The Journal of the INSTITUTE OF METALS

and

METALLURGICAL ABSTRACTS

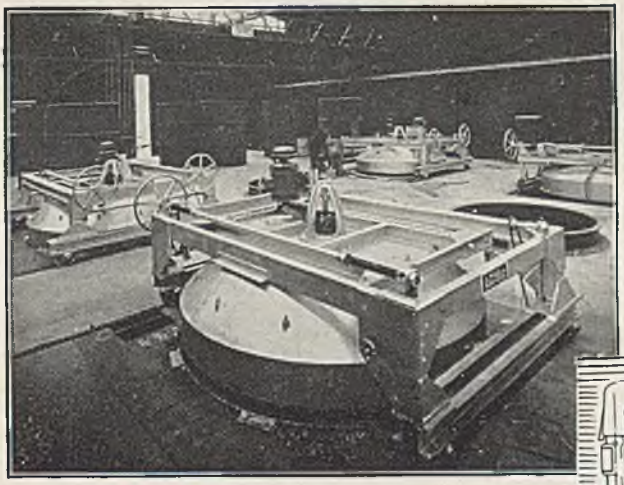
In this Issue:

DECEMBER 1946

 Entered at Stationers' Hall

ECONOMICAL HEAT-TREATMENT OF NON-FERROUS METALS

FORCED AIR CIRCULATION FURNACES



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

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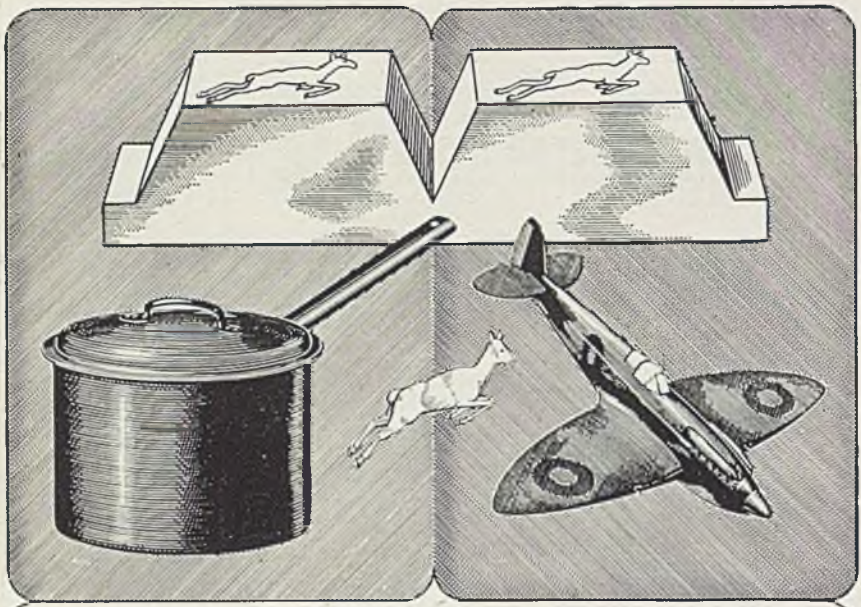

a page from the booklet 'Kynal' and 'Kynalcore' aluminium alloys

ALUMINIUM and ALUMINIUM ALLOYS

'Kynal' and 'Kynalcore' Wrought Productions and their Classifications
Mechanical Properties and Complementary Specifications

SCHEDULE I

Classification (I.C.I.)	Form	Condition	Complementary Specifications: D.T.D.	B.S.S.	S.T.A.M.	Mechanical Properties (Minimum unless stated otherwise): 0·1% Proof Stress Tons/in.²	Ultimate Stress Tons/in.²	Elongation % on 2 in.	Brinell Hardness (See p. 10)	Other Tests (See p. 10)	Remarks
ALLOYS NOT HEAT-TREATED											
'KYNAL' P419	SHEET AND STRIP	Soft	—	—	—	—	6-7·5	20-25	26	Flat [4]	For low to medium strength applications where good ductility is required. Suitable for cold forming, welding (fusion or spot) anodises well, has good corrosion resistance.
		} Hard	653	—	AW3C	7·5	7·5-9·5	5-12	35	1T [4]	
		} Hard	211A	—	—	—	11	5	45	1T [4]	
	BARS AND SECTIONS	As extruded	—	—	AW3A	—	9	10	40	—	
	TUBES	} Hard	—	—	AW3B	—	8·5-10·5	—	—	—	
'KYNAL' M35/1	SHEET AND STRIP	Soft	634	146	—	6	11	18	45	Flat [4]	For medium strength applications where good ductility and very good corrosion resistance are required, particularly under marine conditions. Suitable for welding (fusion or spot), and anodising. Has moderate machining qualities.
		} Hard	606	—	AW4C	12	15	5	67	1T [4]	
	BARS AND SECTIONS	As extruded	—	144	AW4A	—	11	18	—	—	
	TUBES	Soft	310B	—	—	—	9-11 [2]	—	45	[6]	
		} Hard	440	—	AW4B	11	15	—	67	—	
'KYNAL' M35/2	SHEET AND STRIP	Soft	180H	—	—	7	14	18	56	Flat [4]	
		} Hard	—	—	AW5C	13	18	5	75	2T [4]	
	BARS AND SECTIONS	As extruded	—	—	AW5A	8	14	18	56	—	
	TUBES	Soft	—	—	—	8	14	18	56	[6]	
		} Hard	—	—	AW5B	12	18	5	75	—	
'KYNAL' M36	SHEET AND STRIP	Soft	—	—	—	8	17	18	45	Flat [4]	For intermediate strength applications, where good ductility and very good corrosion resistance are required, particularly under marine conditions. Suitable for anodising.
		} Hard	—	—	AW6C	17	20	5	80	2T [4]	
	BARS AND SECTION	As extruded	—	—	AW6A	8	16	18	50	—	
	TUBES	Soft	—	—	—	8	17	18	45	—	
		} Hard	—	—	AW6B	14	18	5	80	—	
	WELDING ROD AND WIRE	Soft	303	—	AW6D	—	16-21	—	45	[5]	
'KYNAL' M37	SHEET AND STRIP	Soft	182A	—	AW7C	9	20-23	20	60	1T [4]	For higher strength applications. Has excellent corrosion resistance under marine conditions. Suitable for anodising.
	BARS AND SECTIONS FOR FORGING	Softened	291	—	AW7A	9	20	18	56	—	
	TUBES	Soft	[illegible]	—	—	9	20-23	18	56	[12]	
		} Hard	[illegible]	—	AW7B	16	25	5	—	—	
		Hard	186A	—	—	17-18 [7]	25-26 [7]	—	95	[12]	
	WIRE FOR RIVETS	Soft	191A	—	—	—	20-23	—	56	[5]	For medium strength applications where good ductility and very good corrosion resistance are required.
		Hard	[illegible]	—	—	—	27	—	80	[5]	

NOTE. *The figures quoted in brackets refer to Notes on page 10. Proof Stress values marked with an asterisk are 0·2 %*

The purpose of this booklet is to place before constructional engineers and designers the more important physical properties of 'Kynal' and 'Kynalcore' products, which are manufactured by the Metals Division of Imperial Chemical Industries Limited. The data will enable them to select the alloys most suitable for their specific requirements. The services of our technical and research departments are available to all users of light alloys. Copies of the booklet can be obtained from :—

IMPERIAL CHEMICAL INDUSTRIES LTD., LONDON, S.W.1

M.86

The Journal of the
INSTITUTE OF METALS

DECEMBER 1946

CONTENTS

December 1946.

THE INSTITUTE OF METALS

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Secretary:
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Editor of Publications:
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Administrative and Editorial Offices: **4 GROSVENOR GARDENS, LONDON, S.W.1.**
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INSTITUTE NEWS AND ANNOUNCEMENTS

INSTITUTE OF METALS (PLATINUM) MEDALLISTS, 1947.

THE Institute of Metals Medal in platinum for the year 1947 has been awarded by the Council to Dr. J. L. Haughton and Dr. Marie L. V. Gayler (Mrs. Haughton) jointly, in recognition of their outstanding services to the science of non-ferrous metallurgy.

GENERAL MEETINGS.

Changes in 1947.

It has been obvious for some time that the "technical" sessions at March and Autumn Meetings of the Institute have been insufficient to provide adequate time for the discussion of those published papers that were deemed suitable for oral discussion.

To endeavour to cope with this difficulty, it was decided, as an experiment, that at the Autumn Meeting of the present year two simultaneous sessions should be held for the discussion of papers. Opinions on the desirability of this have, however, been divided. In consequence, the Meetings Committee has given further careful study to this problem, and has had the advantage of constructive criticism from some members, for which it expresses its warmest thanks.

The Council has now approved the Committee's recommendation that for 1947, and in future if found successful, (*a*) one more day shall be added to the Annual General Meeting, for the discussion of papers; (*b*) a General Meeting, for discussion of papers, shall be held on the day after the May Lecture; and (*c*) such other General Meetings of the Institute shall be held, at the most suitable locations, as may be required to give adequate time for discussions.

In future, morning sessions will begin at 10 a.m. Two papers only will be on the programme for discussion at each session, but one paper that is not likely to stimulate much discussion will be available at the end of each session, to be taken if time permits.

Authors will be limited to a period of 5 minutes in which to introduce themselves to the meeting and indicate any points on which they would particularly like discussion, but not less than 10 minutes will be allotted to each author in which to make a reply.

Speakers in the discussions will be discouraged from reading from notes, as extemporary contributions are much to be preferred, but no restriction will be placed on the use of notes of the necessary headings of their discussion and of data.

Visits to works and institutions of interest to members, and the Annual Dinner-Dance, are being revived in 1947. A two-day symposium on "Internal Stresses in Metals and Alloys" is being organized, and it is expected that a Students Tour to Sweden will be arranged in July.

The Meetings Committee hopes that these functions will be wholeheartedly supported by members, and will be glad to receive further suggestions for the improvement of the meetings.

Annual General Meeting, 5, 6, & 7 March 1947.

The programme arranged for this meeting, of which full details will be sent to members in January 1947, is :

Wed., 5 March.

10 a.m. Business meeting; Reports of Council and Hon. Treasurer; presentation of Institute of Metals (Platinum) Medal.

10.45 a.m.–12.30 p.m. Addresses by Institute of Metals Medallists.

2.30–5 p.m. Presentation and discussion of two papers.

7 for 7.15 p.m. Dinner-Dance at the Savoy Hotel (a Carroll Gibbons dance band; tickets 30*s.* each).

Thurs., 6 March.

10 a.m.–12.30 p.m. Presentation and discussion of two papers.

2.30 p.m. Visits to works and institutions (eight invitations have been received).

Fri., 7 March.

10 a.m.–12.30 p.m. Presentation and discussion of two papers.

BOUND VOLUMES OF THE JOURNAL.

With reference to the announcement made on page xxiv of the September issue of the *Journal*, members are requested to note that the reintroduction of the pre-war custom of providing members with bound volumes in addition to the monthly issues will not be possible during the present financial year. The Council regrets this decision, which is due to paper supply and other difficulties.

Members should, therefore, carefully preserve their monthly copies for binding in the cases that will be supplied as in recent years. This refers to Volume 73 of the *Journal* that will close with the August 1947 issue, and Volume 14 of *Metallurgical Abstracts*, which will close with the December 1947 issue. Special index numbers will be published for each volume.

COUNCIL.

In accordance with the Articles of the Institute, Members of Council—who retire at regular intervals of service—are elected with effect from March of each year, except the Chairmen of the Local Sections, whose annual election dates from the commencement of the Session. Whereas other Members of Council are elected by the Members of the Institute as a whole, those who are Local Sections' Chairmen are elected by the members of their particular Sections.

The Members of Council elected as representatives of the Local Sections for the year 1946–1947 are :

Birmingham : E. A. Bolton, M.Sc.
London : J. H. Watson, M.B.E., M.C., Ph.D., B.Sc., A.R.S.M.
Scottish : A. B. Graham.
Sheffield : Frank Mason.
Swansea : Harry Davies.

Brief biographical details are given below.

Mr. E. A. Bolton, M.Sc., was born in 1899 and educated at the George Dixon Grammar School, Birmingham, and Birmingham University. He served in the Royal Air Force in 1918–1919. While holding the position of Works Chemist to the Non-Ferrous Casting Co., Birmingham, he won the Hingeley Scholarship in 1919, entered the University, and obtained the degree of M.Sc. in metallurgy in 1922. Mr. Bolton held a Research Fellowship with the

DR. J. H. WATSON, M.B.E., M.C., B.Sc., A.R.S.M.

British Non-Ferrous Metals Research Association in 1922–1923, and entered the Research Department of The British Aluminium Co., Ltd., at Warrington, in 1923. Joining the staff of Kynoch, Ltd., Birmingham (later I.C.I., Ltd.) in 1925, as Assistant Departmental Manager, he transferred to the Company's Selly Oak Works in 1935 as Deputy Factory Manager, and became Factory Manager at the commencement of 1946.

Mr. Bolton, who joined the Birmingham Metallurgical Society in 1917, was Member of Council of that Society for a number of years, and was President in 1936–1937. He was elected a Fellow of the Institution of Metallurgists in 1946.

