various magnesium-rich alloys was studied in the range 412°-575° C., using atmospheres of oxygen and air. Magnesium forms a protective oxide coating at low temp., but at higher temp. a non-protective, loose scale is formed, while at the highest temp. combustion may occur. Under conditions where the rate of oxidation is const. (linear oxidation), the logarithm of the rate is directly proportional to the reciprocal of the abs. temp. The energy of activation E in this range is 50,500 cal., and the action const. A is 6.2×10^{12} mg./sq. cm. per hr. In general, alloving increases the rate of oxidation if the alloying element depresses the m.p. appreciably. A theory is proposed according to which the early stages of oxidation result in the formation of a protective film. On reaching a critical thickness, the film splits and a linear zero-order action begins at the surface of the metal. At the highest temp.,

vaporization of magnesium and oxidation in the vapour state probably occur.-W. H.-R.

Grain-Boundary Penetrations by Liquid Metals. I.—Some Service Failures. W. R. Smith and P. E. J. Forsyth (*Metallurgia*, 1946, 34, (202), 186–188.— Grain-boundary penetration by a molten metal is discussed with reference to copper, aluminium, and ferrous alloys, special consideration being given to the nature of the alloy and of the liquid metal in contact with it, and to the presence of tensile stresses either applied externally or present as internal stresses across the grain boundary. Intercrystalline failure of copper alloys caused by season-cracking or penetration by molten metals in soldering is dealt with, reference being made to the susceptibility to penetration of alloys with a completely β -structure. The intercrystalline penetration of steels by solders and brazing alloys, and of aluminium-copper-magnesium-zinc alloys by Wood's metal is also considered.—J. W. D.

Theory of the Shrinkage Phenomena in Alloys. A. A. Bochvar and O. S. Zhadaeva (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 534–545).—[In Russian]. An attempt is made to develop a theory of the relationship between linear shrinkage and the alloy composition for various types of binary systems.—N. A.

[†]Some Metallurgical Investigations on Non-Ferrous Alloys Carried Out in England During the War. John L. Haughton (*Mém. Soc. Ing. Civils France*, 1945, 98, (6/8), 323-328).—A brief review of some of the theoretical and practical metallurgical research work carried out in England during the war includes investigations on atomic structure of metals, the allotropic modification of cobalt, the effect of cold work on orientation and crystal structure, age-hardening, the effect of small quantities of silicon, tellurium, bismuth, and other metals on copper, the metallographic examination of aluminium alloys, and the study of the oxidation of aluminium and magnesium by the electrondiffraction method. A list of the equilibrium diagrams or modifications thereof published during this period is given.—J. H. W.

The Chemistry of Metallic Alloys. N. V. Agecv (*Izvest. Akad. Nauk* S.S.S.R., 1941, [Khim.], (6), 653-659).—[In Russian]. The reaction of metals to form solid solutions and intermetallic phases is determined by the electron configuration and atomic vol. of the components.—N. A.

On the Calculation of the Simplest Binary Equilibrium Diagrams. B. Ya. Pines (*Zhur. Eksper. Teoret. Fiziki*, 1943, 13, (11/12), 411-417).—[In Russian]. P. gives approx. equations for the decomposition curves representing phase changes, and explains the relations between the const. from which the simplest types of equilibrium diagram are obtained.—N. A.

On the Question of the Ferromagnetism of Alloys. V. Rudnitsky (Zhur. Eksper. Teoret. Fiziki, 1940, 10, (1), 63-66).—[In Russian]. A discussion of a number of theoretical questions connected with the ferromagnetism of alloys, in particular the dependence of the Curie point and the magnitude of the magnetic saturation on the degree of order.—D. A.

*On Solid Solutions. I.—A Model of Elastic Spheres Applied to Solid Solutions, and the Deviation from Vegard's Law. B. Ya. Pines (*Zhur. Eksper. Teoret. Fiziki*, 1941, 11, (1), 147–158).—[In Russian]. Lattice distortion in a solid solution has been calculated with the aid of a model made up of elastic spheres. The change in lattice dimensions of a disordered solid solution has been evaluated for a series of binary systems. Comparison of the quantities calculated with experimental data has shown that the proposed method of computation enables the sign and order of magnitude of the departure from Vegard's law to be determined for many binary metallic systems. The method is not applicable, however, to alloys of the transition metals, or to gold-silver alloys.—D. A.

Vol. 13

The Change in Resistance of Ordered and Disordered Solid Solutions in a Magnetic Field. V. Rudnitsky (Zhur. Eksper. Teoret. Fiziki, 1940, 10, (7), 783-785).—[In Russian]. A theoretical survey is made of the question of the change of the additional resistance of an alloy in a magnetic field at the transition from the disordered to the ordered state. At this transition the degree of anisotropy of the properties of the electrons may change considerably as a result of the increase of the additional Brillouin zones ("superzones") caused by the appearance of the greater degree of order in the crystal lattice. —D. A.

On the Theory of Second-Order Transformations. I.—The Change in the Elementary Crystal Cell with a Second-Order Transformation. II.—Second-Order Transformations in Alloys. E. M. Lifshits (Zhur. Eksper. Teoret. Fiziki, 1941, 11, (2/3), 255-268, 269-281) .- [In Russian]. [I.-] A theoretical consideration of phase changes which are not accompanied by evolution or absorption of heat and which are characterized by a sudden change in heat capacity, i.e. the so-called second-order transformations or Curie points. It is shown that such changes can occur only between phases having different degrees of symmetry, the symmetry of one phase being always lower than that of the other. All possible changes in the Bravais lattice that can take place at the Curie point have been investigated. In the majority of cases the transformation results in the duplication of one or other of the lattice units. [II.--] An investigation was made of the possibility of second-order transformations occurring in order-disorder transformations in alloys of the substitution type. Possible superstructures were considered for face-centred cubic, body-centred cubic, and hexagonal close-packed lattices in which second-order transformations may take place. Such transformations are possible in the ordering of CuPt, β-brass, Cu, AlMn, and Fe, Al. On the other hand, Curie points appear to be impossible in ordered alloys of the CuAu and Cu₃Au type .- D. A.

On the Energy of Mixing and the Energy of Ordering of Solid Solutions. B. Ya. Pines (*Zhur. Eksper. Teoret. Fiziki*, 1941, **11**, (6), 725-727).—[In Russian]. A calculation of the potential energy of a solid solution.—D. A.

III.--STRUCTURE

(Metallography; Macrography; Crystal Structure.)

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

*New Method for Preparing Micro-Specimens so that the Edges are Preserved. P. M. Trismakov, F. A. Mikul'chik, and Sh. L. Lobrushkin (Zavod. Lab., 1941, 10, (3), 323-324).—[In Russian]. It is recommended that coarse polishing be carried out by means of tin-lead alloys covered with emery, and fine polishing by means of 40% wax and 60% resin, or 40% paraffin and 60% resin, or alumina.—N. A.

[†]The Physico-Chemical Problem of the State of Metallic Surfaces. Paul Bastien (Mém. Soc. Ing. Civils France, 1945, 98, (6/8), 344–356).—The problem of the state of the true surface of a metal, i.e., the metal/air discontinuity and immediately subjacent metal, has two essential aspects : the geometric and the physico-chemical. The latter is considered from three points of view : (i) the theoretical physico-chemical state, (ii) the real state, very different from (i), and (iii) the principles of the methods of study of the constitution and structural state of the metallic surface. The first concerns crystal structure and growth and the intentional alteration of the surface by cementation, heattreatment, electrolytic deposition, and chemical deposition. The second concerns the alteration in the form of the metal by solidification in a mould, by plastic deformation, and by machining, and its effect on the crystal surface. The methods of studying the state of the surface considered involve the use of the metallographic microscope, the electron microscope, X-ray diffraction, and electronic diffraction. 19 references are given.—J. H. W.

The Determination of Optimum Heating and Cooling Rates in Differential Thermal Analysis. M. V. Zakharov (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (8), 78-95).—[In Russian]. Z. discusses factors affecting the character of the curves obtained in thermal analysis by using the Le Chatelier-Saladin pyrometer.—N. A.

Universal Apparatus for Rapid X-Ray Structure Analysis. L. V. Al'tshuller (Zavod. Lab., 1940, 9, (8), 872-876).—[In Russian]. Descriptive.

—N. A. Apparatus for Rapid X-Ray Structure Investigations at High Temperatures. V. A. Tsukerman (Zavod. Lab., 1940, 9, (10), 1115-1119).—[In Russian]. Descriptive.—N. A.

Rapid Methods of Exposure in X-Ray Structure Analysis. M. M. Umansky (Zavod. Lab., 1940, 9, (8), 869-871).—[In Russian]. Focusing methods are described.—N. A.

The Theory of the Focusing of Axial Pencils of Rays and Methods for High-Speed X-Ray Structure Analysis. L. V. Al'tshuller (*Zhur. Eksper. Teoret. Fiziki*, 1943, 13, (11/12), 888–898).—[In Russian]. Principles and methods are dealt with.—N. A.

The Theory of the Fine Structure of the Absorption Bands of the X-Ray Spectra of Solids. A. I. Kostarov (*Zhur. Eksper. Teoret. Fiziki*, 1941, 11, (1), 60-73).—[In Russian]. A new theory is developed according to which the fine X-ray absorption spectra of solids, and also of polyatomic gases, are caused by the scattering of the waves of X-ray electrons by the atoms in the immediate neighbourhood. The fine structure of the X-ray absorption spectrum of polycrystalline copper has been calculated, and the results are in good agreement with experimental data.—D. A.

Calculation of the Effect of the Thermal Oscillation of the Atoms on the Scattering of X-Rays by Polycrystals. L. M. Brekhovskikh (Zhur. Eksper. Teoret. Fiziki, 1942, 12, (7/8), 287-310).—[In Russian]. An attempt is made to arrive at a theory of the scattering of X-rays in a polycrystalline specimen on the basis of the thermal oscillation of the atoms. The conditions are considered under which the thermal oscillations can be neglected.—D. A.

V.-POWDER METALLURGY

*On the Pressing of Platinum [Powders] and Similar Metals. O. E. Zvyagintsev (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 426-430).—[In Russian]. Experiments were carried out on the pressing of platinum powders and subsequent annealing at 1000° C. for $1\frac{1}{2}$ hr. The results show that platinum obtained in this way has a structure, density, and toughness superior to that of platinum obtained from molten metal.—N. A.

Recent Developments in Powder Metallurgy. R. Kieffer and W. Hotop (*Metallwirtschaft*, 1944, 23, (40/43), 361-366; also (translation) *Metal Ind.*, 1945, 66, (22), 342-344; (23), 354-356; (24), 378-380).—A review of recent literature. Fundamental conceptions, the manufacture of metal powders, and the production of sintered metals and alloys, together with their technical applications, are briefly surveyed.—E. N.

*The Production of Sintered Components by the Die-Pressing Process. K. Marquardt (*Metallwirtschaft*, 1944, 23, (40/43), 377-379).—Mixtures of copperzinc and copper-aluminium powders were prepared by cold pressing and sintering and by hot pressing, and the resulting products were compared. It is shown that the compacts made by hot pressing had better mechanical properties, especially density and hardness. Furthermore, the dimensions could be controlled within closer tolerances.—E. N.

*Extrusion in Powder Metallurgy. R. Kieffer and W. Hotop (*Metallwirtschaft*, 1944, 23, (40/43), 379-386).—Compacts were prepared of iron, nickel, copper, silver, tungsten-copper, and tungsten-silver by cold pressing, sintering at a high temperature, and then extruding into wires, tubes, and sections. The microstructure, density, hardness, and mechanical and electrical properties of the resulting products were studied and shown to be almost identical with those of similar cast or wrought materials.—E. N.

Porous Metals in the Chemical Industry. J. W. Lennox (*Indust. Chemist*, 1944, 20, (238), 600-604, 615).—Filters and diffusion diaphragms are available in the form of sheet, discs, and conical capsules; the present account refers mainly to a 90 : 10 bronze, but copper-nickel alloys are likely to be used for the purpose later. The porous material should preferably be moulded to the exact size and shape required, as its cutting and machining properties are poor. Soldering is practicable if the flow of solder and flux is restricted; spot and seam welding can be carried out easily. The relationship between porosity, pore size, pressure, and rate of flow of petrol, oil, and Cl_4 is shown in tabular form; graphs correlate porosity, thickness, and rate of flow, and diagrams show the design of apparatus for flow tests and for demonstrating the use of porous metal for the separation of liquids of different surface tension.

-P. R.

VI.---CORROSION AND RELATED PHENOMENA

The Corrosion of Metals.—I-IV. —— (Sheet Metal Ind., 1946, 23, (236), 309-320, 334; (227), 527-532; (228), 731-736; (229), 933-940, 954; (230), 1145-1146, 1159; (231), 1333-1342, 1350).—[I.—] The nature and mechanism of corrosion is considered, each contributing factor being discussed separately in some detail. [II.—] The various types of corrosion are considered, including direct oxidation at low and high temp., dezincification, electrolytic corrosion, intercrystalline attack, impingement attack, and corrosion fatigue. [III.—] The factors which influence corrosion testing are discussed and the tests used are described; these include atmospheric, spray, total-immersion, alternateimmersion, and partial-immersion tests in liquids in movement, soil corrosion tests, and tests with simultaneous application of stress and corrosion. The need for standardization of tests is explained. [IV.—] The corrosion of iron and steel is discussed.—R. GR.

Electrolysis and Corrosion of Underground Power-System Cables. L. J. Gorman (*Elect. Eng.*, 1945, 64, (6), 329-336).—A comprehensive review of the subject in which are discussed (i) electrolytic corrosion, (ii) stray-current electrolysis, (iii) electrolysis surveys and tests, (iv) classification of cablesheath corrosion, and (v) mitigation of cable-sheath corrosion.—E. V. W.

Nitric and Sulphuric Acids: [Use of Non-Ferrous Metals in] Transport and Handling. — (Indust. Chemist, 1944, 20, (234), 345-352; (235), 416-422; (236), 475-480; (237), 537-543).—Memorandum No. 13 of the Directorate of Ordnance Factories and the Ministry of Supply. The transport and handling of nitric and sulphuric acids are reviewed. Non-ferrous metals and alloys used for pump or tank linings, valves, and other purposes include aluminium, lead, tellurium-lead, regulus metal (lead containing 12-15% antimony), R. 55 alloy, and Everdur; the special applications of these are indicated.

Vol. 13

-P. R.

XI.—Analysis

VII.—PROTECTION

(Other than by Electrodeposition.)

*The Mutual Displacement of Metals from Vapours of Their Salts and the Application of These Processes to the Protection of Metals. N. A. Izgaryshev (*Izvest. Akad. Nauk S.S.S.R.*, 1941, [Khim.], (6), 673-681).—[In Russian]. The process of the displacement of chromium and aluminium from vapours of their chlorides has been studied, and also the diffusion layers formed by these metals in iron and steel. The corrosion- and heat-resistance of parts protected by aluminium and chromium is demonstrated.—N. A.

VIII.—ELECTRODEPOSITION

*The Production of Nickel Hydroxide by the Electrolysis of the Sulphate. Albert Nicol (Compt. rend., 1946, 222, (18), 1034-1035) .- The formation of nickel hydroxide during the electrodeposition of nickel has been described by various investigators. In the present research, the electrodeposition of nickel hydroxide from solutions of the sulphate running from N/1000 to N was studied, using the method previously described (Compt. rend., 1945, 222, 491; 1946, 222, 382; Met. Abs., 1946, 13, 126). The current was kept const. at about 10 m.amp., and the dissolved hydroxide was estimated by conductivity for solutions of N/1000, N/500, and N/200, and by variation of pH for N/10 and N. The results are tabulated. For normalities of 1/1000 and 1/500 the deposit is green, granular, and non-adherent. For N/200 it is similar, with some greyish spots, apparently due to the basic sulphate, since at N/10 the deposit is still non-adherent and consists of a yellowish film containing a large amount of sulphate. At N, the deposit begins to adhere to the cathode as a greyish mass consisting of nickel with green spots of hydroxide. This precipitate dissolves rapidly in cold, conc. hydrochloric acid. The deposits were analysed by Guichard's method, which showed that the hydroxide was Ni(OH)₂. The transformation to the anhydrous oxide begins at 225° C., or, if the basic sulphate is present, at 700° C. It was also found that during electrolysis the pH becomes approx. neutral. The conclusions reached are similar to those in the case of dilute solutions of silver and copper.—J. H. W.

XI.—ANALYSIS

*A Selective Spot-Test for Copper. Philip W. West (Indust. and Eng. Chem. (Analyt. Edn.), 1945, 17, (11), 740-741).—On a filter paper are placed in succession 1 drop of 20% malonic acid solution, 1 drop of the solution to be tested, 1 drop of 10% ethylenediamine solution, and 1 drop of alcoholic 1% dithiooxamide solution; a green colour develops if Cu is present to the extent of 0.3 microgram at a conc. of 1 in 10⁵. Only excessive amounts of Pd and Pt interfere by giving brown stains.—A. R. P.

*Detection of Ytterbium in Mixtures of Rare Earths. G. Beck (*Helv. Chim.* Acta, 1946, 29, (3), 506-507).—[In German]. A characteristic reaction for Yb, especially valuable since this element shows no absorption bands in the visible spectrum, consists in reducing a (sulphate) solution with Na amalgam in the cold, addition of (a) conc. oxalic acid solution, (b) a small amount of solid naphtho-resorcin, and (c) a vol. of fuming HCl equal to the total vol. of the solution, boiling, cooling, and extracting with ether. The extract is coloured pink if Yb is present.—P. R.

*Quantitative Fluorescent Method for the Determination of Aluminium. A. L. Davydov and V. S. Devekki (Zavod. Lab., 1941, 10, (2), 134-138).--[In Russian]. It is proposed to make use of the reaction of Al with quercetin $(C_{15}H_{10}O_7)$, and the optimum conditions have been determined. The max. intensity of fluorescence is attained immediately after addition of the quercetin and remains const. for several hr.—N. A.

*The Determination and Separation of Bismuth and Magnesium Using 8-Hydroxyquinoline. H. G. Haynes (Analyst, 1945, 70, (829), 129–131).—The Bi is precipitated from a neutral tartrate solution buffered with acetic acid and Na acetate to a pH of $5\cdot2-5\cdot8$, and the Mg precipitated from the filtrate by adjusting the pH to >7.5 with NH₄OH. Re-precipitation of the Mg oxine is advisable.—A. R. P.

*New Method of Fractionating the Rare Earths with Nitrilo-Triacetate : Separation of Lanthanum and Cerium. G. Beck (*Helv. Chim. Acta*, 1946, 29, (2), 357-360).—[In German]. The nitrilo-triacetate complex of La, formed by dissolving the oxalate in nitrilo-triacetate, is decomposed by acidifying the solution to pH 6, the La being precipitated as oxalate. Ce^{TV}, Ti, Zr, Th, and Mn^{IV} are precipitated from oxalate-nitrilo-triacetate solutions by rendering these feebly alkaline and oxidizing with H₂O₂, the Ce separating as the orangecoloured perhydroxide provided that the pH is kept const. by additions of ammonia. A detailed account is given of the precipitation of La as oxalate by acidifying with acetic acid; the purity of the product depends on close control of pH. The method is also applicable to Sa-Gd mixtures.—P. R.

*The Determination of Mercury as Mercuric Iodate. C. H. R. Gentry and L. G. Sherrington (*Analyst*, 1945, 70, (836), 419–421).—The solution containing 0·1–0·3 g. of Hg is treated with 1 c.c. of HNO₃, diluted to 100 c.c., and treated while boiling with 2 g. of HIO₃ in warm, saturated solution. After 5 min., the solution is cooled rapidly and filtered through a grade-4 sintered-glass crucible, the precipitate being washed with cold 1% HNO₃ containing 2% of HIO₃ and finally thrice with cold water. After drying at 140° C. for 1 hr. the precipitate is weighed; it contains 36·44% Hg. Alternatively the washed precipitate, collected on filter paper, may be rinsed back into the beaker and treated with 3 g. of KI and 5 c.c. of HCl; the liberated I is then titrated with 0·1N·Na₂S₂O₃, 1 c.c. of which = 1·672 mg. of Hg. Ag, Pb, Bi, Ti, Zr, and Fe^{...} interfere.

-A. R. P.

*Micro-Volumetric Method for the Determination of Potassium, Rubidium, and Cæsium. O. G. Sheintsis (Zavod. Lab., 1941, 10, (2), 151-153).—[In Russian]. K, Rb, and Cs are precipitated as hexanitrodiphenylamines, the precipitate washed with dry ether and then dissolved in acetone, and the hexanitrodiphenylamines reduced by excess of V⁺⁺.—N. A.

*The Precipitation of Tin by Tannin. H. Holness and W. R. Schoeller (Analyst, 1946, 71, (839), 70–74).—Sn can be separated from Fe, V, Al, Be, Cu, and Pb but not from Sb, Zr, or Ti, by precipitation with tannin from a hot chloride solution containing NH_4Cl and HCl to 0.05N; the white, flocculent precipitate settles rapidly and, after washing with 2% NH_4NO_3 solution to remove all Cl', can be ignited directly to SnO_2 . In oxalate solutions Sn is somewhat more readily precipitated by tannin than is Ta and hence can be separated from Zr in this solution.—A. R. P.

*The Gravimetric Determination of Tin in Alloys by the Tannin Method. W. R. Schoeller and H. Holness (*Analyst*, 1946, 71, (842), 217-220).—Leadbase white metal is dissolved in Br-HCl, the excess of Br is boiled out, and the solution diluted to 150 c.c. with hot water and boiled for $\frac{1}{2}$ hr. with 1 g. of Ni powder to remove the Sb. The filtered solution is oxidized with Br and the Sn precipitated by the basic-acetate method; the washed precipitate is dissolved in 3-5 g. of $(NH_4)_2C_2O_4$ dissolved in 50 c.c. of N-HCl, and the filtered solution is adjusted to nearly neutral with NH₄OH boiled with NH₄Cl and precipitated with tannin, the precipitate being washed with 2% NH₄NO₃ solution and ignited to SnO_2 . Tin-brasses are dissolved in *aqua regia* with 0.05 g. of Fe wire, the Sn and Fe are precipitated with NH_4OH and washed free from Cu, the precipitate is dissolved in acid oxalate as above and the analysis completed in the same way. Bronzes are analysed in a similar way to brasses, Ni reduction being used in addition if Sb is present. To determine Sn in zinc-base die-casting alloys 100 g. are dissolved in 700 c.c. of 1:1 HCl, a little bromine water is added (or HNO₃ to dissolve Cu), the solution is diluted to 1000 c.c., treated with 1 g. of taunin and ammonia until the Al begins to precipitate, the precipitate is collected, washed, and dissolved in $(\text{NH}_4)_2\text{C}_2\text{O}_4$ and HCl, and the Sn re-precipitated with tannin after adding a little Fe⁻⁻⁻ to act as indicator in adjusting the acidity.—A. R. P.

*Polarographic Determination of Titanium. A. M. Zan'ko, B. A. Geller, and A. D. Nikitin (*Zavod. Lab.*, 1940, 9, (9), 976–979).—[In Russian]. The possibility of determining small quantities of Ti in the presence of large quantities of Al and Fe has been investigated.—N. A.

*The Precipitation of Titanium by Tannin from Chloride Solutions. W. R. Schoeller and H. Holness (*Analyst*, 1945, 70, (834), 317–323).—Ti is precipitated quantitatively from chloride solutions by tannin when the acidity does not exceed 0.02N; in this feebly acid solution it can be separated from V, Al, and Fe^{...}, but not from Zr or Th which are also quantitatively precipitated. The greater part of the Ti is best precipitated in 0.1N-acid containing NH₄Cl and the remainder by neutralizing the filtrate to 0.005-0.01N with dilute NH₄OH. —A. R. P.

*Studies in the Analytical Chemistry of Tungsten. III.—The Precipitation of Tungsten with Tannin. D. A. Lambie (Analyst, 1945, 70, (829), 124–128).—Phenazone (antipyrine) is a suitable substitute for cinchonine in Schoeller and Jahn's tannin method for determining W (Analyst, 1927, 52, 504–514; 1934, 59, 466; J. Inst. Metals, 1927, 38, 500). The alkaline tungstate solution is treated with 10 g. of NH₄Cl, 1 g. of tannin for every 0.1 g. of W present, HCl until neutral and 5 c.c. of 1: 1 acid in excess, and then at 60–70° C. with 20 c.c. of 10% phenazone for every 1 g. of tannin. After cooling overnight the precipitate is collected, washed with acidulated NH₄Cl, solution and ignited to WO₃. Organic acids and MOO₄" interfere; the Mo can be separated as sulphide in the usual way.—A. R. P.