DR. J. H. WATSON, M.B.E., M.C., B.Sc., A.R.S.M., was born in 1895, and educated at Malvern College, the Royal School of Mines, and London University. In the 1914–1918 war he served for four years as a Royal Engineer officer in France and Italy (M.C. and mention in despatches).

Dr. Watson joined the Royal Mint as an Assistant Assayer in 1921, and is now Assayer. He is a Member of the Institution of Mining & Metallurgy, and a Freeman of the City of London.

MR. A. B. GRAHAM was born in 1889, educated at Hutcheson's Grammar School, and the Royal Technical College, Glasgow. After some years with G. & J. Weir, Ltd., Cathcart, as Works Superintendent of their "Monel" Department, and in a similar capacity with Monel-Weir, Ltd., he joined Henry Wiggin & Co., Ltd., in 1932, when the business of Monel-Weir, Ltd., was acquired by The Mond Nickel Co., Ltd. For the past 14 years he has been Works Manager and subsequently General Manager of the present Henry Wiggin Plant at Glasgow.

Mr. Graham is a Member of the Institution of Engineers & Shipbuilders in Scotland.

MR. FRANK MASON was born in 1877 and educated at University College and the University of Sheffield. From 1907 to 1922 he was Manager of Mappin & Webb, Ltd., Royal Works, Sheffield, being "lent" to the Ministry of Munitions from

MR. A. B. GRAHAM.

Mr. F. Mason.

1916 to 1919 in connection with research and manufacture of cupro-nickel and brass during the 1914–1918 war. In 1917 and 1918, and for subsequent periods, he has been Lecturer in Electro-metallurgy at Sheffield University.

Since 1926, Mr. Mason has been Managing and Technical Director of Stainless Plating, Ltd., Sheffield, and Technical Consultant to its associated companies. He is a Member of the Institution of Electrical Engineers, a member of the Sheffield Chamber of Commerce Committee on Education, a Member of the Sheffield Cathedral Council and some of its committees, and Honorary Secretary of the Cathedral Extension Fund.

Mr. Mason has been Chairman of the Sheffield Local Section for the years 1924–1926, and 1937 to the present date; since 1937 he has been a Member of Council, and served on several of its committees.

Mr. Harry Davies was born in 1893, educated at King Edward VI Grammar School, Stourbridge, was an articled pupil of Joseph Lones, F.I.C., Public Analyst from 1907 to 1911, and studied metallurgy from 1911 to 1915 at Birmingham University, at which he was awarded a Bowen Research Scholarship in 1915.

He has held the appointments of Metallurgist to the Dunlop Rubber Co., Ltd., Birmingham (1915–1917); Research Metallurgist to Rudge-Whitworth, Ltd., Coventry and Birmingham (1917–1920); Senior Chemist and Metallurgist, Elliotts Metal Co., Ltd. (and later I.C.I., Ltd.), Birmingham (1920–1934); Chief Metallurgist, I.C.I., Ltd., Landore, Swansea (1934–1938), and has held the position of Technical Manager at Landore since 1938.

Mr. Davies was Secretary of the Birmingham University Metallurgical Society in 1914; Lecturer in Non-Ferrous Metallurgy at the Birmingham Technical College from 1916 to 1934; Senior Vice-President of the Birmingham Metallurgical Society in 1933, and was elected a Fellow of the Institution of Metallurgists in 1946.

He has held the Chairmanship of the Swansea Local Section previously, from 1937 to 1938.

Mr. Harry Davies.

NOMENCLATURE AND TERMINOLOGY.

The tentative proposals of the Nomenclature and Terminology Committee which are set out below are published for criticism by members, who are invited to send their comments to the Secretary for consideration by the Committee.

Cavitation.

During recent years there has been a tendency for the word "cavitation" to be used with reference to porosity in metals, *e.g.*, "interdendritic cavitation in magnesium alloy castings."

The original use of this term in relation to metallurgy has been in association with the erosion of metals by water, a phenomenon first observed in 1894 with the propeller blades of destroyers. Since that time the effect has been observed not only in marine work, but also in hydraulic turbines and centrifugal pumps, where erosion occurs on the blades and other parts subjected to high-velocity liquid flow, when cavitation takes place in the liquid.

The use of the word "cavitation" to signify porosity in metals is liable to cause confusion, and is to be deprecated.

The term "cavitation" shall not be used in the publications of the Institute as a synonym for porosity in metals.

Thermal Treatment.

The term "thermal treatment" is applicable to any process of heating and cooling of metals, whether for beneficial or other purposes, and is a general term covering all such processes. It may be used, for example, in describing laboratory treatment where heating of specimens is carried out to produce particular metallographic structures. In industrial practice it might be used, for instance, to describe the heating of an ingot.

"Thermal treatment" does not necessarily require the application of heat; cooling of the metal below normal temperatures may come into this category. Moreover, it is not necessary for the metal to be in the solid state.

Heat-Treatment.

"Heat-treatment" denotes a particular type of thermal treatment. It has a specific meaning, especially in ferrous metallurgy, and its general definition might be: "the thermal treatment of *solid* metals for the purpose of improving their properties."

It may be emphasized that the object of the treatment is to improve the properties of the metal, as, for example, to toughen or harden the metal. The process may be a simple one or a sequence of operations such as heating, soaking and cooling at a given rate. Refinement of grain-size is a form of "heat-treatment" because it results in an improvement in properties.

Annealing.

There is a tendency to use the term "annealing" in a number of loose ways, divorced from the meaning already established. For example, the heating process carried out on alloys before ageing is sometimes referred to as "annealing," when heating to cause solution of the ageing constituent is meant.

It must be remembered that in ferrous metallurgy "annealing" has a distinct meaning in one process, *i.e.*, that of heating a steel above the critical point, followed by slow cooling in the furnace, as distinct from "normalizing," where cooling is allowed in air. A general definition of the term "annealing" should not exclude this use of the term.

A definition which seems to satisfy most requirements is: "Annealing is the thermal treatment of metals for the purpose of softening them."

The action of "annealing" may or may not result in recrystallization.

Stress Relieving.

Stress relieving is the thermal treatment of metals at comparatively low temperatures above room temperature but below the normal annealing temperature, with the *primary* object of relieving internal stresses. This term should not be confused with low-temperature annealing, which is a softening process, and comes into the category of annealing.

INFORMATION AND LIBRARY SERVICE.

Members desiring to borrow books or obtain scientific, technical, or other information not directly connected with the Institute's own publications or activities, are requested *not* to address them by letter or telephone to the Assistant Secretary's department but to the Librarian or Information Officer, respectively, at the Joint Library and Information Department, 4 Grosvenor Gardens, London, S.W.1 (telephone: Sloane 6233).

Frequent enquiries of this nature to the Assistant Secretary's department delay action by the Librarian or Information Officer, to whom such enquiries must, necessarily, be referred.

Enquiries on educational matters should be made to Dr. N. Stuart, Education Officer, Joint Committee on Metallurgical Education, 4 Grosvenor Gardens, London, S.W.1.

PERSONAL NOTES

Mr. J. C. Bailey, B.Sc., who has been acting as Information Officer to the Aluminium Development Association, has been appointed Liaison Officer, to co-ordinate the work of the technical committees and the senior technical staff. Mr. Bailey, who is a graduate of Birmingham University, was for some years on the staff of I.C.I. Metals, Ltd., and, before the war, with Murex Welding Processes, Ltd.

Dr. C. H. Desch, F.R.S., has accepted nomination as President of the Iron and Steel Institute for a second term of office to begin at the 1947 Annual General Meeting.

Mr. E. C. Ellwood, B.Sc., has returned from a three-months' tour in Canada and the United States where (under arrangements made by the Department of Metallurgy, King's College, Newcastle-on-Tyne) he has been studying present practice in non-ferrous metal smelting, and visiting University metallurgical departments and other research laboratories.

Dr. H. J. Gough, C.B., M.B.E., D.Sc., Ph.D., F.R.S., delivered the Thirty-Third Thomas Hawksley Lecture to the Institution of Mechanical Engineers on 15 November 1947, on "Research and Development Applied to Bomb Disposal."

Mr. Frank Hudson will be in charge of the new Foundry Service Section of the Development and Research Department of the Mond Nickel Co., Ltd. Dr. A. B. Everest, B.Sc., will still be primarily responsible for all matters concerning the application of nickel cast-iron in industry.

Dr. W. Hume-Rothery, M.A., F.R.S., delivered the 1946 Annual Lecture to the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers at the National Metal Congress of America, held at Atlantic City, N.J., U.S.A., on 19 November 1946. His subject was "Electrons, Atoms, Metals, and Alloys." Dr. Hume-Rothery has spent two months in the U.S.A., and has recently returned.

Dr. G. Lawton, B.Sc., who has been Principal of Doncaster Technical College since 1931, has been recommended by the Sheffield Technical Education Committee for the post of Principal of the College of Commerce and Technology, Sheffield. This appointment is subject to the approval of Sheffield Education Committee.

Mr. D. P. C. Neave, M.A., has been appointed a director of Fison's, Ltd., in the place of Mr. L. B. Robinson, who has resigned.

Death.

The Editor regrets to announce the sudden death, on 1 November 1947, of Mr. Henry Toplis, who for more than twenty years was Technical Representative in the Birmingham area for Kasenit, Ltd., of London.

OTHER NEWS

Ancient Metallurgy.

The Royal Anthropological Institute has appointed a Mining and Metallurgical Committee to investigate problems of early metallurgy. Among the first to be studied is man's early use of copper. Samples of "native copper" from many parts of the world are being collected and analysed, with the object of relating, if possible, their particular composition to that of ancient specimens of copper work. Dr. C. H. Desch, F.R.S. (Past-President), is a member of the Committee.

Research on Metal Finishing.

During the war, metal-finishing problems were of a specialized nature, but peace-time requirements are for decorative finishes of a high order, particularly for goods for export. Finishing processes have, therefore, assumed primary importance. Owing to increased costs, finishes of the highest standard can only be achieved economically by using modern methods.

The Research Board of the British Non-Ferrous Metals Research Association has decided that an extension of the facilities in its laboratories to provide for researches on metal finishing offers an economical and efficient method of tackling these problems. Before the war the Association's interest in electrodeposition was dealt with by co-operation with the Research Department, Woolwich. It is considered, however, that the Association is in a unique position to serve the metal-finishing industry by undertaking in its own laboratories researches on metal-finishing processes in parallel with its work on other aspects of metal quality.

The Association is, therefore, embarking on an extension of its laboratories to provide facilities for a metal-finishing section. This will include an experimental electroplating shop and a special laboratory for research of a more fundamental kind.

These new research facilities, coupled with the Information and Technical Advisory Services which the Association gives its members, will provide strong technical backing for the British plating industry.

The Association wishes to contact all firms interested in this project, and invites companies concerned with metal finishing in any form (other than paint or lacquer) to write to the Director, British Non-Ferrous Metals Research Association, Euston Street, London, N.W.1, stating the type of work in which they are interested.

New Aluminium Plant.

On a 100-acre site at Rogerstone, near Newport, Mon., a continuous-type rolling mill is under construction for the mass output of aluminium sheet products, and will be completed in 1948 for Northern Aluminium, Ltd., one of the largest associates of the Canadian corporation, Aluminium, Ltd. At present, the world's only continuous rolling mills for aluminium are in the United States.

The expansion at Rogerstone, embracing a main series of rolling machines more than a quarter of a mile in length, will result in production methods as efficient as those in any country. The plant and equipment will cost more than £2,500,000. An output of 50,000 tons of sheet products per annum is planned from the new equipment, and this can be extended to 150,000 tons if necessary. By comparison, the greatest annual rate of aluminium sheet production during the war from all plants in the United Kingdom was just over 100,000 tons.

Sheet and Strip Metal Users' Technical Association.

The Winter Conference and General Meeting of the Association will be held in London on Friday and Saturday, 31 January and 1 February 1947. There will be five technical sessions during the two days, and a banquet on the evening of 31 January.

X-Ray Spectroscopy.

A course of ten lectures on X-ray spectroscopy is to be given in the

Department of Physics and Mathematics at the Sir John Cass Technical Institute, Jewry St., Aldgate, London, E.C.3. The lectures will be delivered by Mr. H. P. Rooksby, B.Sc., of the Research Laboratories of the General Electric Co., Ltd., on Mondays from 6 to 7 p.m. beginning on 20 January 1947. The fee for the course is 20*s*.

German Scientific Developments.

The Military Governments of the British, American, and French Zones of Occupation in Germany maintain agencies which are engaged in the collection of reports on German technical and industrial development. These several agencies operate in the Western Zones through the medium of British, American, and French Field Information Agencies, Technical (F.I.A.T.).

In the course of operations it was found that there was a great deal of information on fundamental scientific research in the natural sciences which had not been published during the war. F.I.A.T. has evolved a plan to gather this information through the co-operation of German scientists.

The plan provides for the writing of a series of reviews in a manner and format similar to those of the Annual Reports of the Chemical Society (London), and metallurgy is one of the subjects covered.