*On the Determination of Zinc with Dithizone—a Photometric Mixed Colour Method. G. Kortüm and B. Finchh (*Chemie*, 1944, 57, (9/12), 73–74).—[In German]. In the colorimetric estimation of Zn by dithizone according to the method of H. Fischer and G. Leopoldi (*Aluminium*, 1943, 25, 356–357; *Met. Abs.*, 1945, 12, 334) the errors amount to 1-5% of the Zn content. An investigation was made of the sources of error and the following results were obtained: (i) the extinction factor varies by 0.5% for every 1° C. difference in temp.; a convenient working temp. is 25° C.; (ii) the optimum acidity is at *p*H 6; (iii) the presence of NH₃ in the solution used for decolorizing interfering elements does not affect the Zn determination; (iv) SiO₂ should be filtered off in the initial stages; (v) removal of excess dithizone with dil. Na₂S solution causes a slight loss of Zn as ZnS and the quantity of dithizone should, therefore, be kept as small as possible. It is concluded that when these conditions are taken into account and the method modified accordingly, the determination is accurate to +1.5% of the Zn content.—E. N.

*Determination of Zirconium by the Iodate Method. Yu. A. Chernikhov and T. A. Uspenskaya (Zavod. Lab., 1941, 10, (3), 243-251).—[In Russian]. The conditions for the formation of the iodate $2Zr(IO_3)_3$, KIO_3 , $8H_2O$ have been determined. The proposed volumetric method is based on the relation of Zr^{IV} to IO_3 in this compound and leads to the reductometric determination of IO_3 in the precipitate obtained.—N. A.

*Polarographic Analysis of Aluminium Alloys. I. M. Kolthoff and George Matsuyama (Indust. and Eng. Chem. (Analyt. Edn.), 1945, 17, (10), 615-620).—Detailed procedures are given for determining Fe, Cu, Pb, Ni, and Zn in Al alloys by the polarograph. The alloy is dissolved in 15% NaOH solution and the mixturo is boiled with excess of HNO_3 to dissolve all the alloying constituents. After diluting to a standard vol., aliquot portions are taken for the various determinations. Fe and Cu are determined together unless the Fe : Cu ratio is large; in this case the Fe^{***} is reduced with NH₂OH before obtaining the Cu wave. Pb is determined after reducing the Fe^{***}, removing the Cu as CuCNS and adjusting the pH, and the Ni and Zn are determined in a similar solution after addition of Na citrate and pyridine. Various modified procedures are given for special cases where the metals occur in unusual ratios. An analysis for the five metals takes only 45 min.—A. R. P.

*Determination of Copper in Aluminium and Magnesium Alloys by Internal Electrolysis. I. I. Blok, N. A. Shumilova, and N. F. Gorskaya (Zavod. Lab., 1941, 10, (1), 28-31).—[In Russian]. A method has been worked out for the determination of Cu (up to 4.5%) in Al alloys by internal electrolysis without the use of diaphragms.—N. A.

Photometric Determination of Silicon in Aluminium and Its Alloys. W. H. Hadley (*Analyst*, 1945, 70, (827), 43-45).—Criticisms of H.'s method are discussed and filter combinations are given for use with the Spekker absorptiometer.—A. R. P.

*Quantitative Spectrochemical Analysis of Aluminium by the Electric Arc. Ir. J. Eeckhout (Verhandl. K. Vlaam. Acad. Wetensch., Lett. Schoone Kunst. Belg., 1941, [W.], 111, (1), 1-148) .-- [In Flemish]. This paper, which has almost the scope of a text-book, is remarkable in that it deals with the analysis of Al and its alloys by arc spectra instead of with the usual spark. Blocks of metal of 10×20 mm. cross-section are used as the electrodes and an arc 1.2 mm. long is maintained by a current of from 1 to 1.5 amp. Other methods are discussed, including the use of one graphite and one metal electrode, which is said to be second-best. A precision given by a standard deviation of about 4% of the conc. of minor elements present is claimed over most of the range. Calibration lines are given for Fe from 0.0002-4, Si 0.001-10, Cu 0.0003-10, Mg 0.0001-12, Mn 0.07-1.6, and Zn 0.7-20%. Ternary alloys are briefly dealt with, and tables of correction factors are given with the aid of which the data already given can be corrected to allow for the effect of one element on the relative line intensity of another element. Some examples of chemical and spectrographic analysis of Duralumin are quoted to illustrate this method. E. also deals with the principles of spectrum evaluation by means of stepped spectra, taken through a rotating sector and with the necessary corrections for reciprocity-law failure of the photographic plate and for spectrum backgrounds. A chapter is devoted to a statistical analysis of the sources of error in the results, which are predominantly due to the source, plus possibly heterogeneity of the samples. Various makes of photographic-plate emulsion are compared in detail, mostly British, and there is an adequate bibliography.-E. VAN S.

Semi-Quantitative Spectrographic Analysis of Aluminium Alloys. A. A. Yavnel (Zavod. Lab., 1940, 9, (9), 999-1001).—[In Russian]. A method has been worked out for distinguishing between 15 different kinds of Al alloys by means of the steeloscope.—N. A.

Spectrographic Analysis of Aluminium Alloys for Silicon, Iron, and Magnesium. N. A. Sokolov (Zavod. Lab., 1940, 9, (11/12), 1276-1278).-[In Russian].-N. A.

*The Application of New Means of Excitation in the Spectrographic Analysis of Light Alloys. K. A. Sukhenko (Zavod. Lab., 1941, 10, (6), 605-609).---[In Russian]. S. has investigated the relative intensities of line pairs in the spectra of Al and Mg alloys obtained in a spark of the ordinary type, using Wolbank's method, and in the interrupted arc.—N. A.

The Use of Spectrographic Analysis in the Production of Aluminium. M. S. Beletsky (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 627-628).—[In Russian]. Working conditions are given for the analysis of Al and Silumin. —N. A.

*Spectrum Analysis of Certain [Aluminium and Bearing] Alloys. N. A. Zheleztsov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 623–626).—[In Russian]. Describes certain improvements in technique for the analysis of Al alloys containing Si, Cu, Mg, Mn, and Cu in the rapid control of production. The use of clips to hold the electrodes and employment of an automatic timer speed up the exposures; also the reduction of self-inductance in the spark circuit reduces the pre-exposure sparking time. Microphotometric methods are used in which the contrast factor of the plates is controlled by measuring two lines. The method is also applied to the estimation of Sb, Pb, Fe, and Cu in bearing metal, average errors of the order of 2–3% being obtained. By rapid processing and a radiant-heat drier the time needed for duplicate analyses is shortened to about 15 min.—E. VAN S.

*A Contribution to the [Spectrographic] Analysis of Iron-Nickel-Aluminium Alloys. I. M. Minz (*Iztest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 669-670).—[In Russian]. Arc spectra and a visual steeloscope have been used for checking the composition of Fe-Ni-Al alloys and it was observed that the length of the arc gap had a strong influence on the relative intensity of the spectrum lines. Co lines in these alloys are fainter than in steel of the same Co content, and the annealed alloys show weaker lines of the other elements relative to Fe, especially if the Al content is high.—E. VAN S.

Spectrum Analysis of Silumins by the Method of Photographic Interpolation at the Ural Machinery Works (Uralmashzavod.). A. D. Glukhov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 619–622).—[In Russian]. Spark spectra of Al alloys are used with a method of photographic interpolation in which standard alloys are not repeated on each plate. By selecting the exposures so that the blackenings lie in the linear portion of the curve, the same calibration graphs can be used for various plates. A table of the lines used for the estimation of Si, Mg, Fe, Mn, and Cu in Al alloys is given and the sources of spectrographic instead of chemical methods in foundry control is estimated.

-E. VAN S.

Experience of Spectrographic Work in the Works' Laboratory. V. A. Kuznetsov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 643-644).—[In Russian]. Deals with Al alloys.—N. A.

*Spectrum Analysis of Metallic Antimony by Means of Compressed Electrodes. S. M. Solodovnik and A. K. Rysanov (*Izvest. Akad. Nauk-S.S.S.R.*, 1945, [Fiz.], 9, (6), 635–638).—[In Russian]. Spark spectra of tablets made from powdered Sb were used for the analysis of Sb alloys containing Pb, Bi, Cu, Sn, Ag, Cd, As, Au, Co, Ni, Mn, and Fe and tables of the lines used are given. Synthetic standards were made from Sb alloys, powdered and diluted with pure Sb. The richer alloys were also diluted for analysis so that comparisons were only made with <0.3–0.5% of the element present in the tablet. The method results in a probable error of 3–5% of the conc. of the element estimated.—E. VAN S.

*The Cobalticyanide Ion as a Precipitant for Metal Ions. Determination of Cadmium in Pb-Sb-Cd and Pb-Sn-Cd Alloys, Silver in Lead, and Manganese in Citrate Solutions. B. S. Evans and D. G. Higgs (Analyst, 1945, 70, (830), 158-165).—Cd is completely precipitated with $K_3Co(CN)_8$ in 15-20% HNO₃ or H_2SO_4 solutions but not from chloride solutions. To determine Cd in cable alloys containing 0.15-0.25% Cd, 5 g. of alloy is dissolved in 1:1 HNO₃ and

-N. A.

the solution evaporated with KNO₃ to remove Sn. The filtrate is adjusted to 15% HNO₃ and treated with 20 c.c. of 10% K₃Co(CN)₆ solution. The precipitate is collected, washed with 5% HNO₃ containing 1% of the precipitant, and decomposed with NaOH; the resulting Cd(OH₂ is washed free from Co, dissolved in H₂SO₄, purified by precipitation with H₂S, and converted into CdSO₄ for weighing. A similar method can be used for determining Zn in Pb, or Ag in Pb, the Ag being finally weighed as AgCl. Mn is completely precipitate being converted to MnO₂ with NaOH and H₂O₂ and determined by the bismuthate process. Quadrivalent V is precipitated completely from sulphate solutions by K₃Co(CN)₆ and can subsequently be determined volumetrically after freeing it from Co by precipitation as vanadyl hydroxide with Na₂S₂O₄ and NaOH.—A. R. P.

*Polarographic Determination of Bismuth, Nickel, Lead, and Zinc in Copper. S. A. Pletenev, E. I. Dubovitskaya, and T. V. Aref'eva (Zavod. Lab., 1940, 9, (8), 824–827).—[In Russian]. Pb and Bi are separated from Cu by precipitation with hydroxide of iron and polarographed in 6N-HCl. To determine Ni and Zn, Cu is removed by electrolysis and the polarographic analysis is then carried out in 0.1N-CH₃COONH₄ and 0.025N-KCNS.—N. A.

*Electrogravimetric Determination of Copper in Copper-Base and Tin-Base Alloys by Controlled-Potential Electrolysis. James J. Lingane (Indust. and Eng. Chem. (Analyt. Edn.), 1945, 17, (10), 640-642).—The alloy (0.5-2 g.) is dissolved in 8 c.c. of HCl and 2 c.c. of HNO₃, the solution boiled to expel NO₂ and free Cl₂, treated with 100 c.c. of 23% Na tartrate solution, I g. of urea, 10 c.c. of 20% NaOH solution and 1-2 g. of NH₂OH,HCl, diluted to 200 c.c., and electrolysed at -0.36 V. versus a saturated calomel electrode using platinum-gauze cylindrical electrodes, the anode being half the dia. of and inside the cathode. The Cu is completely precipitated in 60 min. if the solution is stirred with a motor-driven glass paddle, the shaft of which passes through the anode cylinder. Relatively large amounts of Sn, Pb, Sb, In, and many other metals do not interfere if the potential is controlled to ± 0.02 V. of -0.36 V.—A. R. P.

*The Photometric Analysis of Copper-Base Alloys. II.—The Determination of Manganese by Oxidation at Room Temperature. John H. High (Analyst, 1945, 70, (826), 18-19).—An aliquot of the solution containing 0.25 g. of Cu is treated with 10 c.c. of 15% (NH₄)₂S₂O₈ solution, 1 c.c. of 7.5% AgNO₃ solution, and 1 c.c. of 10% urea solution. After 15 min. the solution is diluted to 100 c.c. and the absorption measured in the Spekker apparatus.—A. R. P.