Each paper is under the editorship of a specially selected senior author, whose responsibility it is to select collaborators for individual reviews and to prepare the final manuscript. These manuscripts are expected to be available through the facilities of the National F.I.A.T. early in 1947. The authors chosen for the papers on metallurgy are M. Hansen and W. Eilender.

Faraday Lecture.

Sir Robert Robinson, D.Sc., LL.D., P.R.S., has accepted the invitation of the Council of the Chemical Society to deliver the Faraday Lecture during the Society's Centenary Celebrations in July 1947. The Faraday Lectureship was founded in 1867 to commemorate Michael Faraday, who was elected a Fellow of the Society in 1842 and was one of its Vice-Presidents.

The lecture, which will be delivered in the Central Hall, Westminster, London, S.W.1, on Wednesday, 16 July 1947, will form the principal scientific event of the Centenary Celebrations. It is especially fitting that Sir Robert, a Past-President of the Society, should have been chosen to deliver the lecture, for, had the Centenary Celebrations taken place in 1941, exactly 100 years since the foundation of the Chemical Society, he would have presided over them.

Electron Jubilee Celebrations.

The fiftieth anniversary of the discovery of the electron by Sir Joseph Thomson, O.M., occurs next year. To mark this jubilee, and to demonstrate the tremendous influence that such an advance in pure physics may have on the life of the community, the Institute of Physics and the Physical Society are jointly arranging a series of meetings and other functions to take place in London on 25 and 26 September 1947. A special exhibition, to remain open to the public for several weeks, will be held at the Science Museum, South Kensington, and will show the development of the vast range of modern industrial equipment from its earliest experimental origins.

It will be recalled that Sir Joseph Thomson was elected an Honorary Member of the Institute of Metals in 1916, and gave the Fifth May Lecture, in 1915, on "Conduction of Electricity Through Metals." He died in 1940, at the age of 83.

Royal Statistical Society.

A North-Eastern Group, centred on the Tyne and Wear areas, and including a Tees-Side Sub-Group, has been formed of the Industrial Applications Section of the Society. This Section is concerned with the application of statistical techniques to all aspects of industry.

Details may be obtained from the Assistant Secretary, Royal Statistical Society, 4 Portugal Street, London, W.C.2.

Raw Materials Guide.

The Board of Trade have published a revised Raw Materials Guide, which sets out all the raw materials controlled by them and by the Ministry of Supply, giving brief details of the types of control in force and the addresses to which any enquiries should be addressed. It is obtainable, price 1*s.* 6*d.*, through any bookseller or newsagent.

German Patent Specifications.

Over 70,000 German civil patent specifications, covering war-time developments in German industry and research, have been brought to Britain from the Berlin Patent Office, and are open to inspection at the Patent Office Library, 25 Southampton Buildings, Chancery Lane, London, W.C.2. The specifications are in German. Name and subject indexes are available up to the end of 1942 and quarterly name indexes up to September 1943. Subject searching after 1942, however, may be facilitated by reference to copies of the weekly classification list, *Patentblatt.*

LOCAL SECTIONS MEETINGS

Birmingham Local Section.—Professor M. L. Oliphant, Ph.D., F.R.S.: "Metallurgical Aspects of Atomic Energy." (James Watt Memorial Institute, Great Charles Street, Birmingham, Thursday, 2 January 1947, at 6.30 p.m.)

Birmingham Local Section.—Open Discussion: "Scale Removal." (James Watt Memorial Institute, Great Charles Street, Birmingham, Thursday, 23 January 1947, at 6.30 p.m.)

London Local Section.—Mr. A. Makower, M.A.: "Lead." (4 Grosvenor Gardens, London, S.W.1, Thursday, 9 January 1947, at 7 p.m.)

Scottish Local Section.—Brains Trust. (Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, Monday, 20 January 1947. Light snack meal at 6 p.m.; lecture at 6.30 p.m.)

Sheffield Local Section.—Dr. C. J. Smithells, M.C.: "Recent Developments in the Aluminium Industry." Joint meeting with Sheffield Society of Engineers and Metallurgists. (Royal Victoria Hotel, Sheffield, Monday, 20 January 1947, at 6.15 p.m.)

Swansea Local Section.—Professor W. R. D. Jones, D.Sc.: "Magnesium Alloys." (Metallurgy Department, University College, Cardiff, Thursday, 16 January 1947, at 6.30 p.m.)

MEETINGS OF OTHER SOCIETIES

Chemical Engineering Group.—Dr. W. D. Jones, M.Eng.: "Flame Spraying of Metals and Plastics." (Geological Society, Burlington House, London, W.1, Friday, 17 January 1947, at 5.30 p.m.)

Electrodepositors' Technical Society.—Mr. A. W. Wallbank: "Electroplating Shop Costing." (James Watt Memorial Institute, Great Charles Street, Birmingham, 3, Tuesday, 7 January 1947.)

Electrodepositors' Technical Society.—Coming of Age Dinner and Dance. (Botanical Gardens, Edgbaston, Birmingham, Thursday, 16 January 1947, at 7.30 p.m.)

Electrodepositors' Technical Society.—Dr. G. E. Gardam: "Smoothing Action as a Mechanism in Bright Nickel Plating." (Northampton Polytechnic, St. John Street, London, E.C.1, Monday, 20 January 1947.)

Institute of Physics.—Professor H. S. W. Massey: "Semi-Conductors." (Royal Society, Burlington House, London, W.1, Tuesday, 28 January 1947, at 5.30 p.m.)

News and Announcements

INSTITUTION OF STRUCTURAL ENGINEERS.—Mr. D. V. Pike: "The Application of Aluminium Alloys to Structural Engineering." (Royal Hotel, College Green, Bristol, 1, Saturday, 4 January 1947, for Western Counties Branch; also Great Northern Hotel, Leeds, Wednesday, 15 January 1947, at 6.30 p.m., for Yorkshire Branch.)

MANCHESTER METALLURGICAL SOCIETY.—Mr. E. J. Vaughan, M.Sc., A.R.C.S.: "Modern Analytical Methods." (Engineers' Club, Albert Square, Manchester, Wednesday, 15 January 1947, at 6.30 p.m.)

MANCHESTER METALLURGICAL SOCIETY.—Dr. E. Orowan: "Plastic Working of Metals." (Engineers' Club, Albert Square, Manchester, Wednesday, 29 January 1947, at 6.30 p.m.)

ROYAL AERONAUTICAL SOCIETY, SOUTHAMPTON BRANCH.—Mr. A. Black: "Elementary Metallurgy of Aircraft Materials." (Physics Lecture Theatre, University College, Southampton, Wednesday, 8 January 1947, at 7 p.m.)

SHEFFIELD METALLURGICAL ASSOCIATION.—Dr. J. H. Chesters and Mr. M. W. Thring: "Factors in Open-Hearth Furnace Design." Joint Meeting with Sheffield Society of Engineers and Metallurgists and the Yorkshire Section of the Institute of Fuel. (Lecture Hall, Central Library, Surrey Street, Sheffield, Wednesday, 15 January 1947, at 6.15 p.m.)

APPOINTMENTS REQUIRED AND VACANT.

ASSISTANT EDITOR wanted for an authoritative monthly technical journal, metallurgist preferred; works' experience essential; good prospects. Not over 35. Write in first instance, giving full particulars of educational qualifications, works' experience, salary required, and age, to Box No. 188, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

METALLURGIST required, having sound theoretical knowledge and thorough practical experience, primarily in the heat-treatment of small steel components. Ability to co-operate with production personnel essential. Salary according to age, qualifications, and experience. Application should be made in writing to the Personnel Department, Joseph Lucas, Limited, Great King Street, Birmingham 19.

METALLURGIST required, preferably with a good degree in Metallurgy, Physics, or Chemistry, and with experience in research and development work on copper-base alloys. Preference to applicants aged approximately 30 years. Apply, stating age, qualifications, experience, &c., to Personnel Manager, J. Stone & Co., Ltd., Arklow Road, London, S.E.14.

METALLURGIST required, preferably with a good degree in Metallurgy, Physics, or Chemistry, to undertake research work and development work in connection with light metals. Apply, stating age, qualifications, experience, &c., to Personnel Manager, J. Stone & Co., Ltd., Arklow Road, London, S.E.14.

METALLURGIST, junior, required. Preferably of degree standard, for work on non-ferrous metals and alloys. Apply, stating age, qualifications, experience, &c., to Personnel Manager, J. Stone & Co., Ltd., Arklow Road, London, S.E.14.

METALLURGISTS, 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.C.2.

PRACTICAL METALLOGRAPHER required for the Research Laboratory of radio firm in S.W. London area, to carry out microscopical work on structures of special wires and alloys. Experience of industrial radiography an additional recommendation. Reply, giving full details, to Box 393, L.P.E., 110 St. Martin's Lane, W.C.2, quoting reference "M1."

TECHNICAL SALES or similar commercial appointment required in the non-ferrous metal industry, preferably London area. Gentleman, aged 30, with 12 years' wide commercial and sales experience of the trade and a sound knowledge of metallurgy, seeks permanent post. Box No. 187, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION will shortly have a vacancy for a metallurgist as CHIEF OFFICER of their LIAISON AND TECHNICAL SERVICE DEPARTMENT. Candidates, who must be British subjects, should hold a University degree or its equivalent and have had some years' experience in the non-ferrous metals industry. Salary up to £1000 p.a., depending on age, qualifications, and experience. Applications should reach the Secretary, British Non-Ferrous Metals Research Association, 81–91 Euston Street, London, N.W.1, not later than 11th January 1947.

EFFECT OF IRON AND SILICON IMPURITIES ON THE TENSILE PROPERTIES AND HEAT-TREATMENT CHARACTERISTICS OF SAND-CAST ALUMINIUM–10 PER CENT. MAGNESIUM ALLOY TEST BARS.* 1042

By R. T. PARKER,† Ph.D., B.Sc., A.R.S.M., Member, (Miss) G. M. L. COX,‡ B.A., Student Member, and A. N. TURNER,‡ B.Sc., A.R.S.M., Student Member.

Summary.

It has been observed in the past that, under commercial conditions, sand-cast test bars of aluminium–10% magnesium alloy have variable tensile properties, these variations occurring both within and between groups of bars cast from different melts. In the investigation described in this paper the differences between test bars prepared from the same melts of the alloy were almost eliminated by careful foundry technique, those remaining occurring only with metal of greater impurity content.

To explain the differences between melts, groups of D.T.D. test bars were cast in dry sand from melts containing 0·10–0·75% iron with 0·10–0·50% silicon. It was found that, while an increase of iron has a slightly beneficial effect, an increase of silicon drastically reduces the ultimate tensile strength and elongation. The proof stress value is slightly increased with increasing total impurity content.

The optimum tensile properties of an alloy containing 0·10% iron and 0·10% silicon appear to be approx. 25 tons/sq.in. ultimate tensile strength and 35% elongation on 2 in., these values being obtained from test bars solidified under an air pressure of 100 lb./sq.in.

A comparison of low- and high-purity aluminium–10% magnesium alloy test bars under varying heat-treatment conditions showed that the high-purity alloy is much the more sensitive to differences in solution time and temperature.

I.—Introduction.

During the past few years much interest has been shown in the aluminium-base alloys containing magnesium and several alloys of this type have become deservedly popular, as they have good mechanical properties and corrosion-resistance. This is particularly true of the casting alloy which contains 10% magnesium. The specified minimum mechanical properties of test bars cast in dry sand in this alloy to specification D.T.D. 300A are: ultimate tensile strength 16 tons/sq.in. and elongation 7% on 2 in., but it has been found that values far in excess of these minima can be obtained. The chief disadvantages of these aluminium-base alloys are in the difficulties caused in working, and particularly in casting, by the presence of magnesium.

* Manuscript received 2 July 1946.
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Much data on this matter are given in an article [1] on an attempt to replace the standard D.T.D. test bar by one which gives properties more indicative of the quality of the metal and less dependent on outside factors such as the technique of the operator. In this article typical results from four sets of four D.T.D. test bars are quoted (see Table I) to show that the scatter between bars in each set was so great that

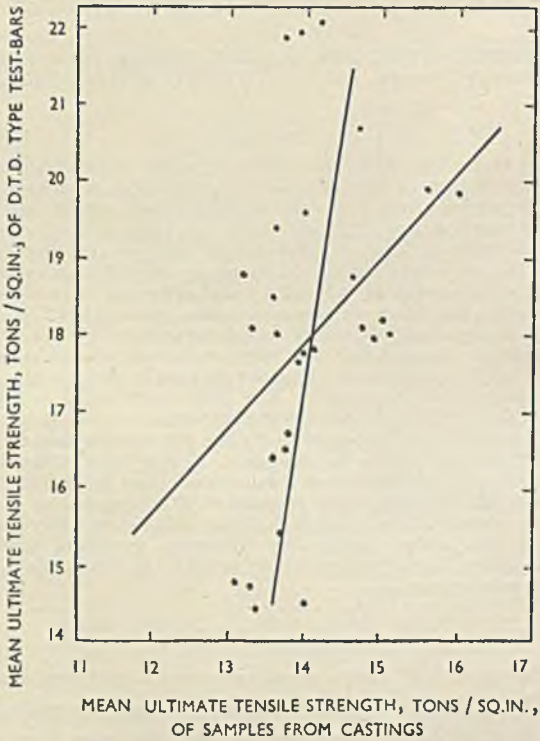

Fig. 1.—Relationship Between D.T.D. Test Bars and Test Pieces Cut from Castings from the Same Melts.

comparison of the sets is difficult. The difference between the highest and lowest values given in Table I is even more remarkable, however, as they range from 14·0 to 22·1 tons/sq.in. ultimate tensile strength and 6–19% elongation on 2 in. Some more data given in the article confirm this range of mechanical properties; thus, Fig. 1 (reproduced from the article mentioned) shows the relation between the properties of D.T.D. test bars and of test pieces taken from sectioned castings made from the same melts. Although they are quoted as " mean values of the four

test bars," it will be seen that the range of ultimate tensile strength is from about 14 to about 22 tons/sq.in. It should be noted that when the results of testing an alternative type of test piece were obtained in the same way, the range was still from about 16½ to 23 tons/sq.in.