An Analytical Method for the Determination of Gold, Platinum, and Palladium in Copper-Nickel Slimes. N. K. Pshenitsyn and P. V. Simanosvky (*Izvest. Sekt. Platiny*, 1940, (17), 135-138).—[In Russian]. Conc. HCl is recommended for dissolving Cu and Ni. Pd and Pt dissolved at the same time are subsequently separated by HCOOH.—N. A.

Analysis of Copper Slimes Containing Metals of the Platinum Group. N. K. Pshenitsyn and P. V. Simanovsky (*Izvest. Sekt. Platiny*, 1940, (17), 129–133).— [In Russian]. P. and S. give a scheme for the analysis of slime and describe a method for the determination of moisture and platinum-group metals.

*The Analysis of Chromium-Zinc Bronzes. Z. S. Mukhina and M. L. Mironenko (Zavod. Lab., 1941, 10, (2), 145-147).—[In Russian]. A mixture of acids is used to dissolve the bronze; a method has been evolved for determining Zn with ortho-oxyquinoline.—N. A.

*The Determination of Iron, Manganese, and Aluminium in Bronzes After Separation of Copper as Oxalate. F. H. Edwards and J. W. Gailer (*Analyst*, 1945, 70, (835), 365-368).—The drillings (2 g.) are dissolved in 20 c.c. of $1:1 H_2SO_4$ and 20 c.c. of 100 vol. H_2O_2 keeping the temp. below 40° C. After boiling to remove the excess of H_2O_2 , 10 c.c. of 1:1 HCl is added to dissolve any precipitate followed by 150 c.c. of 10% $H_2C_2O_4$ solution. The mixture is boiled for 10 min., cooled, diluted to 250 c.c., and decanted through a dry double Whatman 40 paper. An aliquot 50 c.c. is taken for Fe and Mn, evaporated with 10 c.c. of H_2SO_4 and 5 c.c. of HNO₃ to fumes, diluted to 100 c.c., boiled, and cooled; 10 c.c. is used for Fe by the thiocyanate method and 20 c.c. for Mn by the periodate method, both metals being estimated by means of the Spekker absorptiometer. An alternative procedure is given for low Fe contents in Cu alloys. Al is determined by treating a 100 c.c. aliquot of the oxalate filtrate exactly as in the Mn and Fe method to destroy oxalic acid, then removing Cu, &c., with H_2S , separating Fe and Al from Mn, &c., by the basic-acetate method, determining the Fe iodometrically and the Al by precipitating with thiosulphate followed by ignition to Al_2O_3 .—A. R. P.

*The Volumetric Determination of Tin and Antimony in Brasses and Bronzes After Their Separation by Distillation. H. L. Lehmann (Analyst, 1945, 70, (836), 428-430).-The sample (2.5 g.) is dissolved in 20-30 c.c. of HCl and 10-15 c.c. of 100 vol. H, O, added in 2-3 portions and the solution is transferred to a distillation flask with the aid of 20 c.c. of $1:1 H_2SO_4$. The flask is heated by means of a cyclohexanol bath and the distillate passes through a condenser to a receiving flask, distillation being accelerated by bubbling a slow stream of air through the solution. When the cyclohexanol boils, 25 c.c. of a 1:3 mixture of conc. HCl and HBr is slowly run into the distillation flask; when this acid has distilled off, a further 15 c.c. of the same acid mixture diluted with 30 c.c. of water is run in in a slow stream and this is distilled off; finally, the first distillation with conc. acid mixture is repeated. The distillate is reduced with a nickel spiral and the Sn" determined by titration with KI-KIO3 mixture. If Sb is also present the distillate is boiled with 5 g. of KClO₃ to expel Br, then with 2 g. of Na2SO3 to reduce the Sb, and titrated with 0.1N-KBrO, for Sb. The titrated solution is reduced with Ni for the titration of the Sn.-A. R. P.

Spectrum Analysis of Non-Ferrous Alloys [Brasses and Bronzes]. V. K. Prokofiev (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (9), 607-618).—[In Russian]. Arc and spark spectra of brasses and bronzes have been used for analysis (a) by means of a steeloscope in the visual region, (b) by a spectrograph, and (c) by a direct photocell and filter instrument used as a spectrophotometer. The influence of the upper electrode of the arc on the spectra is noted. Cu, Ni, Al, and graphite were each tried and gave different relative intensities for the Pb, Sn, and Zn lines in the spectra of brasses; in general, Cu is better.—E. VAN S.

Some Results of the Use of Spectrographic Analysis [for Brass]. A. R. Striganov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 641-642).—[In Russian]. Description of a method used for determining Pb (0.01-0.20%) in brass (62 and 70% Cu).—N. A.

Quantitative Spectrum Determination of Aluminium in Tin Bronzes. N. F. Zakhariya (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 629–632).—[In Russian]. Arc spectra of bronzes were used to estimate Al in the range of 0.01-0.05% in tin bronzes with a great saving of time. Al lines are compared with Ni lines from the nickel rod used as the second electrode. A comparison of chemical and spectrographic results is given in detail and the results are in fair agreement.—E. VAN S.

Spectrographic Analysis of Bronzes. Simplification of the Three-Standard Method. M. S. Ashkinadzi and R. S. Tripol'skaya (*Zavod. Lab.*, 1941, **10**, (6), 624–626).—[In Russian]. A method is proposed for constructing analytical curves from a single standard. The analysis of bronze for Zn (0.8–3.3%), Sn (5.7–10.2%), and Mn (0.7–1.8%) gives satisfactory results by this method.

DD

Cf. Izvest. Akad. Nauk S.S.S.R., 1941, [Fiz.], 5, (2/3), 289-292; Met. Abs., 1944, 11, 299.-N. A.

Method for the Spectrographic Analysis of Tin Bronzes in the Ultra-Violet Region of the Spectrum. L. E. Vvcdensky and A. K. Andon'eva (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 633–634).—[In Russian]. Describes the determination of six constituents in the following ranges of composition : Sn 6-11, P 0.01-1.35, Zn 0.05-3, Al 0.01-0.20, and Pb 0.05-0.40%.—N. A.

The Determination of Nickel in Magnesium Alloys. J. T. Minster (Analyst, 1946, 71, (839), 74–77).—An apparatus for separating Ni from Mg by electrodeposition into a Hg cathode is described with reference to drawings and a wiring diagram. The Mg in the spent electrolyte is then determined with 8-hydroxyquinoline.—A. R. P.

*Spectrochemical Analysis of Palladium in Platinum. P. Van der Voort (Bull. Soc. Chim. Belg., 1945, 54, 57-72).—Various types of arc- and spark sources are compared for the estimation of Pd in Pt. For sensitivity, a D.-C. arc between a Pt globule and a graphite cathode is recommended; with this as little as 0.001% of Pd can be detected. Spark spectra are much less sensitive. An arc with mechanical interruptions was tried, but not an A.-C. arc. A glow discharge can be obtained in air at ordinary pressures between a Pt globule and an Ag wire within narrow limits of current: 0.25 amp. at 370 V. is recommended across a 1.5-mm, gap. Pd can be detected in this source down to 0.01% and the reproducibility of spectra is quite good. Chemical methods of purifying Pt are also discussed.—E. VAN S.

*Determination of Thickness and Composition of Tin-Lead Alloy Coatings on Terne Plate. J. W. Price (Analyst, 1946, 70, (826), 10-14).—A sample of known area to give ≥ 0.8 g. of coating is degreased cathodically in 1% Na₂CO₃ solution, and then immersed in 100 c.c. of a solution of 20 g. of Sb₂O₃ in 800 c.c. of HCl and 200 c.c. of water until the coating is dissolved; the Fe base is then cleaned from metallic sponge by means of a rubber-tipped rod, removed from the solution, washed, dried, and weighed. The solution is boiled for 10 min. in an atmosphere of CO₂, cooled, diluted with an equal volume of water, treated with 1 g. of KI and starch, and titrated for Sn with KIO₃. The difference between loss in wt. of the plate and the Sn content is Pb.—A. R. P.

*The Determination of Small Quantities of Silica, Alumina, and Lime in Tungsten Carbide Powder. C. E. A. Shanahan (Analyst, 1945, 70, (836), 421-423).—The carbide (2.5 g.) is heated in a silica boat in a slow stream of HCl (gas)-air at 650° -800° C. or CHCl₃-air at 600° -650° C. until all the W is volatilized as chloride and oxychloride, leaving a white residue which is analysed by any convenient method for SiO₂, Al₂O₃, and CaO. During volatilization of the W the temp. must not exceed the above-mentioned limits otherwise SiCl₄ and AlCl₃ are volatilized.—A. R. P.

*Quantitative Analysis by Internal Electrolysis. A. Schleicher and T. Todoroff (Z. Elektrochem., 1944, 50, (1), 2–7).—S. and T. review the technique of quantitative analysis by galvanic or internal electrolysis. The theoretical basis, types of apparatus, electrolytes, and the influence of agitation and temp. of the solution are discussed. A method for the estimation of Cu in the presence of various conc. of Pb and Fe is described in detail, together with its application to the analysis of Cu alloys and copper pyrites.—E. N.

Internal Electrolysis [for Quantitative Analysis]. W. Cule Davies and C. Key (Indust. Chemist, 1944, 20, (237), 544).—Internal electrolysis, *i.e.* the deposition of a metal from a dissolved salt by means of an electric current generated in the cell itself, permits certain easy separations to be made, which if carried out by "external" electrolysis would need close control. In order to ensure quantitative separation, the metallic deposit must be neither spongy nor too hard and adherent. An illustrated account is given of an assembly carrying thermometer, two anodes enclosed in permeable cells, a platinumgauze electrode, and stirring gear. The estimation of Cu in pyrites by means of this apparatus is reported in detail, and the results compared with those obtained by other methods. The accuracy of the method is illustrated by a tabulated comparison of the "known" and "found" percentages of Cu in five common alloys in the presence of several interfering elements. A further tabulated summary indicates conditions for a number of separations, *e.g.*, of Cd and of Ni in the presence of large amounts of Zn, Cu (in steel), Ag (in Pb), and Hg (in brass).—P. R.

Qualitative Analysis of Non-Ferrous [Scrap] Metals. A. D. Mayants (Zavod. Lab., 1941, 10, (3), 362-372).—[In Russian]. A review of drop methods for the analysis of non-ferrous scrap.—N. A.

Qualitative Analysis Without Sulphuretted Hydrogen. — (Indust. Chemist, 1944, 20, (239), 672).—A short account is given of a scheme of qualitative analysis suggested by L. Rosenthaler (Helv. Pharm. Acta, 1944, 19, 95), consisting in the precipitation of metals from appropriate solutions by means of Mg metal, after the elimination of Pb, Ag, and Hg'. The metals are precipitated in 3 groups, each of which is then examined by means of special reagents. —P. R.

[†]Spectrochemical Analysis of Metals and Alloys. P. Van Pee (*Techn.*-*Wetensch. Tijdschr.*, 1944, (3), pp. 8).—[In Flemish]. A competent review, with bibliography, of continental publications, mostly of the period 1933-1942. —E. VAN S.

Experimental Work in the Spectrographic Laboratory. V. N. Nikitin (*Izvest. Akad. Nauk S.S.S.R.*, 1945,*[Fiz.], 9, (6), 645-646).—[In Russian]. Describes the determination of Mg, Fe, Mn, Si, Zn, Cu, Ni, P, Sn, Pb, and Al in Cu and Al alloys.—N. A.

On the Spectrographic Analysis of Powdered Specimens. N.S. Vasileyskaya (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 639-640).---[In Russian]. A method is described for determining 0.03-0.2% Ag.---N. A.

The Present Position of Spectrographic Analysis in the U.S.S.R. and Proposals for Its Development. G. S. Landberg (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 585-591).—[In Russian].—N. A.

Methods of Calibration in Spectrographic Analysis. C. Weyn (Techn.-Wetensch. Tijdschr., 1944, (3), pp. 14).—[In Flemish]. A detailed survey of methods of calibration used in spectrographic analysis by microphotometric methods. After a discussion of photographic theory as applied to microphotometry, various methods of determining the relative intensities of spectrum lines from the microphotometer measurements are described and compared. The method in which a rotating sector is used so that part or the whole of the calibration curve can be established for each line measured is selected as best, and the simplification of this method by graphical calculating devices is described in detail. Special attention is paid to Belgian and American work. The methods of making background correction, and the determination of relative intensities from measurements of line widths are also described.

-E. VAN S.

Instruments for Spectrum Analytical Investigations and Their Production in the U.S.S.R. S. A. Khrashanovsky (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 721-732).—[In Russian]. K. reviews the production of optical instruments for spectrochemical analysis in the U.S.S.R., and describes the design of some of the instruments, including a new type of steeloscope. Standard electrical equipment for light sources will also be made.—E. VAN S.

Some New Types of Apparatus for Spectrographic Analysis. L. M. Ivantsov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 733-738).—In Russian]. A review.—N. A.

XII.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

An Apparatus for the More Accurate Determination of Hydrogen Liberated from Acids by Metals. B. S. Evans and D. G. Higgs (Analyst, 1945, 70, (835), 356-362).—An apparatus and technique is described for evaluating the metal content of magnesium, aluminium, zinc, and other metals by measuring the hydrogen evolved when the metal is dissolved in acid. The apparatus used consists of a measuring vessel with a single graduation on a constriction in the neck, with a water jacket with efficient water circulation. The amount of metal taken is such that the vol. of hydrogen evolved will approximately fill the flask, and the final adjustment of the gas vol. is made by means of a water manometer and adjustment of the temp.—A. R. P.

[Apparatus for] the Determination of Nickel in Magnesium Alloys. (Minster). See p. 362.

New Developments in the Study of Surface Chemistry. Earl A. Gulbransen (Metal Progress, 1946, 49, (3), 553-559).—Fundamental factors in the study of a given surface are its physical form, the chemical nature of the surface layer, and the speed at which chemical and physical changes occur on and through the surface. These may be studied by the electron microscope (opaque materials being investigated by means of surface replicas), the electron-diffraction camera, and the vacuum micro-balance. The design and operating principles of these types of apparatus are described, the working system being illustrated by diagrams.—P. R. The Electron Microscope and Its Application to the Study of Metals.

The Electron Microscope and Its Application to the Study of Metals. Robert G. Picard (*Metallurgia*, 1946, 34, (202), 181–185).—The principle of the electron microscope is briefly discussed, special reference being made to the optical analogy between light and electron microscopes and to the special technique required for specimen preparation. The application of the electron microscope to the study of metals is dealt with, consideration being given to the study of the structure of metallic surfaces, where accurate replicas of the surfaces have to be made for examination, and to the various methods used for the preparation of such replicas. P. also describes the technique used in the application of the electron microscope to the study of the atomic structure of metals and alloys.—J. W. D.

A New Model of Reflecting Spectrograph. L. E. Vvedensky (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], 9, (6), 750-752).—[In Russian]. A new autocollimating-mirror type of spectrograph with Cornu prism has a mirror with a focal length of 820 mm. and a flat field from 2200-3500 Å. The resolving power is 17,120 and a similar model of longer focal length is being designed. —E. VAN S.

*A Simple X-Ray Spectrometer. R. S. Rivlin and H. P. Rooksby (J. Sci. Instruments, 1946, 23, (7), 148-150).—Describes a simple X-ray spectrometer which is suitable for determining the orientation, relative to the crystal axes, of a surface cut on a single crystal, when the orientation is already approx. known. The apparatus is made almost entirely from standard Meccano parts.—W. H.-R.

*A Simple Method of Shielding for Use on an X-Ray Spectrometer. F. Happey and A. W. Porter (J. Sci. Instruments, 1946, 23, (7), 160).—Describes the construction of an X-ray trap for use where long exposures are necessary. —W. H.-R.

*A Simple Measurer for X-Ray-Powder-Diffraction Photographs. J. Gibson (J. Sci. Instruments, 1946, 23, (7), 159).—Description of a simple sliding vernier instrument which is easy to construct, and gives readings to 0.05 mm. —W. H.-R.

1946 XIII.—Physical and Mechanical Testing, &c. 365

*A Machine for the Summation of Fourier Series. G. Hāgg and T. Laurent (J. Sci. Instruments, 1946, 23, (7), 155–158).—A machine is described which will perform a purely electric summation of Fourier series.—W. H.-R.

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

Rationalization of Aluminium Alloy Specifications. A. E. Russel (J. Roy. Aeronaut. Soc., 1945, 49, (409), 14-20).—R. pleads for extension of the scope of the routine testing of materials, to permit a balanced assessment of specification strength values. This valuation should take into account the gain in the operational efficiency of aircraft resulting from increasing the minimum acceptable stresses at the cost of increased scrap. The behaviour of materials in compression is best represented by a curve of the ratio of the stress to the tangent modulus plotted against stress. As a spot check, the 0·1% proof stress is a better indication than the 0·2% proof stress. A complete revision of the max. acceptable tolerances of sheet material is necessary, in R.'s opinion. Until improved rolling-mill equipment is available, the limits should be narrowed, with a strong bias towards nominal average thickness, *i.e.*, with unequal bilateral tolerances. This procedure would be quite safe owing to the very local nature of the low spots which could be catered for in design. R. suggests that the increased cost of materials consequent on the changes would be economically sound from the operations point of view.—H. S.

Apparatus for the Creep Testing of Non-Ferrous Metals. K. I. Portnoy. (Zavod. Lab., 1940, 9, (9), 1020-1024).--[In Russian]. Descriptive.--N. A.

The Sorting of Sheets of AMTs [Aluminium-Magnesium-Zinc] Alloy from Duralumin Sheets by a Thermoelectric Method. V. L. Blinov and D. I. Il'in (Zavod. Lab., 1945, 11, (2/3), 222-223).—[In Russian]. The equipment is described.—N. A.

Sorting Bronzes and Brasses with the Steeloscope. V. E. Bel'masov (Zavod. Lab., 1940, 9, (11/12), 1272–1276).—[In Russian].—N. A.

Quality Control and Research on [Wimet] Commented Carbides. — (Machinery (Lond.), 1946, 68, (1759), 809-816).—The manufacture of Wimet sintered carbide is described, with particular reference to the inspection methods employed for production control. The equipment of the metallurgical, spectrographic, and X-ray crystallographic sections of the Wimet research laboratories is described.—J. C. C.

Non-Destructive Inspection of Castings. Clyde L. Frear and Robert E. Lyons (Amer. Foundryman, 1946, 9, (4), 120–133).—A general, illustrated review in which are discussed a number of non-destructive methods of inspection. These include visual inspection, sound or percussion tests, impact tests, pressure tests, radiographic examination, magnetic inspection, electrical-conductivity tests, and tests with fluorescent materials and supersonics.—J. E. G.

RADIOLOGY

30 Years of X-Ray Research at the G.E.C. Research Laboratory. A. W. Hull (Amer. J. Physics, 1946, 14, (2), 71-79).—A reminiscent historical review describing H.'s crystallographic work and the development of the X-ray tube from the 1913 Coolidge tube to the modern one- and two-million-volt tubes and the betatron. Metallic barium serves as a lubricant in the rotating-anode tube. Beryllium windows are used in X-ray tubes intended for generating the characteristic rays from targets of low atomic number. The radiation from the latter type of X-ray tube may be used for measuring the thickness or density of materials by its absorption.—L. M.
†Radon. Its Properties and Proparation for Industrial Radiography. J. A. T. Dawson (J. Sci. Instruments, 1946, 23, (7), 138-144).—A lecture given before the Industrial Radiology Group of the Institute of Physics. The use of radon instead of radium for γ -radiography enables higher γ -ray intensities to be obtained from bulks of smaller dimensions, and so improves the quality of the photographs. The principles governing the growth and decay of radon are described, and also methods for its extraction and purification. Radiographs of a 2-in. steel plate with penetrameters lying on top are reproduced in order to compare radon and X-ray radiographs.—W. H.-R.

Development of Stereoscopic Photography and Radiography. Leslie P. Dudley (Light Metals, 1945, 8, (89), 259-270; also (abridged) Indust. Radiography Non-Destructive Test., 1946, 5, (1), 23-25, 39).—Lecture to the British Institute of Radiology.—L. M.

Institute of Radiology.—L. M. Apparatus for the X-Ray Determination of Principal Stresses. M. P. Zheldak (Zavod. Lab., 1940, 9, (7), 755–757).—[In Russian]. Descriptive. —N. A.

On the Determination of the Sensitivity of the Visual Method of Control by X-Rays. A. K. Trapeznikov (Zavod. Lab., 1940, 9, (8), 876-878).—[In Russian]. Screens at the Semashko works reveal defects of 6-8% thickness; Patterson screens 5-6% for magnesium alloys and 4-5% for aluminium.

-N. A.

New X-Ray Tubes for Radiology. V. I. Rakov (Zavod. Lab., 1941, 10, (1), 73-76).—[In Russian]. A review.—N. A. New [X-Ray] Ion Tube (T4). G. I. Aksenov and A. I. Gaiko (Zavod.

New [X-Ray] Ion Tube (T4). G. I. Aksenov and A. I. Gaiko (Zavod. Lab., 1941, 10, (3), 324-326).—[In Russian]. An X-ray tube designed by A. and G. for structure analysis is described.—N. A.

A Test for Lead-Screen Contact. H. E. Seemann and L. L. Macgillivray (*Indust. Radiography Non-Destructive Test.*, 1946, 5, (1), 17–19).—A test object for investigating the contact between lead screens and the film is made by supporting lead shot one layer deep in the meshes of wire gauze, the shot being held in position by shellac. Lead shot of 0-14 in. dia. and gauze with six square openings per inch and a wire dia. of 0.035 in. are recommended.

-L. M.

XIV.—TEMPERATURE MEASUREMENT AND CONTROL

A "Cold-Junction" Box for Thermocouples. L. Bastings (J. Sci. Instruments, 1946, 23, (6), 132).—A device is described for keeping the cold junction of a thermocouple at 25° C. instead of using an ice box. The apparatus is essentially a toluene thermostat-regulator incorporating a bath of transformer oil within the regulating bulb; the cold junction is placed in this bath. The whole is placed in a cork-lined cabinet which the regulator keeps at 25° \pm 0.05° C.—W. H.-R.

XV.—FOUNDRY PRACTICE AND APPLIANCES

*Segregation of Iron, Manganese, and Titanium in Aluminium Piston Alloys, (Meyer-Rässler and Laurs). See p. 348.

*Blister Formation in Semi-Fabricated Parts of Aluminium or Aluminium Alloys. (Domony). See p. 345.

*On the Question of Modification of Silumin. A. G. Spassky and V. V. Rogozhin (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 566-569).—[In Russian]. Aluminium-silicon alloys appear to have an inherent modified structure. Sodium eliminates the segregates of silicon in the liquid alloy and thus brings about solidification in the near-equilibrium state. Modified structure can be obtained by heating the alloy to temp.

1946 XV.—Foundry Practice and Appliances 367

above $900^{\circ}-1000^{\circ}$ C., followed by rapid cooling. The temp. of superheating has a decisive influence.—N. A.

*Microporosity in Magnesium Alloy Castings. L. W. Eastwood and J. A. Davis (Amer. Foundryman, 1946, 9, (4), 148-155).—It is submitted that the principal factors determining the occurrence of microporosity in magnesium alloy castings are : (i) the alloy composition, (ii) the gas content of the melt, and (iii) the degree of feeding provided. In this investigation four alloys were studied : (1) A8—aluminium 8, zinc 0.4, and manganese 0.2%; (2) AZ 91—aluminium 9.4, zinc 0.4, and manganese 0.2%; (3) A.S.T.M.-AZ 63—aluminium 6, zinc 3, and manganese 0.2%; and (4) A.S.T.M.-AZ 92—aluminium 9, zinc 2, and manganese 0.2%; magnesium providing the balance in all cases. A.S.T.M.-AZ 63 is markedly inferior to the other three alloys in respect of its tendency to microporosity. Variation in pouring temp. had little effect upon the amount of microporosity produced. The amount of microporosity produced.—J. E. G.

Centrifugal Casting of a Magnesium Part. F. P. Strieter and R. J. Maenner (*Amer. Foundryman*, 1946, 9, (5), 43-47).—An illustrated account of the commercial production of a magnesium alloy ring, 12 in. in dia. and weighing 2.8 lb., by the centrifugal-casting process. The composition of the alloy used was : aluminium 9, zinc 2, manganese 0.2%, magnesium remainder.

-J. E. G.