The possibility of obtaining strengths of 23 tons/sq.in., coupled with a high elongation, from a sand-cast alloy is attractive and the investigation described in this paper was undertaken to determine under what conditions consistently high values for the properties are realizable with the aluminium alloy containing 10% magnesium.

In considering the wide range of properties obtainable with the alloy, a number of factors come to mind as being possibly responsible. For

TABLE I.—*Typical Results from Sets of Four D.T.D. Test Bars. Standard Deviation of Test Bar* 1·72 *tons/sq.in.*

Property.	Melt.			
	1.	2.	3.	4.
Ultimate tensile stress, tons/sq.in.	15·7	14·0	22·1	17·8
	17·6	17·0	20·7	18·3
	19·2	16·7	17·7	20·2
	16·5	18·0	21·8	16·3
Elongation, %	6	6	19	7
	7	8	16	6
	10	8	11	10
	7	10	10	7

instance, it is well known that the alloy is not easy to handle in the foundry. The fairly high magnesium content of 10% means that the molten alloy is easily oxidized, and this is accompanied by loss of magnesium and the danger of entrapped oxide films in the casting. For this reason overheating must be avoided and a special melting technique used to keep oxidation at a minimum and to clean the alloy of the oxide skins which are unavoidably formed. Another feature of the alloy is that on casting into a sand mould reaction may take place between the metal and moisture in the mould. This is countered in practice by using inhibited sands or by inhibition of the metal itself. If this is not done, the results of "sand attack" are oxidation of part of the surface of the casting and absorption of gas. The molten metal may also absorb gas from the atmosphere. In either case, dissolved gas leads to unsoundness in the casting. Shrinkage unsoundness may be caused by poor feeding which, in turn, may be due either to composition differences, incorrect casting temperature, or hindrance offered

by oxide films. Composition and heat-treatment also influence the properties of a perfectly sound casting, free from oxide films.

The factors which possibly affect the strength of the cast alloy may be summarized as:

(i) Gas porosity.
(ii) Shrinkage porosity.
(iii) Presence of oxide films.
(iv) Composition.
(v) Heat-treatment variables.

In assessing the relative importance of these factors, it was considered that careful foundry technique would eliminate gas porosity and oxide films. Such a technique was developed and, while it was rigorously adhered to, consistent properties were obtained. Shrinkage porosity was minimized, although not completely eliminated, by using D.T.D.-type sand moulds which incorporate a fairly large proportion of "head" to test bar, standardizing feeding conditions.

Thus, two factors were left to be investigated, and their discussion forms two main divisions of this paper:

The effect of variation in composition on the tensile properties, using a single heat-treatment technique. The two impurities most commonly met with in practice are iron and silicon, and it is with these that the first part of this paper principally deals. Specification D.T.D. 300A permits a variation in magnesium of 9·5–11·0%, and a brief preliminary study was made to determine the effect of variation of magnesium within this range.

The effect of heat-treatment variables on the tensile properties. Two alloys were used containing large and small amounts of iron plus silicon, respectively.

A brief study was also made of some aspects of the influence of unsoundness on the tensile properties. This is dealt with in Part IV of the paper.

It may be useful here to interpolate a summary of the limits of composition and heat-treatment required by specification D.T.D. 300A, and the minimum mechanical properties which may be expected from the alloy. They are:

(*a*) *Composition.*

Magnesium 9·5–11·0%.
Copper $\ngtr$0·15%.
Silicon $\ngtr$0·35%.
Iron $\ngtr$0·35%.

(*b*) *Heat-Treatment Conditions.*

Heat-treated at 425°–435° C. for not less than 8 hr. Quenched in oil at not more than 160° C. or allowed to cool in the furnace to 385°–395° C. and then oil-quenched. The castings shall be allowed to remain in the oil for not more than 1 hr. and then quenched in water or cooled in air.

(*c*) *Minimum Mechanical Properties.*

Dry-sand test bars: ultimate tensile strength $\not<$16 tons/sq.in.; elongation $\not<$7%.

Green-sand test bars: ultimate tensile strength $\not<$17 tons/sq.in.; elongation $\not<$7%.

II.—Effect of Variation of Iron and Silicon on the Structure and Tensile Properties of Dry-Sand-Cast Aluminium–10% Magnesium Alloy.

1.—*Method of Investigation.*

In brief, the method was to cast batches containing five D.T.D. test bars in each of 21 compositions, and then to give them a standard heat-treatment within the limits of specification D.T.D. 300A.

(a) *Test-Bar Moulds.*

A fresh consignment of sand was obtained for the work and moulds of the D.T.D.-type were prepared in tubes 4 in. in dia. and 12 in. long. Moulds thus prepared for the next day's use were dried overnight by baking for 8 hr. at 300° C., and were cooled to room temperature some hours before casting took place. During the casting campaign, the consignment of sand was re-used several times, but no addition other than water was made and no effect on the results was detected. The properties of the sand in the green condition and after baking were:

	Green.	Baked.
Permeability	60 AFA units.	47·6 AFA units.
Compression strength	7½ lb./sq.in.	405–446 lb./sq.in.
Moisture	3·2%.	Nil.
Boric acid	...	5·4%.

(b) *Raw Materials, Melting, and Casting.*

Aluminium ingot of 99·85% purity, magnesium ingot of 99·8% purity, and commercial hardeners containing 4% iron and 12% silicon were used. All the melts were made from these virgin materials and in no case was metal remelted after the alloy had been prepared.

As previous experience had shown the difficulty of producing test bars giving consistent results under laboratory conditions from metal

ladled out of a large furnace, and since, in addition, small melts only were required for this part of the investigation, each melt was made in a refractory crucible of approx. 10-lb. capacity. To speed up the work, an electrically-heated melting furnace was used as a muffle; it accommodated four crucibles at a time. In this way, four compositions could be prepared at once, this occupying one day. The charges of aluminium

TABLE II.—*Composition and Tensile Properties of Aluminium–10% Magnesium Alloys with Varying Iron and Silicon Contents.*

(Figures are Mean Values of Properties of Five Test Bars in Each Group.)

Identification.	Composition, %.			Tensile Properties.			
	Fe.	Si.	Mg.	0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Standard Deviation of U.T.S. Values.[a]	Elongation, % on 2 in.
BNL .	0·10	0·10	8·90	9·8	18·1	...	12½
BNM .	0·10	0·12	12·20	12·20	24·2	...	21
BNN .	0·11	0·10	14·80	...	14·9	...	1¾
BNQ .	0·10	0·07	10·50	11·27	24·1	0·21	26½
BNR .	0·37	0·22	10·30	11·30	21·4 *	1·11	17½ *
BNS .	0·38	0·07	10·50	11·40	24·1 †	4·75	24½ †
BNT .	0·10	0·34	11·30	11·00	18·7	0·51	13
BNW .	0·37	0·37	10·40	10·60	17·5	0·32	10½
BNX .	0·11	0·26	10·80	10·85	19·7	0·09	16½
BNY .	0·22	0·29	10·70	10·90	19·6	0·29	15½
BOJ .	0·21	0·11	10·40	11·25	24·2	0·44	26
BOK .	0·17	0·36	10·20	10·79	17·9	0·43	11½
BOL .	0·54	0·15	10·70	11·36	23·3	0·25	20½
BOM .	0·55	0·29	10·40	11·05	20·8 ‡	2·67	17 ‡
BON .	0·52	0·37	11·10	11·17	19·1 *	1·21	15½
BOO .	0·54	0·47	10·90	10·85	18·05	0·35	10
BOP .	0·39	0·49	11·10	10·78	17·25	0·48	9¾
BOQ .	0·25	0·48	10·60	10·34	15·95	0·11	7½
BOR .	0·12	0·47	10·70	10·49	15·95	0·13	7
BOS .	0·75	0·14	11·70	12·15	22·20	1·20	13½
BPH .	0·77	0·52	11·10	10·26	13·50	0·61	2½

[a] Standard deviation of all 5 bars in each group.
* Mean 4 test bar values.
† „ 3 „ „
‡ „ 2 „ „

in the crucibles were ready to receive the magnesium additions early in the working day, after which the melts were thoroughly stirred and treated with chlorine to ensure homogeneity and cleanness. The metal was at all times covered by an adequate layer of a proprietary chloride–fluoride flux to protect the molten metal from oxidation, and any addition of metal to the crucible was dusted with the same flux. The flux cover was removed before casting (without the aid of any thickening agent), and the melt was allowed to remain protected only by its oxide

skin. No oxidation in excess of that to be expected from a magnesium-free metal was noticed at this stage, the atmosphere above the metal surface probably being rendered inert by the evolution of gases from the flux-impregnated crucible. Great care was taken to ensure that the metal did not become overheated, and the temperature of the melts rarely exceeded 730° C.

The first of the five test bars in each composition was cast at 688° C.,

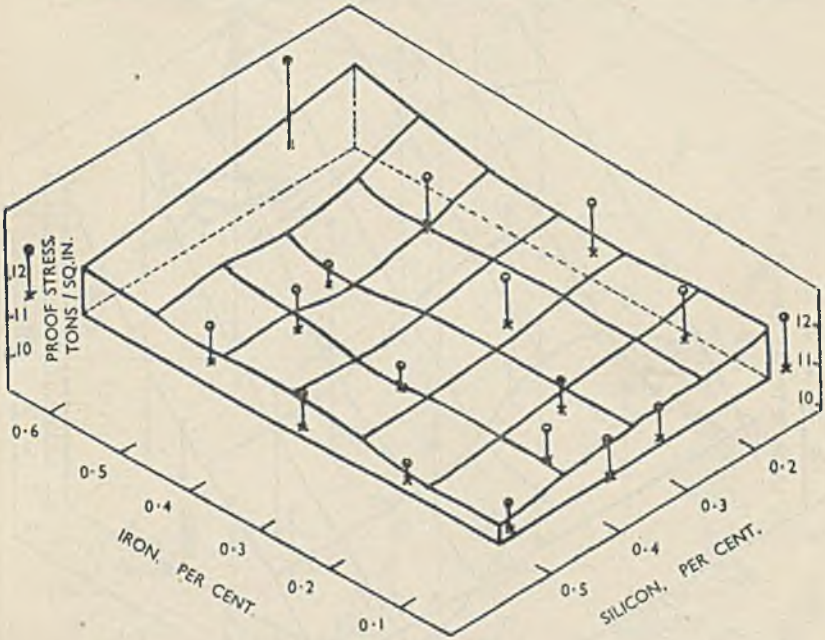

FIG. 2.—0·1% Proof Stress Values of Aluminium–10% Magnesium Alloys Containing Variable Iron and Silicon Contents.

the casting temperature of the subsequent bars decreasing steadily, and the last bar being cast at approx. 665° C. The metal was poured direct from the crucible, the lip of which was carefully cleaned before each mould was filled. One operator poured while another tilted the mould to about 45° and gradually brought it to the vertical position after the test length had been filled. The whole mould, including the head, took about 15 sec. to fill, the test length taking about 5 sec. of this time. Care was taken to fill the moulds steadily, without breaking the metal stream and without splashing.

The alloys prepared were intended to contain 10·5% magnesium, with combinations of 0·10, 0·20, 0·30, 0·50, and 0·75% iron, with 0·10,

0·25, 0·35, and 0·5% silicon. In addition, other alloys were cast to contain low iron and silicon contents, with 9, 12, and 15% magnesium. The results of analyses are given in Table II.

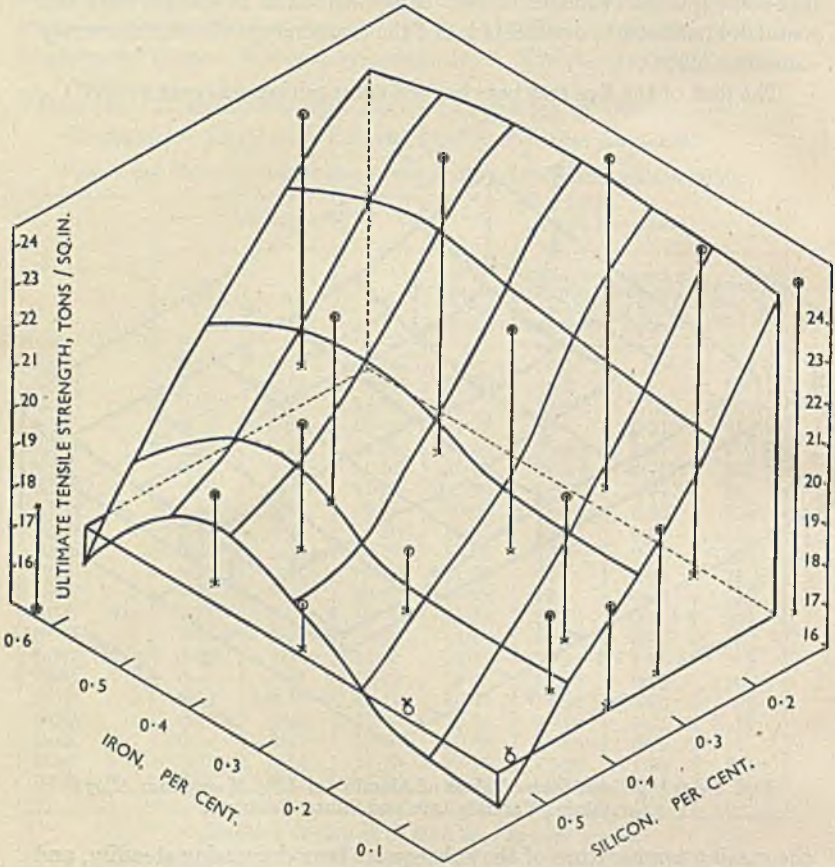

FIG. 3.—Ultimate Tensile Strength Values of Aluminium–10% Magnesium Alloys with Varying Iron and Silicon Contents.

(c) *Heat-Treatment.*

The heads were removed from the test bars, which were then heat-treated, in a small number of batches, in a high-speed air-circulating furnace at 430° C. for 16 hr. The temperature was decreased over a further period of 4 hr. from 430° to 420° C., after which the bars were quenched in oil at 150° C., kept at that temperature for ½ hr., and air-cooled.

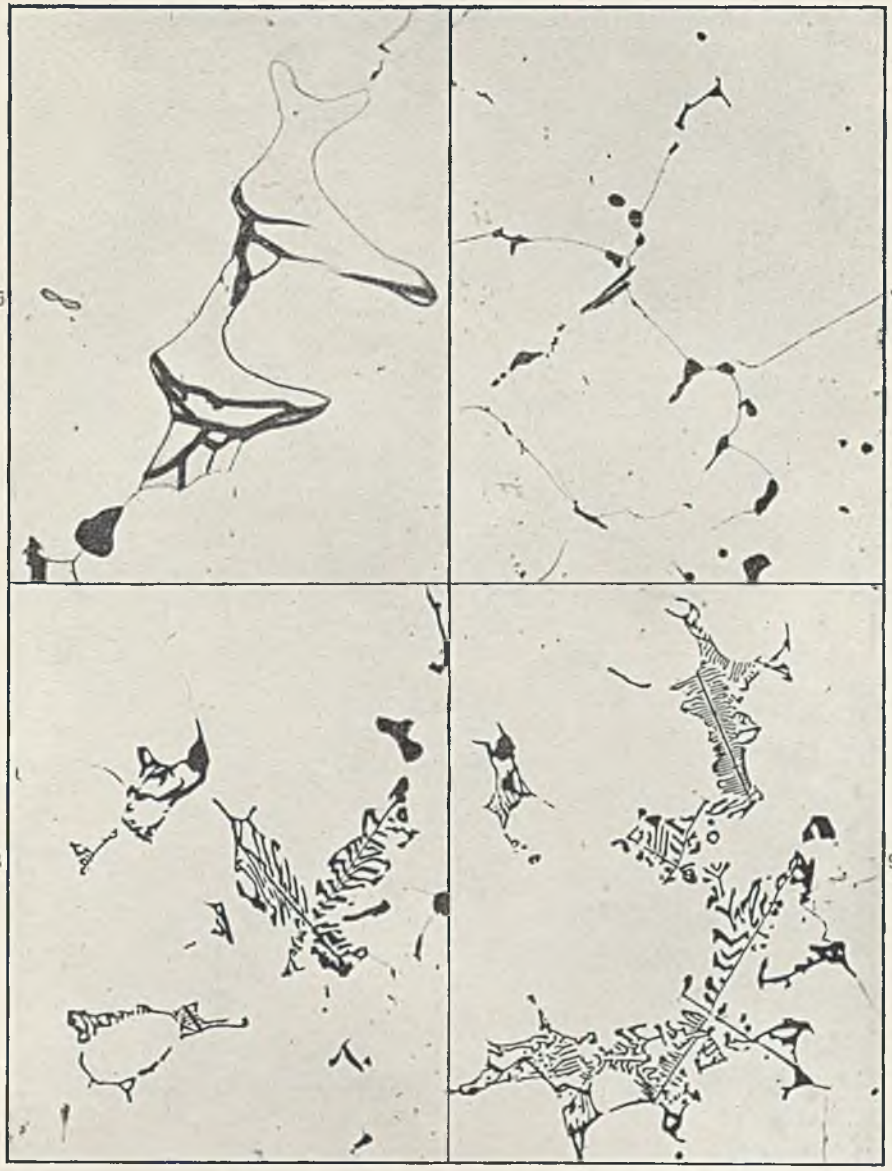

FIG. 6.—Mg_2Al_3 Constituent, Showing Black Bands. × 450.
FIG. 7.—Alloy Containing Iron 0·1 and Silicon 0·1%, Showing Small Amounts of Constituents. × 150.
FIG. 8.—Alloy Containing Iron 0·1 and Silicon 0·2%. × 150.
FIG. 9.—Alloy Containing Iron 0·1 and Silicon 0·3%. × 150.

[*To face p.* 182.

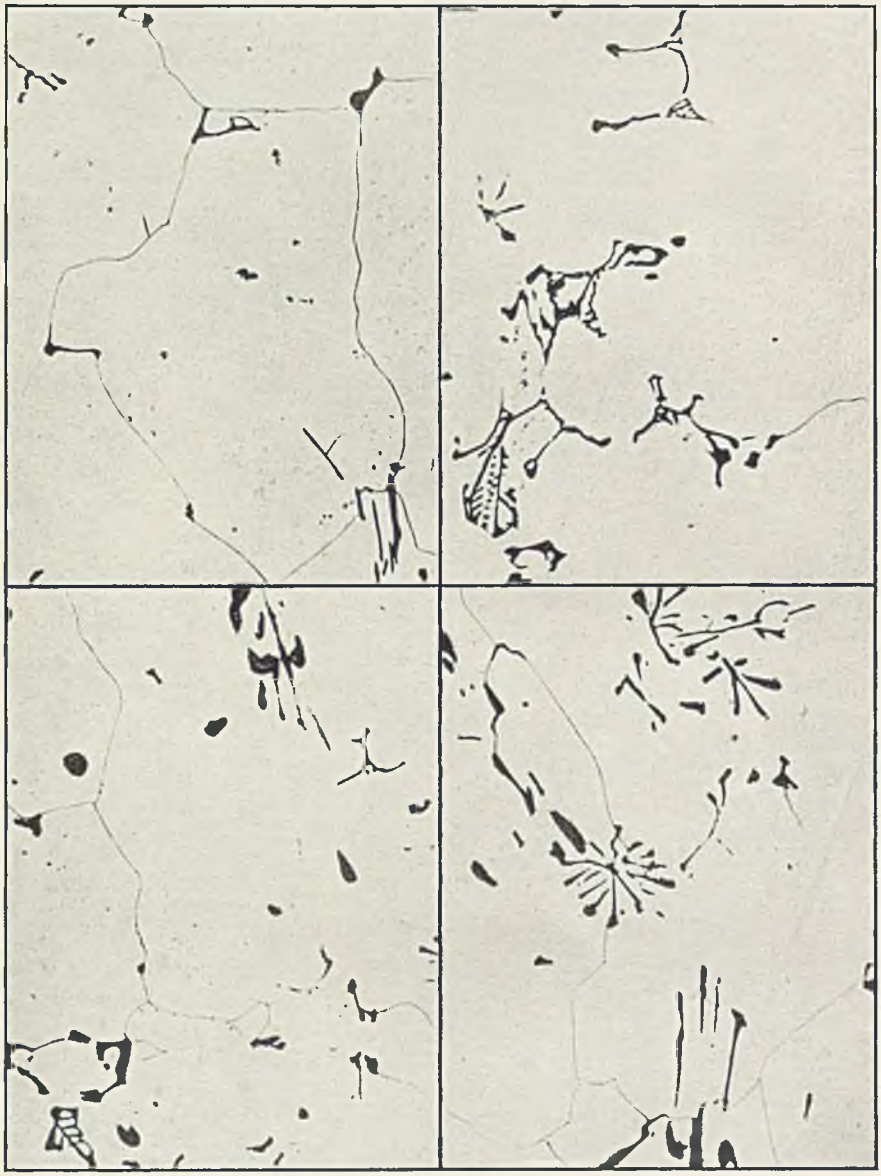

FIG. 10.—Alloy Containing Iron 0·2 and Silicon 0·1%. Small needles of $FeAl_3$. × 150.
FIG. 11.—Alloy Containing Iron 0·2 and Silicon 0·25%. × 150.
FIG. 12.—Alloy Containing Iron 0·35 and Silicon 0·25%. × 150.
FIG. 13.—Alloy Containing Iron 0·5 and Silicon 0·1%, Showing Two Forms of $FeAl_3$—Parallel Plates and Stars. × 150.

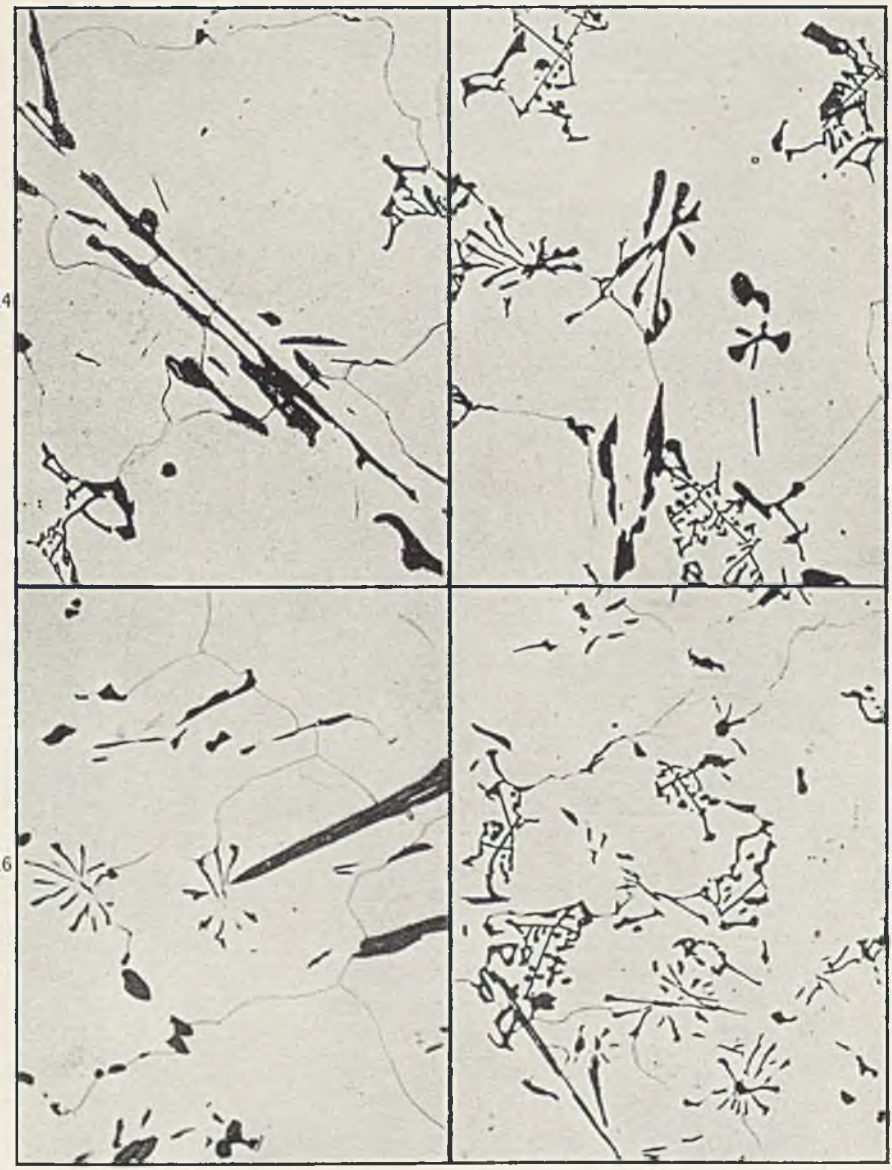

FIG. 14.—Alloy Containing Iron 0·5 and Silicon 0·2%, Showing Large Plates of $FeAl_3$. × 150.
FIG. 15.—Alloy Containing Iron 0·5 and Silicon 0·35%. × 150.
FIG. 16.—Alloy Containing Iron 0·75 and Silicon 0·1%, Showing Large Amounts of $FeAl_3$ Variously Orientated. × 150.
FIG. 17.—Alloy Containing Iron 0·75 and Silicon 0·5%. The Mg_2Si constituent appears around the grain boundaries. In some cases plates of $FeAl_3$ cut through the Mg_2Si showing that the former is the first to separate.