Aluminium Alloy Die-Casting. — (Amer. Foundryman, 1946, 9, (4), 103-111).—Report of the A.F.A. Committee on die-castings. A detailed and illustrated account is given in which are surveyed the various types of die-casting machines and their detailed mechanisms. Metal characteristics with respect to the die-casting process, fettling, and inspection are also reviewed.—J. E. G.

Use of Insulating Pads and Riser Sleeves for Producing Sound Bronze Castings. H. F. Taylor and W. C. Wick (Amer. Foundryman, 1946, 9, (3), 48-68).—See Met. Abs., this vol., p. 231.—J. E. G.

*The Effect of Phosphorus on the Properties of Gun-Metal. (Colton and Loring). See p. 348.

*On the Mechanism of Increasing the Density of Castings by Crystallization Under Pressure. A. A. Bochvar (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (8), 5-14).—[In Russian]. Solidification under pressure results in the shrinkage porosity being reduced and concentrated in the regions of the last crystallization. A pressure of 2-3 atm. is sufficient to reduce the vol. of gas porosity to a value comparable with the vol. of shrinkage porosity. The vol. of the porosity is determined, not by the gas vol. at a given pressure, but by the vol. of shrinkage porosity in which gas pressure does not reach the value of atmospheric pressure. A considerable portion of the gas is retained in solution after solidification under pressure.—N. A.

On the Efficiency of the Method of the Crystallization Under Pressure for Various Alloys. A. A. Bochvar (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (8), 14-21).—[In Russian]. Shrinkage porosity in alloys having a narrow solidification range (up to 10° C.), *i.e.*, eutectic Silumin, 10% "aluminium bronze," and pure metals, is usually of a conc. type. Alloys having a wide solidification interval (up to 70°-140° C.), *i.e.*, aluminium-4% copper, aluminium-1-2% silicon, and copper-5-8% tin, give a dispersed type of shrinkage porosity. Intermediate cases are possible.

---N. A.

Principles of the Delayed-Crystallization Method of Obtaining Castings Free from Shrinkage Porosity. A. G. Spassky (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 551-555).—[In Russian]. S. discusses the possibility of eliminating shrinkage porosity by feeding with liquid metal or by the construction of feeding heads and so delaying crystallization. Shrinkage porosity cannot be eliminated by the maintenance of a uniform temp. distribution in the cooling of the casting.—N. A.

*Shrinkage Phenomena in Alloys as a Function of the Composition. K. I. Akimova (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (8), 22-39).—[In Russian]. Experiments carried out with aluminiumsilicon, aluminium-copper, lead-antimony, lead-cadmium, zinc-tin, and bismuth-cadmium alloys showed that the distribution of shrinkage porosity in alloys forming a eutectic depends on the crystallization interval and the amount of the eutectic. The amount of shrinkage porosity also depends on the crystallization interval.—N. A.

*Effect of Casting Conditions on the Malleability of Alloys. Paul Bastien (Fonderie, 1946, 1, (3), 99–109).—Read before the Association Technique de Fonderie. The factors affecting the malleability of metals and alloys are considered under the following headings: (a) Those depending on the metals or alloys, such as the capacity for crystal slip and its variation with temp., the capacity for forming twins and its variation with temp., the capacity for forging temp.; (b) those depending on the piece itself, such as the shape, weight, and crystal structure; (c) those depending on the deformation, such as type of plastic deformation and rate and extent of deformation; (d) those depending on the contact between the part to be formed and the die, such as rate of cooling and the value of the coeff. of friction. The methods of carrying out tests of these properties and the apparatus required are described.—J. H. W.

Eliminating Castings Defects. Pierce Boutin (Amer. Foundryman, 1946, 9, (3), 42-44).—A summary of the procedures to be followed in tracing castings defects.—J. E. G.

*The Technical Preparation of Work in the Casting of Varied [Bronze] Parts. Charles Dennery (*Fonderie*, 1946, 1, (6), 207-218).—Read before the Association Technique de Fonderie. Experiments were carried out on the design of feeding heads for casting bronze made up from secondary material containing tin, zinc, and lead of the order of 5, 7, and 2% respectively. D. compares the mechanics of self-feeding with those of special feeding heads, and describes the effect of the susceptibility of the alloy to piping and contraction.—J. H. W.

Elimination of the Falling Metal Stream [in Casting]. A. A. Bochvar and A. G. Spassky (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (8), 45-51).—[In Russian]. A mould is filled by creating in it a partial vacuum and drawing in liquid metal, or by forcing the liquid metal with compressed air through a tube into the mould, followed by solidification under pressure. B. and S. suggest an apparatus for this purpose and discuss the advantages of the method.—N. A.

Standard Test Bars for the Non-Ferrous Foundry. Frank Hudson (Found. Trade J., 1946, 79, (1557), 185-191).—Read before the Birmingham Conference of the Institute of British Foundrymen. It is submitted that the keel bar should be tentatively adopted as a standard for copper-base alloy castings.—J. E. G.

Metallurgical Advantages of Centrifugal Casting. —— (J. Commerce, Ship. Eng. Edn., 1946, July 25, p. 1).—Three types of centrifugal casting : true centrifugal, semi-centrifugal, and centrifuge centrifugal, are discussed with special reference to the type of casting produced by each method, and to the speeds used. Special reference is made to the production of coppertin-lead bearing bushes and of gun-metal bushes for marine steel propeller shafts by centrifugal casting.—J. W. D.

Non-Destructive Inspection of Castings. (Frear and Lyons). See p. 365.

1946 XV.—Foundry Practice and Appliances 369

Pattern Analysis for Buyers of Patterns and Castings. Vincent J. Sedlon (*Amer. Foundryman*, 1946, 9, (3), 24–26).—A pattern-classification chart with accompanying description. Suggested materials and methods of construction are given for all sizes of patterns intended to be used for small or large casting production (10–500 or more castings).—J. E. G.

[†]The Use of Ethyl Silicate in the Foundry—Precision Moulding by the *Cire Perdue* Method. Pierre Nicolas (*Fonderie*, 1946, 1, (7), 260–265; also (abridged translation) *Found. Trade J.*, 1946, 79, (1565), 401–402).—Where higher temp. are required, siliceous sand and plaster is not sufficiently refractory. For these, sodium silicate can be used up to a point as a binder for the siliceous sand, but beyond this point pure colloidal silica hydrate is used. This hydrate is formed by the hydrolysis of ethyl tetrasilicate: $Si(OC_2H_5)_4 + 4H_2O = Si(OH)_4 + 4C_2H_5OH$. The development of the process for the manufacture of alloys of cobalt, tungsten, and chromium for aeroplane motors is outlined, and the technique of the process, preparation of the moulds, and the melting, casting, and finishing of the alloys are described.—J. H. W.

*The Control of Moulding and Coring Sands. Raymond Guerin (Fouderie, 1946, 1, (2), 43-52).—Read before the Association Technique de Fonderie. The limitations of testing moulding sands by hand are pointed out and methods are described for the mechanical testing of sands for : (i) humidity and temp., (ii) cohesion, (iii) grain-size, permeability, and fineness. Although the tests described are primarily for natural sands, they apply also, for the most part, to synthetic sands. The properties of coring sands are much more complex than those of moulding sands; the criterion in this case is the dry strength or cohesion, which depends on the facing given to the core and the actual strength of the burnt sand. G. discusses the effect of grain-size, the addition of clay, dust content, and conditions of drying (e.g., 240° C. for max. strength).—J. H. W.

[†]Introduction to the Study of Moulding Sands. Eddie Cambier (*Ing. Chim.*, 1945, 27, (162), 25–43).—C. discusses the principal properties, and the effects of the various constituents, of foundry sands in general and describes a number of tests for these sands.—J. H. W.

Sand Control in a Bronze Foundry. Clinton J. Converse (Amer. Foundryman, 1946, 9, (4), 164-165).—A general account.—J. E. G.

*Bentonites and Clays from the Foundryman's Point of View. Methods for Determining Their Values for Securing Cohesion in the Green State. P. Dauxois (Bull. Assoc. Tech. Fonderie, 1944, 18, (4/12), 44-55; discussion, 55-56).—In the regeneration of used moulding, the ordinary clay that these contain is progressively replaced by bentonites and selected clays. The undoubted advantages of these is somewhat offset by their high price, but this in turn is offset by economy in transport. The usual data of their physical properties are insufficient as a criterion of their use in the foundry, and a study has been carried out to determine by direct trial a series of curves of const. cohesion as a function of the water content and the composition of the sand, thus indicating the characteristics of the mixture.—J. H. W.

[†]Cement Applied to Foundry Moulds. [Randupson Process.] Louis Maillard (Fonderie, 1946, 1, (1), 5-11).—Read before the Association Technique de Fonderie. In the Randupson process, siliceous sand is mixed with about 10% cement and slightly moistened. The moulds and cores are made and, after stripping, left in the air for 48 hr. The sand must be 95-97% pure and contain no alkali fusible at low temp. and little or no clay. The grainsize is 0.25-1 mm.; dust must be avoided as it reduces the permeability. The cement, such as is used in reinforced concrete, is slow-setting and quick-hardening. The permeability, cohesion, facing, manufacture, and behaviour of the moulds are described, and their advantages, disadvantages, and applications discussed. Of the disadvantages, the chief are the long period of drying and the necessity of using the moulds within 3 hr. of their being dry; on the other hand, they have all the advantages of a green sand with high permeability and cohesion, and are suitable for the casting of pieces of all dimensions and weights.—J. H. W.

Core Ovens [for Magnesium Alloy Casting Cores]. H. E. Linsley (Amer. Foundryman, 1946, 9, (3), 27-31).—A general illustrated account of equipment and processing methods for cylinder-head moulds and cores and for magnesium alloy casting cores. Core-sand mixtures for use in connection with magnesium alloys are identified by a dyestuff which is added in liquid form during the first mulling; while the dyestuff does not retain its full colour after baking, it is still readily identifiable.—J. E. G.

The American Foundry. René Kenner, (Jean Montupet, and Robert Ronceray) (Fonderie, 1946, 1, (7), 247-259).—Read before the Comité Technique du Centre Technique des Industries de la Fonderie. As a result of a tour in the U.S.A. it is considered that the development of the foundry industry there is shown by the increase in the capacity for production and by the increase in the quality of the castings. This is due not to sensational inventions but to the application, on a large scale, of the principle of mechanization, of the technique of melting and moulding, and of rigorous control.

J. H. W.

XVII.—FURNACES, FUELS, AND REFRACTORY MATERIALS

Melting Light Alloys in the Electric Furnace. —— (Fonderie, 1946, 1, (5), 189–191).—Practical hints in the use of electric-melting and soaking furnaces for light alloys, principally "Alpax," are given.—J. H. W. An Introduction to the High-Frequency Induction Furnace. J. H. H.

An Introduction to the High-Frequency Induction Furnace. J. H. H. Tcece (J. Inst. Elect. Eng., 1946, 93, [I], (61), 50-51).—Contains a brief description of the homo-polar inductor-type alternator as a source of power for large, high-frequency induction furnaces.—E. V. W.

[†]High-Frequency Electronic-Valve Furnaces. André de Saint-Andrieu (*Fonderie*, 1946, 1, (4), 143-155).—Read before the Association Technique de Fonderie. There are three types of electric furnace: (i) resistance, (ii) arc, and (iii) induction furnaces. The electronic furnace is a type of induction furnace, and the theory, installation, advantages, and uses of a 250-kW. furnace are described. The description also applies to 20-100 kW. furnaces.

-J. H. W.

Induction and Dielectric Heating. — (Metallurgia, 1946, 34, (202), 210-212).—The use of electronic heat, which may be applied in two forms as induction heating and dielectric heating—is discussed with reference to the improvement it has brought about in production and quality in industry. Brief reference is made to each form of heating and to such applications of induction heating as tempering and tipping tool steels, brazing, heating billets for forging, fluxing plated coatings to remove porosity, sintering metallic powders, &c. The use of dielectric heating for drying cores and moulds and for producing physical changes, as in the polymerization of thermosetting plastics, is considered.—J. W. D.