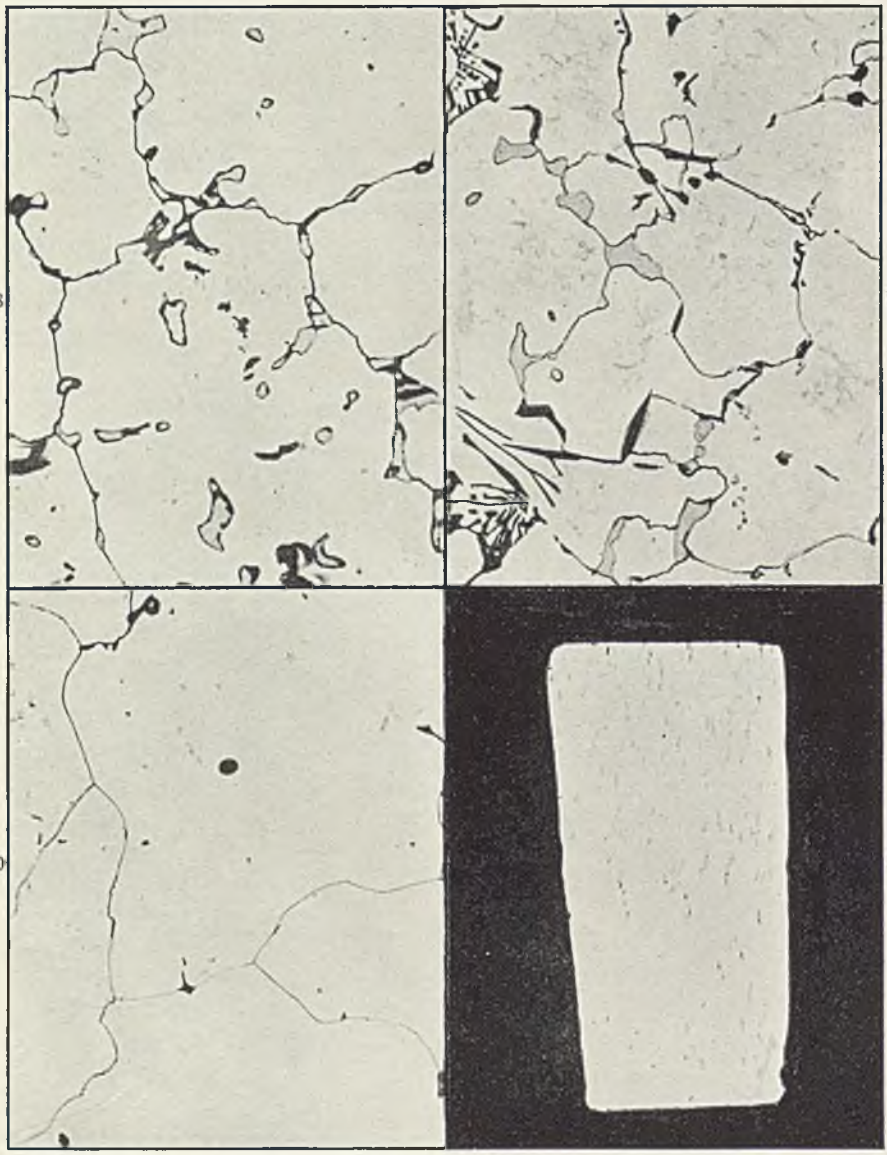

FIG. 18.—High-Purity Un-Heat-Treated Metal, Showing Network of Mg_2Al_3, Grey, and Particles Within the Grains. × 150.

FIG. 19.—Low-Purity Un-Heat-Treated Metal, Showing Mg_2Al_3 at Grain Boundaries and Some Precipitation Within the Grains Along Mosaic Boundaries. × 150.

FIG. 20.—High-Purity Metal Quenched in Oil at 170° C., Showing Continuous Fine Grain Boundaries. × 150.

FIG. 21.—Transverse Banded Unsoundness in Test Bar in Alloy Containing Iron 0·2 and Silicon 0·1%. × 2½.

The bars were machined to standard 0·564 in.-dia. D.T.D. test pieces, and tested approx. 1 week after heat-treatment.

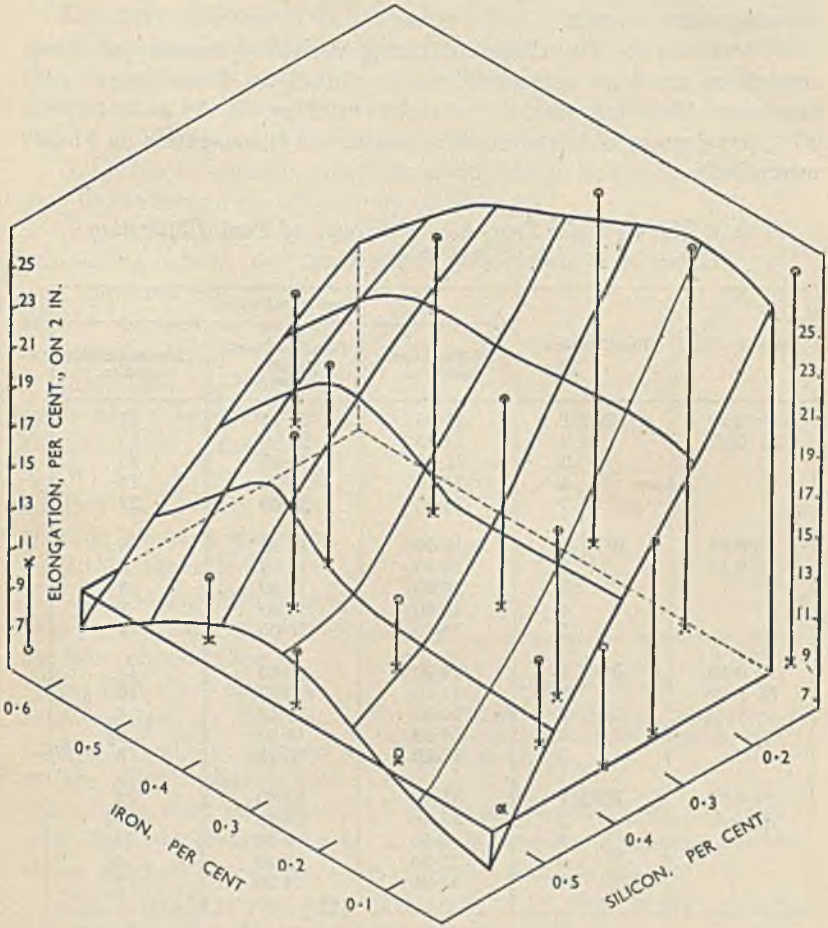

FIG. 4.—Elongation Values of Aluminium–10% Magnesium Alloys with Varying Iron and Silicon Contents.

2.—*Results of Tensile Tests.*

The mean values of the tensile test results, and the corresponding analyses of the alloys, are given in Table II.

The variation in properties caused by increasing the magnesium from 10½ to 12% was small, being of the order of 0·5 tons/sq.in. ultimate

tensile strength. Thus, the results obtained in the main part of the investigation, all of which with one exception were covered by the range 10·20–11·30% were not significantly affected by minor variations in the magnesium content.

The results for the alloys containing variable quantities of iron and silicon are best appreciated when plotted as three-dimensional diagrams. This information is given in Figs. 2, 3, and 4 for 0·1% proof stress, ultimate tensile strength, and % elongation on 2 in., respectively.

TABLE III.—*Tensile Properties of Groups of Bars Illustrating Degree of Reproducibility Encountered.*

Impurity, %.	Identification.	Tensile Properties.		
		0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.
Fe 0·10 Si 0·07	BNQ 1	11·05	24·15	23
	2	11·35	23·80	26
	3	11·40	24·35	29
	4	11·20	24·30	25
	5	11·35	24·00	28
Fe 0·25 Si 0·48	BOQ 1	10·00	15·90	8
	2	10·40	16·05	8
	3	10·50	15·90	8
	4	10·40	15·80	7
	5	10·40	16·05	7
Fe 0·55 Si 0·29	BOM 1	11·00	20·80	18
	2	11·10	20·85	16
	3	10·95	15·15	4
	4	11·00	16·80	6½
	5	11·10	16·10	6
Fe 0·38 Si 0·07	BNS 1	11·40	23·60	22
	2	11·40	24·55	26½
	3	11·40	24·20	25
	4	11·35	17·20	4½
	5	11·25	14·20	2

In considering some of the results it was observed that in some batches a number of "anomalous" values were obtained, and in calculating the mean values for these particular batches these anomalous results were ignored. This applies to a total of 7 bars, from 4 batches. It was considered that these might result principally from mechanical defects such as dross inclusions, cold shuts, or hot tears, &c. These effects were excluded, however, from the bulk of the bars made from metal of higher purity and were usually confined to the last bar of a

batch. The effect is well demonstrated in some batches, for instance in group "BNS" in which two values considerably below the average were obtained (see Table III).

The three-dimensional diagrams have been plotted with the appropriate specification limit value forming the basal plane in each case, so that in general the figures represent properties in excess of the specification minima. The observations detailed below may be made on the results, and they are clearly demonstrated by the figures.

(i) At low silicon concentrations (about 0·10%) iron up to 0·75% has very little effect on the ultimate tensile strength.

(ii) At high silicon concentrations (about 0·50%) iron improves the ultimate tensile strength as it increases up to 0·5%.

(iii) The observations made above apply also to the elongation values.

(iv) At all iron concentrations the effect of increasing silicon is to reduce drastically the ultimate tensile strength and elongation values, particularly when the iron content is low.

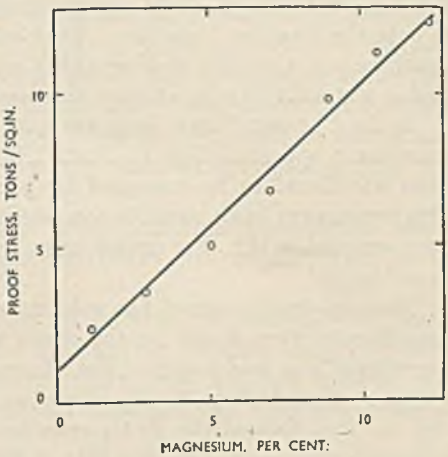

Fig. 5.—Relationship Between Magnesium Content and Proof Stress of Aluminium–Magnesium Alloys.

(v) The effect of iron in counteracting the bad influence of silicon depends on the silicon content, the effect being most marked at high concentrations of silicon. As, however, the iron content exceeds a certain amount (dependent on the silicon content) the values of the properties decrease rapidly.

(vi) Even the poorest properties, given by an alloy containing 0·5% silicon and 0·1% iron, approach specification minima.

A further observation may be made when the individual results of the various batches of five bars are considered (see standard deviation values in Table II and examples in Table III):

(vii) The individual variation in any one batch is surprisingly small with metal which meets the D.T.D. 300A analytical requirements. Alloys of higher impurity content may show more scatter.

Consideration of the data presented for the proof stress enables it to be stated that:

(viii) The effect of the iron and silicon impurities on the proof stress is small, but increasing total impurities tend to increase the proof stress. The change is in no way comparable in magnitude with that brought about with the other two tensile properties. Fig. 5 gives data from some further work on the effect of magnesium content on proof stress, from which it can be seen that the proof stress varies almost linearly with magnesium content from 0 to 12%.

3.—*Micro-Examination of the Alloys.*

Micro-sections were taken from the upper ends of the heat-treated test bars, and were polished to show a longitudinal central face, reaching to near the "as cast" surface. They were examined in the unetched condition and also after etching with a solution of 9% ortho-phosphoric acid in water for 30 min. at room temperature.

In the "as cast" state large amounts of the magnesium–aluminium constituent appeared (Fig. 18, Plate XII), which at greater magnifications was found to be traversed by black bands (Fig. 6, Plate IX). This constituent has a variable composition and different formulæ have been assigned to it.[2] For convenience, in this paper it will be referred to as Mg_2Al_3.

Heat-treatment caused the solution of the Mg_2Al_3, and only two constituents were found in the series of alloys containing varying amounts of iron and silicon. The silicon combined preferentially with the magnesium to form Mg_2Si, which has little solubility in aluminium, and the iron formed the $FeAl_3$ constituent. The Mg_2Si appeared in a characteristic script-like form (Fig. 9, Plate IX) and, being bright blue in the unetched condition, was easily distinguished. The $FeAl_3$ occurred in plates which were encountered in two habits, parallel and in stellate clusters (Figs. 13 and 16, Plates X and XI); these, however, were probably only different sections through a single form. The Mg_2Si occurred on and spread from grain boundaries (Fig. 8, Plate IX), while the $FeAl_3$ plates were found within grains or cutting across boundaries (Figs. 13 and 16, Plates X and XI). In some cases the $FeAl_3$ plates cut across the Mg_2Si (Fig. 17, Plate XI), indicating that the plates separated out first from the melt.