High-Frequency Heating. —— (Automobile Eng., 1946, 36, (471), 13–19). —Some recent developments in the design of high-frequency inductionheating equipment are discussed. The basic principles of the process are considered, and fields of application including brazing, soldering, and sintering outlined. Three types of equipment are discussed, including motor generator, spark-gap converter, and thermionic oscillator. Consideration is also given to the technical advantages of induction heating, the quality of the product, the speed of production, and the economies effected.—J. W. D. On the Resistance to Wear of Rotary Melting-Furnace Linings. E. J. Kohlmeyer (Metall u. Erz, 1944, 41, (9/10), 99-101).—K. discusses the factors influencing the rate of wear of rotary melting-furnace linings: flame temp., temp. of melt, structure and m.p. of the lining, viscosity of the slag, reactions between the slag and the lining, &c. It is recommended that above 1300° C., and when working with alkaline fluxes, the lining should be a well burnt magnesite with a backing brick of grog mixed with 45% of alumina. By the choice of suitable materials the lining life should be, on the average, 2-3 years.—E. N.

XIX.-WORKING

Possible Means of Speeding Up the Rolling of Magnesium Alloys. S. I. Gubkin and E. M. Savitsky (*Izvest. Akad. Nauk S.S.S.R.*, 1941, [Khim.], (6), 669-672).—[In Russian]. The possibility of rolling the alloys MA-1 and MA-3 under selected conditions of temp. and speed, is pointed out.—N. A.

*A Method of Calculation of the Number of Passes in the Cold Rolling of Sheet and Strip. S. I. Gubkin and K. D. Kurakin (Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota, 1940, (9), 570-579).—[In Russian]. For cases where const. pressure is applied for all passes, a method of calculation of the number of passes required is suggested, and formulæ are given. Check tests have been carried out on the method.—N. A.

*Some Observations on Cut Necks in Rolling-Mill Practice [Bronze Bearings]. G. P. Contractor and S. Viswanathan (*Sheet Metal Ind.*, 1946, 23, (230), 1037-1096).—Observations are made on the effect of the structure and composition of the bronze bearing material on the cutting or scouring of roll necks. The effect of inverse segregation on the problem is discussed and the results of experiments described.—R. GR.

*Investigations Into the Rapid Deformation of Aluminium. (Kistler). See p. 345.

XXI.—JOINING

On the Spot Welding of Aluminium. W. Heiz (Schweiz. Arch. angew. Wiss. Techn., 1946, 12, (7), 227).—[In German]. Spot welding is compared with riveting, to the advantage of the former.—N. B. V.

The Relation Between Welding Conditions and Mechanical Properties in , the Spot Welding of Aluminium. R. Irmann (Schweiz. Arch. angew. Wiss. Techn., 1946, 12, (6), 194–195).—[In German]. A brief note, summarizing the effects of welding conditions, in particular electrode pressure, on the quality of spot welds, and indicating the considerable variation in strength of spot welds in different aluminium alloys under identical conditions of welding.—N. B. V.

Determinative Factors in the Spot Welding of Light Metals. H. A. Schlatter (Schweiz. Arch. angew. Wiss. Techn., 1946, 12, (7), 222–226).—[In German]. A review. After briefly indicating the requirements of a good weld, S. discusses the effects of the physical and chemical properties of the aluminium alloys, the shape of the piece being welded, the shape and composition of the electrode, and the current, time, and electrode pressure.—N. B. V.

Electric Spot Welding in Light-Metal Railway-Carriage Construction. Choice of Type of Welding Machine and Description of the Construction. H. A. Schlatter (Schweiz, Arch. angew. Wiss. Techn., 1946, 12, (6), 195-198).--[In German]. A description of the characteristics and operation of a machine specially designed for spot welding light-alloy railway carriages.--N. B. V.

The Use of Spot Welding in the Construction of Light-Metal Railway Carriages. R. Bornand (Schweiz. Arch. angew. Wiss. Techn., 1946, 12, (7), 228-230).--[In German]. A very brief note, with 10 illustrations showing

-P. R.

various aspects of the construction. The machine used is that described by Schlatter (see abstract above).—N. B. V.

The Welded Joint in Non-Ferrous Chemical Plant. W. K. B. Marshall (Indust. Chemist, 1944, 20, (231), 171-181).—See Met. Abs., 1944, 11, 350.

*Welding Flames. T. Courard (Rev. Soudure Autogène, 1945, 1, (1), 22-33). -A comparative thermodynamic study was made of the intrinsic properties of the flames used in welding and of the action of these flames on different industrial metals. The investigation was essentially theoretical, but serves to indicate the general trend in practice. The flames considered were due to the combustion by oxygen of acetylene, hydrogen, town gas, and butane. There are, in general, two periods of combustion : (1) that of primary combustion resulting from the reaction of the gas with the oxygen provided by the torch and taking place in the point of the flame, and (ii) that of a secondary combustion resulting from the reaction of the products of the primary combustion with atmospheric oxygen and taking place in the body of the flame. In autogeneous welding only the primary combustion is used. The results of the investigation indicated that acctylene has considerable advantages over the other three gases studied, owing to its composition and its strongly endothermic nature, as manifested by the conc. of heat, available heat for melting the metals, and the reducing nature of its products of combustion. The use of the other three gases would seem to be confined to the welding of low-m.p.- and not readily oxidizable metals, although even here the oxy-acetylene flame would appear to be preferable.-J. H. W.

XXII.-INDUSTRIAL USES AND APPLICATIONS

Lithium: Extraction, Recovery, and Industrial Uses. (Arend). See p. 345. Magnesium in German Aircraft. H. W. Schmidt (Acronaut. Eng. Rev., 1943, 2, 7-21, 145).

Industrial Significance of the Basic Characteristics of Magnesium. J. D. Hanawalt (Metal Progress, 1946, 49, (3), 548-552; (4), 739-743).—Important factors in the future economic applications of magnesium include (a) wide distribution and universal availability, (b) the need for adequate protection from oxidation in alloying and casting, (c) low freezing point, (d) inertness towards iron, (e) limited workability in the cold and (frequently overlooked) excellent workability at higher temp., (f) ease of fabrication, and (g) high machinability. The development and scope of the German magnesium industry is described. Attention is directed to the simplification in design. and the consequent economy, in taking advantage of the lightness of magnesium by providing thicker sections and thus eliminating ribs and stiffeners. The proportionate increase in bending strength and rigidity is shown to be considerable. Reference is made to the high resilience of magnesium, which is much used, e.g., in rollers for conveyors and wheels for automobiles. Although readily attacked by salt water, magnesium is only slightly affected by ordinary atmospheric conditions .--- P. R.

Magnesium Alloys. Jerome Baird (*Wisconsin Eng.*, 1943, 47, (3), 10–17).— A review of the properties, manufacture, and uses.

Application of Magnesium Alloys. D. A. Tooley (Machinery (Lond.), 1946, 68, (1750), 527-530).—J. C. C.

World Production and Consumption of the Platinum Metals. B. V. Nevsky (Izvest. Sekt. Platiny, 1943, 19, 5-20).—[In Russian].—N. A.

Alloys of Platinum and Palladium and Their Application. V. A. Nemilov (Izvest. Sekt. Platiny, 1943, 19, 21–44).—[In Russian]. A review.—N. A.

The Uses of Platinum and Palladium in the Laboratory. A. M. Rubinshtein (Izvest. Sekt. Platiny, 1943, 19, 45-59).—[In Russian]. A review.—N. A. The Uses of Platinum and Palladium as Catalysts. A. M. Rubinshtein (*Izvest. Sekt. Platiny*, 1943, 19, 61–102).—[In Russian]. A review.—N. A.

Precious Metals in the Chemical Industry. M. Blot (*Chim. et Ind.*, 1945, 54, (4), 227-234).—A general account is given of the properties and uses of gold, silver, the platinum metals, and their derivatives.—J. C. C.

Rare Metals in War-Time—Vanadium. Hermann Baum (Metall u. Erz, 1944, 41, (9/10), 108-109).—A review of the occurrence, manufacture, use, market conditions, world production, and price of vanadium from 1935 to 1941. While Peru is the chief source of supply, the ore deposits in South-West Africa, the Transvaal, Rhodesia, Australia, and the United States are briefly described. The recovery of vanadium in Germany, from vanadium-bearing slags obtained in iron smelting, is mentioned.—E. N.

Uses of High-Grade Zinc Alloys. E. Bjerre (Ingenioren, 1942, 51, (25), M33-44; Chem. Zentr., 1942, 113, (II), 1396; C. Abs., 1943, 37, 5357).— A comprehensive summary, in which B. discusses methods of production, properties, machinability, sand- and permanent-mould die-castings, extruded alloys, bearings, alloys for electrical purposes, armatures, rolling of sheet, and surface treatments.

Substitute Alloys for Brass and Bronze. J. Schoofs (*Rev. Univ. Mines*, 1941, 17, 318-327; *Chem. Zentr.*, 1942, 113, (II), 1396; *C. Abs.*, 1943, 37, 5687).—The zinc-aluminium, zinc-copper, and zinc-aluminium-copper alloys are suitable to replace brasses and bronzes. S. discusses their mechanical properties, behaviour at high and low temp., corrosion-resistance, effect of additions of other metals and of impurities, casting and forgeable alloys, bearing alloys, melting and working practice, surface treatment, and the plating of zinc alloys with nickel, chromium, copper, and brass.

Bearing Parts from Very Pure Zinc Alloys. W. F. Beunderman (*Polytechn. Weekbl.*, 1941, 35, 4-5; *Chem. Zentr.*, 1941, 112, (I), 1728; *C. Abs.*, 1943, 37, 2325).—An alloy consisting of zine 95 (99.99% purity), aluminium 4, copper 1%, and a small amount of magnesium, is described, and suggested as a substitute for the copper-containing alloys GBz 14 and SRg 5. Its tensile strength, yield point, and hardness correspond to, but its extension coeff. is not so great as, those for the copper alloys mentioned. The resistance to wear, which is especially important for bearing metal, was found to be as good for the zine alloy as for the bronzes. The zine alloy machines well; its tendency to splinter off is about the same as that of brasses. Although the coeff. of bronze, the difference is scarcely of practical importance.

Centrifugal Castings in the Shipbuilding Industry. N. N. Sokolov (Sudostroenie, 1945, (3/4), 25-31).--[In Russian]. Metallurgical and engineering aspects of centrifugal castings are discussed. Centrifugal-casting machines and the technique of casting pipes and screws in ferrous and non-ferrous alloys in Russia at the present time are described.--V. K.

XXIV -BIBLIOGRAPHY

(Publications marked * have been received.)

*Alar, Ltd. D.T.D. 424 Aluminium Casting Alloy. Data Sheet. $13\frac{1}{2} \times 8\frac{1}{2}$ in. 1946. London : The Company, 35 New Broad Street, E.C.2.

American Electroplaters' Society. The Adhesion of Electrodeposits. (Research Report No. 1, reprinted from September 1945-January 1946 issues of Monthly Rev. of the Society). Pp. 60. 1946. Jenkintown, Pa.: The Society. (60 c.)

American Society for Metals. Induction Heating. 9×6 in. Pp. 172. 1946. Cleveland, Ohio : The Society. (\$3.)

- American Society for Metals. Magnesium. 9 × 6 in. Pp. 266. 1946. Cleveland, Ohio: The Society. (\$3.50.)
- Andrade, E. N. da C. Advisory Editor. Industrial Research, 1946. Pp. 737. [1946]. London : G. G. Harrap. (21s.)
- Bates, R. S. Scientific Societies in the United States. Demy 8vo. Pp. vii + 246. 1946. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Ltd. (21s.)
- *British Drug Houses, Ltd. The B.D.H. Book of Organic Reagents. Ninth and Enlarged Edition. Demy 8vo. Pp. x + 196. 1946. London: British Drug Houses, Ltd., Graham St., N.1. (4s. 6d.)
- *British Intelligence Objectives Sub-Committee. A German Thermometer for Use in the Range 400°-1200° C. (Final Report No. 345. Item No. 9.) [Mimeographed.] 9½ × 7½ in. Pp. 9. London: H.M. Stationery Office. (1s. 6d.)
- *British Intelligence Objectives Sub-Committee. Aluminium Pistons for Automobile and Aircraft Engines. (F.I.A.T. Final Report No: 602.) [Mimeographed.] 9½ × 7¼ in. Pp. 5. London: H.M. Stationery Office. (6d.)
- *British Intelligence Objectives Sub-Committee. Bi-Metal Tubing. (F.I.A.T. Final Report No. 595.) [Mimeographed.] $9\frac{1}{2} \times 7\frac{1}{4}$ in. Pp. 6. London: H.M. Stationery Office. (1s.)
- *British Intelligence Objectives Sub-Committee. Electric-Furnace Design, Manufacture, and Application in Germany. (Final Report No. 533, Item No. 31.) [Mimeographed.] 9½ × 7½ in. Pp. 109. London: H.M. Stationery Office. (9s. 6d.)
- *British Intelligence Objectives Sub-Committee. German Domestic Gas-Appliance Industry. (Application of aluminium and lead.) (Final Report No. 588. Item No. 30.) [Mimeographed.] 91 × 71 in. Pp. 44. 1946. London: H.M. Stationery Office. (4s.)
- *British Intelligence Objectives Sub-Committee. German Piston Manufacture. (Final Report No. 499. Item Nos. 18, 19, and 26.) [Mimeographed.] 9½ × 7¼ in. Pp. 119. 1946. London : H.M. Stationery Office. (11s.)
- *British Intelligence Objectives Sub-Committee. Industrial Heat-Treating Furnaces in Germany. (F.I.A.T. Final Report No. 434.) [Mimeographed.] 9½ × 7¼ in. Pp. 22. London: H.M. Stationery Office. (2s. 6d.)
- *British Intelligence Objectives Sub-Committee. Industrial Safety in Germany. (J.I.O.A. Final Report No. 45.) (Report prepared by Field Information Agency, Technical U.S. Group Control Council for Germany.) [Mimeographed.] 9½ × 7¼ in. Pp. 150. 1946. London: H.M. Stationery Office. (13s. 6d.)
- *British Intelligence Objectives Sub-Committee. Metallgesellschaft A.G. and the Lurgi Group of Chemical Engineering Companies. (Final Report No. 335. Item Nos. 2, 21, 22, 29, 30.) [Mimeographed.] 9½ × 7½ in. Pp. 209. London: H.M. Stationery Office. (20s.)
- *British Intelligence Objectives Sub-Committee. H. Walter Kommanditgesellschaft, Kiel. (Materials in the manufacture of bi-fuel rockets.) (Final Report No. 556. Item No. 4.) [Mimeographed.] 9½ × 7¼ in. Pp. 20. 1946. London : H.M. Stationery Office. (2s.)
- *British Intelligence Objectives Sub-Committee. The Extruded Brass-Rod Industry in Germany. (Final Report No. 386. Item No. 21.) [Mimeographed.] 9½ × 7¼ in. Pp. 65. London: H.M. Stationery Office. (6s.)

- British Standards Institution. British Standard Specification for Screw Threads for Copper Tubes. (No. 61, Part 2.) Demy 8vo. Pp. 14. 1946. London: The Institution, 28 Victoria St., S.W.1. (2s., post free).
- Burton, E. F., and W. H. Kohl. The Electron Microscope. 2nd, revised and enlarged, edition. [23 × 16 cm.] Pp. 325. 1946. New York : Reinhold Publishing Corporation. (\$4.00.)
- Carslaw, H. S. Introduction to the Mathematical Theory of the Conduction of Heat in Solids. 2nd edition. 8vo. Pp. 268. 1945. New York: Dover Publications. (21s.)
- *Combined Intelligence Objectives Sub-Committee. Description of Junkers •004 (203) Jet-Propulsion Engines. (Application of aluminium and magnesium.) (Item Nos. 5 and 26. File Nos. XI-6, XII-9, and XIV-4.) [Mimeographed.] 9½ × 7¼ in. Pp. 33. 1946. London: H.M. Stationery Office. (3s.)
- Cooper, H. J. Edited by. Scientific Instruments. Demy 8vo. Pp. 293. 1946. London: Hutchinson's Scientific and Technical Publications. (25s.)
- Desch, C. H. Science and the Social Order. ("Looking Forward" Pamphlet No. 6.) Cr. 8vo. Pp. 49. 1946. London and New York: Royal Institute of International Affairs. (1s.)
- *Electrodepositors' Technical Society. Journal of the Electrodepositors' Technical Society. Volume XX, 1944-45. Demy 8vo. Pp. viii + 217, with frontispicce and numerous illustrations. 1946. London : The Society. (£1 1s. 0d.)

[Contents: O. Wright: "The Lead and Allied Plating of Bearings" (see Met. Abs., this vol., p. 88); H. D. Hughes: "Electrography Applied to the Examination of Electrodeposits" (see Met. Abs., this vol., p. 90); John Kronsbein and Alan Smart: "Electroplating on Wire" (see Met. Abs., this vol., p. 89); J. M. Sprague: "An Investigation on the Silver Plating of Steel" (see Met. Abs., this vol., p. 89); S. Wernick: "Protective Value of Electro-Th as an Undercoating" (see Met. Abs., this vol., p. 89); A. W. Hothersall and G. E. Gardam: "Preparation of Copper Powder by Electrodeposition" (see Met. Abs., this vol., p. 88); G. E. Gardam: "The Production of Machinable Chromium Deposits" (see Met. Abs., this vol., p. 87); S. G. Clarke : "End-Point Indication of the B.N.F. Jet Test for Measurement of Thickness of Zine Coatings on Steel" (see Met. Abs., this vol., p. 16); H. Silman: "Black Finishes for Steel"; J. D. Jevons: "Pressing Technique as a Preliminary to the Production of Good Electrodeposits" (see Met. Abs., this vol., p. 38); S. R. Goodwin and G. M. and H. M. Bechtold: "The Influence of Anodes in Plating Processes" (see Met. Abs., this vol., p. 19); S. G. Clarke and J. F. Andrews: "A Simple Magnetic Tester for Determining the Thickness of Coatings on a Steel Base." (see Met. Abs., this vol., p. 28); G. H. S. Price: "Powder Mctallurgy" (see Met. Abs., this vol., p. 10); C. W. Richards: "Chlornaphthalene Wax for Stopping Off in Electrodeposition Practice; its Advantages and Limitations" (see Met. Abs., this vol., p. 20); David Jackson: "The Effect of Sulphate in the Bengough-Stuart Anodizing Solution" (see Met. Abs., this vol., p. 86).]

- Gabor, D. The Electron Microscope, its Development, Present Performance, and Future Possibilities. (Electronic Engineering Technical Monograph.) Demy 8vo. Pp. 104. 1946. London: The Hulton Press. (4s. 6d.)
- Gibbs, L. E. Cold Working of Brass. 9 × 6 in. Pp. 112. 1946. Cleveland, Ohio : American Society for Metals, 7301 Euclid Avenue. (\$2.)
- *Giffen, Edmund. Engineering Research in the University. $9\frac{3}{4} \times 6\frac{1}{4}$ in. Pp. 12. 1946. London : Oxford University Press. (1s. 6d.)
- Hedley, W. H. The Basis of Sheet-Metal Drafting. Demy 8vo. Pp. 118. 1945. London: Longmans, Green, & Co. (6s.)

- Heitler, W. Elementary Wave Mechanics. Pp. viii + 136. 1945. Oxford: Clarendon Press. (7s. 6d.)
- Institute of Welding. Classified Catalogue of the Library. 2nd edition. Pp. 180. [1946.] London: The Institute. (3s. 6d., post free.)
- Institute of Welding. Sir William J. Larke Medal Competition Prize Papers. Pp. 156, with 125 illustrations and 18 folding drawings. 1946. London : The Institute. (12s. 6d. post free.)
- *Motock, G. T. Extraction and Uses of Beryllium in Germany. (U.S. Bureau of Mines, Inform. Circ. No. 7357.) [Mimeographed.] 10½ × 8 in. Pp. 12. 1946. Washington: U.S. Department of the Interior.
- *Motock, G. T. Extraction and Uses of Lithium in Germany. (U.S. Bureau of Mines, Inform. Circ. No. 7361.) [Mimeographed.] 10¹/₂ in. × 8 in. Pp. 23. 1946. Washington: U.S. Department of the Interior.
- Perrault, R. Le Coball. $10 \times 6\frac{1}{2}$ in. Pp. viii + 152, with 26 figures and 3 plates. 1946. Paris: Dunod, 92 rue Bonaparte. (390 fr.)
- *Pirenne, M. H. The Diffraction of X-Rays and Electrons by Free Molecules. $5\frac{1}{2} \times 8\frac{1}{2}$ in. Pp. xii + 160, with 82 illustrations in the text and 2 plates. 1946. Cambridge : The University Press. (12s. 6d. net.)
- Rice-Oxley, F. B. Quin's Metal Handbook and Statistics, 1945. Pp. 368. [1946.] London : Metal Information Bureau. (10s.)
- Schrödinger, Erwin, Statistical Thermodynamics. (A course of Seminar Lectures delivered in January-March 1944 at the School of Theoretical Physics, Dublin Institute for Advanced Studies.) Cr. 8vo. Pp. vii + 88. 1946. Cambridge : The University Press. (6s.)
- *Schlain, D., J. D. Prater, and B. L. Lukens. A Study of Anodes for Electrolytic Manganese. (U.S. Bureau of Mines, Report of Investigation No. 3863.) [Mimeographed.] $10\frac{1}{2} \times 8$ in. Pp. 20. 1946. Washington : U.S. Department of the Interior.
- *Schlain, D., J. D. Prater, and B. L. Lukens. Effect of Impurities on the Electrodeposition of Manganese. (U.S. Bureau of Mines, Report of Investigation No. 3872.) [Mimeographed.] 10½ × 8 in. Pp. 18. 1946. Washington : U.S. Department of the Interior.
- *Simon, W. H. Edited by. American Arc Welding Patents. With a Fore-Word by W. F. Hess. Volume I.—Materials, Accessories, Electrodes, Welding Rods, Alloys, Electrode Holders, Welding Shields. Demy 4to. Pp. ix + 574, with 420 illustrations. 1945. London: Bailey Bros. and Swinfen, Ltd., 11 Ronalds Road, Highbury, N.5. (£10 10s. 0d.).
- Smith, J. Campbell. The Chemistry and Metallurgy of Dental Materials. Med. 8vo. Pp. v + 317. 1946. Oxford : B. H. Blackwell. (21s.)
- *U.S. Department of Commerce, National Bureau of Standards. Pipe Nipples : Brass, Copper, Steel, and Wrought Iron. 2nd edition. (Commercial Standard (S5-46.) [Mimeographed.] $10\frac{1}{2} \times 8$ in. Pp. 12. 1946. Washington, D.C. : Superintendent of Documents.

NEW JOURNAL

Bulletin de la Société Française de Métallurgie. (Publishes Proceedings of the Society, dealing with ferrous and non-ferrous metallurgy.) Published half-yearly by the Society, 44 Rue de Rennes, Paris, VI. First issue published 1945.

POLITECHNIKH

In your post-war planning leave your

PRESSING

problems to



AND



LIMITED

Head Offices Rea Street • • • Birmingham, 5

Established 1852



UNITED ANODISING LIMITE

(Controlling Alumilite and Alzak Ltd., Aluminium Protection Company Limited, British Anodising Limited.)

ELECTRO-BRIGHTENING, SULPHURIC ACID ANODISING, DYEING AND SEALING

The processes now owned or controlled by the United Anodising Group of Companies have played a vital part in the war effort.

Members of the Group own or are exclusive Licencees for the United Kingdom, India, Australia and the Union of South Africa.

BRITISH PATENTS Nos.

378,521	401,579	436,154	412,193	540,146	449.175
381,402	406,988	436,481	412,205	558,926	463,790
387,806	407,208	440,287	479,063	559,393	483.776
391,903	409,679	489,169	483.727	559.394	525.734
393,996	407,457	491,974	489,220	359.494	528.314
396.204	413,814	496,613	537.474	382.287	474.609
401,270	433,484	528,748	558,925	429,344	476,161

The Australian, Indian and Union of South Africa Patents Numbers will be given on application. The Authorisations given by the Minister of Aircraft Production or other Government Departments

for the use of patented processes for war purposes do not of course cover ordinary commercial use. In view of the extended use of anodising, including use of the processes covered by the patents mentioned above, favourable consideration will be given to grants of licences and sub-licences to

approved manufacturers.

All enquiries should be addressed to :---

UNITED ANODISING LTD., 40, Brook Street, London, W.1. Mayfair 4541.

ALL COMMUNICATIONS REGARDING ADVERTISEMENTS SHOULD BE ADDRESSED TO THE ADVERTISING MANAGERS. MESSRS. T. G. SCOTT & SON, LTD., TALBOT HOUSE, ARUNDEL STREET, LONDON, W.C.2.

PRINTED IN GREAT BRITAIN BY RICHARD CLAY AND COMPANY, LTD., BUNGAY, SUFFOLK.