Increases in iron and silicon content produced obvious increases in the amounts of the corresponding constituents. In the high-purity alloy (Fig. 7, Plate IX) there was very little constituent; the addition of a small amount of silicon up to 0·2% caused the immediate appearance of Mg_2Si (Fig. 8, Plate IX). Extremely fine needles of $FeAl_3$ were formed on the addition of 0·2% iron (Fig. 10, Plate X) and these became larger with increasing amounts of iron (Figs. 12, 14, 16, Plates

X and XI). There was a certain interdependence in the amounts of the two constituents which occurred with increasing iron and silicon contents. Where the silicon content was constant, increase of the iron suppressed the amount of Mg_2Si present (see Figs. 8, 11, and 12, Plates IX and X, and also Figs. 9 and 15, Plates IX and XI). The increase of silicon with a constant iron content had no apparent effect on the amount or form of the iron constituent.

The variation in the iron and silicon content had a marked effect on the appearance of the fractures of the broken test pieces. That of the high-purity material was white and finely crystalline and increases in the iron content caused coarsening in this crystalline appearance. The addition of as little as 0·2% silicon turned the fractures blue and those of the specimens containing 0·35 and 0·50% silicon were very blue and rugged. The addition of iron modified this appearance somewhat. The specimens containing 0·75% iron and 0·50% silicon had fractures markedly different from the rest, being mottled, light in colour and glassy; the microstructure was also finer than expected (Fig. 17, Plate XI).

The grain-size of the range of alloys was approximately the same, that calculated from the micro-specimens was of the order of 25 grains/sq.mm.

Unsoundness in the specimens occurred in well-defined bands perpendicular to the axis of the test bar (Fig. 21, Plate XII). In some cases this unsoundness was more marked near the cast surface. Increasing the impurities increased the soundness, this being more marked with iron.

III.—Effect of Heat-Treatment Conditions on the Structure and Tensile Properties of Dry-Sand-Cast Aluminium–10% Magnesium Alloy.

Specification D.T.D. 300A for aluminium–10% magnesium alloy requires for the heat-treatment of the alloy:

(i) Solution treatment at 425°–435° C. for $\not<$16 hr., followed by:

(ii) Quenching in oil at $\not>$160° C., or:

(ii(*a*)) Cooling in the furnace to 385°–395° C. and quenching in oil at $\not>$160° C.

(iii) The castings should remain in oil at $\not>$160° C. for not more than 60 min.

Tests were therefore commenced to determine the effect on the tensile properties of the undermentioned heat-treatment variables:

(i) The time and temperature of the solution treatment.
(ii) The temperature and nature of the quenching medium.
(iii) The time and temperature of the "precipitation treatment."

The effect of decreasing the solution temperature prior to quenching was not studied.

1.—*Method of Investigation.*

(*a*) *Material.*

100 test bars were prepared in each of two qualities of material, one batch being of high purity and the other of low purity. Both batches

TABLE IV.—*Analytical Data of Groups of Test Bars "BNZ" and "BOT" and Typical Properties to be Expected of Them.*
(100 Bars, *i.e.*, 20 Lots of 5 Bars Each, in Each Group.)

A.—Analyses.

	BNZ; High Purity.		BOT; Low Purity.	
	Iron, %.	Silicon, %.	Iron, %.	Silicon, %.
Range . . .	0·10–0·15	0·09–0·14	0·36–0·47	0·22–0·395
Average . . .	0·132	0·112	0·395	0·320
Standard deviation .	0·016	0·015	0·030	0·033

*B.—Mechanical Properties.**

	BNZ; High Purity.		BOT; Low Purity.	
	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.
Range . . .	22·5–24·0	22–26	17·0–20·75	9–18
Average . . .	23·5	24	18·0	13
Standard deviation .	0·25	1	1	3

* The average properties are those to be expected of alloys of the "average" compositions of "*A*" above.

were made from virgin materials in lots of five bars at a time, using the same technique as that described in the first part of the paper. Each lot was analysed and the data given in Table IV show the mean values of iron and silicon content together with the deviations from these mean values. From these values the probable tensile properties were deduced by reference to the work described in the first part of the paper. It should be noted that while the high-purity alloy could be depended on to give results not affected to any marked extent by composition

variations, the range of composition of the low-purity material was such as to obscure, in some cases, changes in properties brought about by heat-treatment variations.

(*b*) *Heat-Treatment.*

Solution treatment was carried out in a high-speed air-circulating furnace, with a temperature control of approx. $\pm 1°$ C. In all cases the two purities of metal were heat-treated together.

Heavy lubricating oil was used for quenching, the tank containing about 20 gall.

(i) *Effect of Variations in Solution Time and Temperature.* Specimens were treated at 410°, 425°, 435°, and 450° C. for times varying from 2 to 24 hr. They were quenched in oil at 150° C. and kept at 150° C. for 30 min.

(ii) *Effect of Medium and Temperature of Quenching.* The specimens were treated at 430° C. for 16 hr., the temperature being decreased to 420° C. over a further period of 4 hr. They were quenched in oil at temperatures from room temperature (20° C.) to 170° C., and quenched in water at room temperature and 100° C. In each case specimens were kept at their quenching temperature for 30 min. Specimens were also cooled in air and in the furnace.

(iii) *Effect of Time of Low-Temperature Treatment at* 150° C. The solution treatment was similar to that described in (ii) above. The temperature of the oil before quenching was 135° C.; it increased to 156° C. on quenching and was thereafter kept between 148° and 152° C. for times up to 96 min.

2.—*Results of Tensile Tests.*

Tests were carried out in duplicate, but in some of the later work only one proof stress value per pair of results was obtained in view of the remarkable consistency of the values. The results are plotted graphically in Figs. 22–27.

(*a*) *Effect of Variations in Solution Time and Temperature* (*see Figs.* 22–25). The solution treatment of the aluminium–10% magnesium alloy between 410° and 435° C. led to the solution of the Mg_2Al_3. (See "Examination of Microstructures," p. 193.) As might be expected, the degree of solution by heat-treatment increased with time and temperature, the tensile properties varying with the amount remaining undissolved. Elongation was affected more than ultimate tensile strength, and small amounts of residual constituent, which made no significant difference to the ultimate tensile strength, caused a marked reduction in the elongation.

In all cases the 0·1% proof stress was only slightly affected, the very low ultimate tensile strength and percentage elongation values associated with the presence of undissolved Mg_2Al_3 being accompanied by a somewhat lower proof stress value.

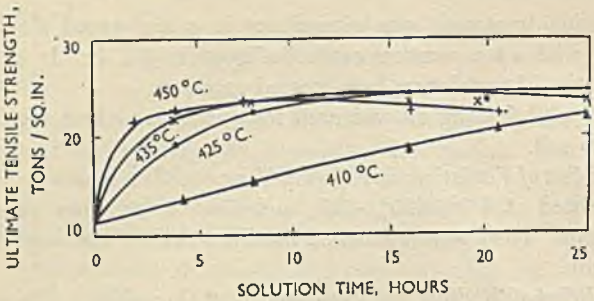

FIG. 22.—Effect of Variation of Solution Time and Temperature on the Ultimate Tensile Strength of Aluminium–10% Magnesium Alloy of High Purity (BNZ Series).

The outstanding difference between the two alloys was in their relative susceptibility to solution treatment. The improvement brought about in the low-purity alloy by the increased solution of the Mg_2Al_3

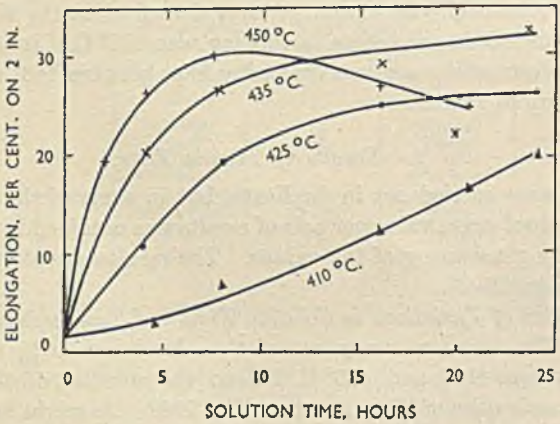

FIG. 23.—Effect of Variation of Solution Time and Temperature on the Elongation Value of Aluminium–10% Magnesium Alloy of High Purity (BNZ Series).

was only of the same order as the scatter caused by variations in composition.

(*b*) *Effect of Medium and Temperature of Quenching* (*see Fig.* 26).

The effect on the microstructure of increasing the temperature of quenching and decreasing the rate of cooling was to increase the amount and size of the reprecipitated Mg_2Al_3. This was not accompanied by a change in tensile properties except in the case of air- and furnace-cooling,

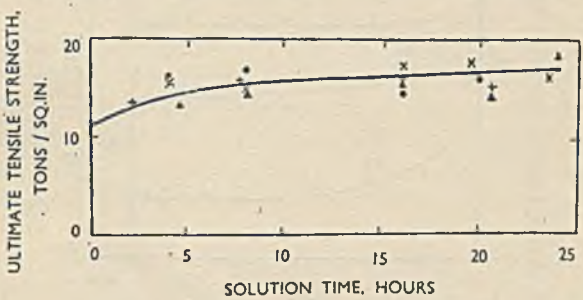

Fig. 24.

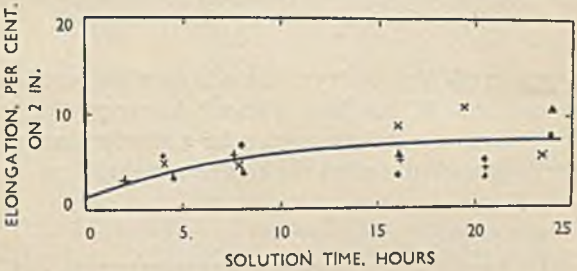

Fig. 25.

Figs. 24 and 25.—Effects of Variation of Time and Temperature of Solution Treatment of Aluminium–10% Magnesium Alloy of Low Purity (BOT Series): Fig. 24.—Ultimate Tensile Strength; Fig. 25.—Elongation.

Key to Figs. 24 and 25.

▲ 410° C. ● 425° C. × 435° C. + 450° C.

which reduced the properties to 11·3, 21·2, and 14 and 10·6, 14·2, and 2 (for 0·1% proof stress, ultimate tensile strength, and percentage elongation on 2 in., respectively) for the high-purity alloy.

There appeared to be a very slight increase in properties at the low quenching temperatures, but quenching in hot and cold water led to no further improvement.

(c) *Effect of Time of "Low-Temperature" Treatment at* 150° C. (*see Fig.* 27). It is considered that the time for which specimens were held at 150° C. had no significant effect on the tensile properties. The apparent decrease in properties obtained by "ageing" for periods of

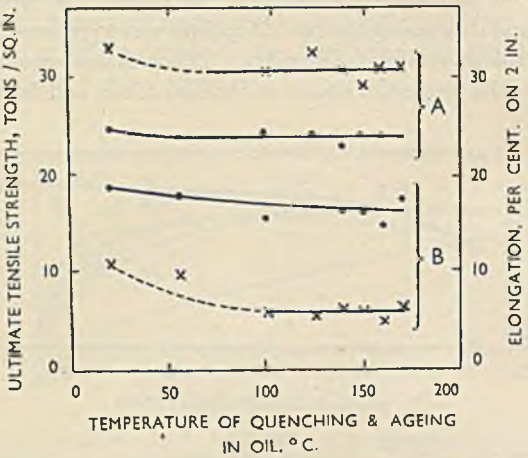

FIG. 26.—Effect of Temperature of Quenching and Ageing on the Tensile Properties of Aluminium–10% Magnesium Alloy.

less than 5 min. in the high-purity material is more likely to be due to an insufficient quench. It has been shown,[3] however, that ageing at 150° C. for 30 days or more and ageing for a shorter time at a higher temperature does markedly affect the hardness of the alloy.

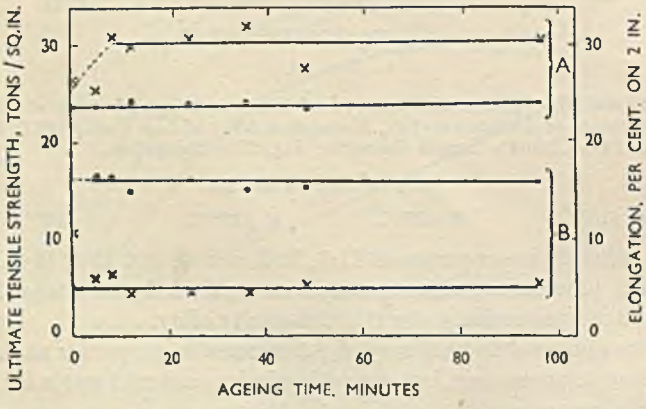

FIG. 27.—Effect of Ageing Time at 150° C. on Tensile Properties of Aluminium–10% Magnesium Alloy.

Key to Figs. 26 and 27.

A. High-Purity Alloy. ●——● Ultimate tensile strength.
B. Low-Purity Alloy. ×——× Elongation.

3.—*Examination of Microstructures.*

Specimens were prepared in the same way as those described in Part II of the paper. The material was first examined in the " as cast " state and it was seen that the Mg_2Al_3 formed a network around the grain boundaries and also occurred within the grains (Fig. 18, Plate XII). With the alloy of less purity there appeared to be a precipitate within the grains along mosaic boundaries (Fig. 19, Plate XII). This characteristic was noted by previous investigators.[3] Heat-treatment caused this constituent to enter into solution to a greater or less extent.

Two complete ranges of specimens were examined, solution treated at all specified temperatures for 4 hr., and for all specified times at 425° C.

The amounts of the magnesium constituent left undissolved varied gradually from the as cast condition (Figs. 18 and 19, Plate XII) to the case where all had entered into solution leaving continuous fine grain boundaries (Fig. 20, Plate XII). It was necessary to increase the solution temperature to 450° C. to cause complete solution in 4 hr., while 20 hr. were needed at 425° C. Heat-treatment at the high temperature of 450° C. did not result in any apparent overheating, but it appeared that the iron and silicon constituents in the impure alloy were slightly broken up.

The effect of quenching after solution treatment was to control the re-precipitation of the magnesium constituent. Cooling the metal in the furnace caused a general precipitation of the constituent. This precipitate spread inward from the grain boundaries, which were composed of discrete particles of constituent. Quenching in oil at 170° C. produced the normal appearance of continuous fine grain boundaries (Fig. 20). Quenching at lower temperatures suppressed this precipitation until after a quench in water at room temperature none was detected after prolonged etching.

There was only a slight difference in the amount of precipitate at grain boundaries between specimens held in oil at 150° C. for ½ min. and 96 min.

The only difference after comparable heat-treatments between the high- and low-purity metal, was in the amounts of Mg_2Si and $FeAl_3$ present.

IV.—Influence of Unsoundness on the Structure and Tensile Properties of Dry-Sand-Cast Aluminium–10% Magnesium Alloy.

In a number of cases, indicated in Table V, D.T.D. test bars of selected compositions were solidified under an air pressure of approx.

100 lb./sq.in. Standard sand moulds were placed in cylindrical steel pressure vessels, the metal poured as usual into the moulds, and the vessels closed and air pressure applied within 30 sec. of pouring. Pressure was maintained until about 15 min. after the first application.

In some cases the resulting bars were machined to standard test pieces of 0·564-in. dia., but in two cases bars were split into quarters longitudinally. They were clamped together for heat-treatment and sub-standard test pieces 0·162 in. in dia. were made from them. They were tested and compared with the full-size test pieces and with other quartered test pieces not solidified under pressure, to provide information on the consistency of the tensile properties and the effect of unsoundness thereon.

On testing the specimens it was found that the 0·564-in. dia. test pieces solidified under pressure gave somewhat greater ultimate tensile strength and much greater elongation values than ordinarily solidified material of similar composition (see Table V). Pressure-solidified bars slit into quarters gave remarkably consistent properties, very similar to those of the 0·564 in. pressure-solidified bars. Ordinarily solidified bars slit into quarters gave properties which were variable and inconsistent as compared to those of full-size bars taken from the same melt. This difference in behaviour could be paralleled by a similar difference in soundness as seen in the micro-sections.

As has been mentioned, the soundness of normally solidified bars increased with increasing impurity, particularly with iron; in fact the soundness of a normally-solidified specimen containing 0·5% iron and 0·1% silicon was comparable with that of a high-purity alloy solidified under pressure. It seemed unlikely, therefore, that the pressure solidification of alloys with a high iron content would be beneficial. That this was so can be seen from Table V, Groups "BOO" and "BOS."

V.—Conclusion.

The factors influencing the tensile properties of test bars cast from melts of aluminium–10% magnesium alloys may be divided into two groups:

1.—*Mechanical.* This includes all defects such as hot tears, oxide inclusions, &c., and is mainly responsible for the wide variation in properties sometimes found in a single batch of production metal. Given satisfactory foundry practice, the most important single variable is the operator's technique. Although, using the standard D.T.D. test bar, consistent results can be produced under laboratory conditions from material complying with the D.T.D. 300A chemical specification,

TABLE V.—*Effect of Method of Solidification on the Homogeneity of Aluminium–10% Magnesium Alloy Sand-Cast Test Bars.*

Ref.	Size of Bar.	Diameter of Test Piece, in.	0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.	Remarks.	
BNZ25	Full size	0·564	11·35	24·8	32½		
BNZ40	,,	,,	11·00	23·95	34½		
BNZ65a	Quartered	0·162	...	23·9	34		
b	,,	,,	...	24·0	36		
c	,,	,,	...	23·8	...	Solidified under pressure.	
d	,,	,,	...	24·0	34		
BNZ76a	,,	,,	...	23·6	32		
b	,,	,,	...	23·4	32		
c	,,	,,	...	23·5	36		
d	,,	,,	...	23·5	32		
BNQ1	Full size	0·564	11·05	24·15	23		
2	,,	,,	11·35	23·80	26		
3	,,	,,	11·40	24·35	29		
4	,,	,,	11·20	24·30	25		
5	,,	,,	11·35	24·00	28		
BNH1a	Quartered	0·162	...	20·40	16		
b	,,	,,	...	18·00	12	Solidified normally.	
c	,,	,,	...	16·35	13		
d	,,	,,	...	18·00	10		
BNH5a	,,	,,	...	22·70	25		
b	,,	,,	...	...	...		
c	,,	,,	...	23·90	30		
d	,,	,,	...	22·90	34		
BOO1	Full size	0·564	10·75	18·25	11½	Solidified under pressure.	
2	,,	,,	10·90	18·50	11½		Fe 0·54
3	,,	,,	10·95	17·70	7	Solidified normally.	Si 0·47
4	,,	,,	10·90	17·70	9		
5	,,	,,	10·75	18·00	10		
BOS1	,,	,,	12·00	21·30	13	Solidified under pressure.	
2	,,	,,	12·20	23·20	15½		Fe 0·75
3	,,	,,	12·15	22·90	14	Solidified normally.	Si 0·14
4	,,	,,	12·20	23·10	15½		
5	,,	,,	12·20	20·60	10		

this is not possible under the less-closely controlled conditions of production working. Hence, the failure of test bars to attain specification properties for one of the above-mentioned reasons is not necessarily a reflection on the quality of the metal.

2.—*Metallurgical.* Of the factors examined in the metallurgical field, the effect of silicon is the most remarkable. A slight variation in silicon content gives a sharp change in the ultimate tensile strength and percentage elongation. Other composition changes, viz., magnesium over the specification range and iron up to 0·5%, seem to have much less effect on the tensile properties. Of the heat-treatment variables, quenching temperature and after-quenching treatment have practically no effect on the tensile properties over the ranges investigated. High-purity material, however, is sensitive to inadequate solution treatment.

It must be emphasized that all the investigations described in this paper dealt with the effect of various factors on tensile properties only. No reference has been made to the effect of these factors on other properties, such as impact strength, fatigue strength, or static and stress corrosion. The effect of some of the apparently unimportant heat-treatment variables may prove to be of considerable importance to the corrosion-resistance of the alloy.

Acknowledgements.

The authors thank Mr. P. W. Rolleston, Vice-President of Aluminium Laboratories, Ltd., and Mr. Gordon H. Field, Director of the Research Division, Banbury, for their interest, encouragement, and permission to publish the results of this investigation, and also their colleagues in the laboratories who have carried out the machining, mechanical testing of test pieces, and chemical analyses.

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2. H. W. L. Phillips, *J. Inst. Metals*, 1946, **72**, 151.
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HOT-SHORTNESS OF THE ALUMINIUM–SILICON ALLOYS OF COMMERCIAL PURITY.* 1043

By A. R. E. SINGER,† B.Sc., Member, and P. H. JENNINGS,† B.Sc., Student Member.

Synopsis.

The hot-shortness of the commercially-pure aluminium–silicon alloys was studied by means of casting and welding experiments.

Castings were made in an annular mould in which stresses are set up by contraction during cooling. It was found that under the conditions of casting used the severity of cracking of the alloys increases with increasing silicon content to a maximum at approx. 0·7% and then decreases to zero with alloys containing about 3% silicon. With greater percentages of silicon no cracking was observed.

In welding experiments carried out on sheet material under conditions of restraint the maximum amount of cracking was found to occur at a composition of approx. 0·8% silicon, the severity of cracking then decreasing to a low value as before.

The present theories of hot-shortness are modified and extended to accord with the results of this investigation, and the degree of cracking in the castings and welds has been related to the mechanical properties of the alloys at high temperatures.

I.—Introduction.

Many aluminium alloys show such a degree of hot-shortness that they are suitable only for the simplest of castings. Tears and cracks generally develop in these alloys during or soon after casting, when the material is under stress whilst still at a high temperature. The importance of studying and explaining the hot-shortness of aluminium alloys has long been realized, but only rather limited progress has been made in this field. The object of the present investigation was to study the mechanism of hot-shortness in aluminium alloys and its dependence on composition and mechanical properties at high temperatures. As it was apparent that in the first instance work would have to be limited to a single series of alloys, the aluminium–silicon series was chosen partly owing to its structural simplicity and partly because some experiments have already been carried out by other investigators.

"Hot-shortness" is usually associated with casting behaviour, and is studied by some kind of casting test. Because the casting and welding processes are similar, however, it may also affect welding properties, and, in fact, it has often been observed that there is a con-

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nection between casting hot-shortness and a tendency to weld-cracking. Attention has therefore been devoted to devising casting and welding tests by which hot-shortness could be estimated with some accuracy.

Finally, it seemed desirable to try to link the results of the casting and welding experiments with the known mechanical properties of the alloys at high temperatures.

II.—Previous Investigations.

1.—*Casting Experiments.*

One of the earliest investigations of hot-shortness in aluminium alloys was by Archbutt, Grogan, and Jenkin,[1] who prepared die-castings in several alloys in common use. Two types of casting were used, a complicated branched tubular casting and a shouldered tensile test piece. In both cases the alloys were classified according to the mechanical properties of the castings and their tendency to fissuring. The results were of immediate practical value to the manufacturer of aluminium castings, but the choice of alloys was such as to be of little value in forming a theory of hot-shortness.

A valuable contribution was made by Verö [2] who chill-cast U-shaped test pieces consisting of two vertical arms and a horizontal portion, each 10 mm. in dia. The degree of hot-shortness was measured by the amount of cracking in the horizontal portion caused by the restraint imposed by the vertical arms. Verö showed that in aluminium–silicon alloys hot-shortness increased from zero at a low silicon content to a maximum at approx. 1·6%, and then decreased abruptly to zero at 1·88% silicon. Alloys containing greater amounts of silicon were not hot-short. Verö propounded a theory, referred to later, to explain his experimental results and applied it to other aluminium alloy systems.

Bochvar and Makimdzhanova,[3] in an investigation on aluminium–silicon alloys, found that increasing the silicon content reduced the tendency to crack and that a greater stress was necessary to cause cracking. In comparison with Verö's results, this conclusion can be explained by the fact that no alloys were studied within the critical range, the two alloys with the smallest silicon content being a 99·5% aluminium alloy and an alloy containing 2% silicon.

Lees [4] has shown recently that the tendency of aluminium–silicon alloys to hot-tearing in both sand and die moulds decreases with increase in silicon content, although alloys in the range 0·15–0·75% silicon were not studied.

Other investigators used casting tests in which restraint was brought about by casting cylindrical bars with enlarged ends, and many modifications of this test have been devised. Most of this work has been carried out, however, on complex commercial alloys, and from a theoretical point of view is of limited value.

2.—*Welding Experiments.*

Welding tests on aluminium alloys can roughly be divided into two groups in which: (i) a complex shape or structure is welded and (ii) a restrained weld is made between two sheets clamped rigidly in a massive frame.

In the first group cracking is caused by the restraint imposed by the structure itself, and various simple tests—such as the welding of a cross and a circular patch test [5]—have been devised to determine the susceptibilities of commercial aluminium alloys to fissuring. It is difficult to interpret the results of such tests and to relate the amount of cracking to the probable welding behaviour of the alloy.

Clamped weld tests have been much used for ferrous and non-ferrous alloys and numerous methods have been tried for obtaining effective clamping. Apart from the Reeve test, in which the individual sheets are fixed by being welded to the restraining plate, sheets to be welded have been fixed by a friction hold, by a circular depression in the sheets (the Focke–Wulf test), and by an indented groove.[6] Most of these methods have given good results and the choice of a test depends largely on the thickness and composition of the material to be welded. Mechel [7] found that clamped welds in aluminium containing 0·4% silicon showed considerable cracking, but that no cracking occurred when an 8% silicon filler rod was used. Similarly, West [8] observed that restrained welds in commercially-pure aluminium cracked more than those in super-pure aluminium and that with the use of a 4% silicon filler rod there was still less cracking. No investigation seems to have been made of the welding properties of alloys containing 0·5–4% silicon.

III.—Preparation of Alloys.

The present research was carried out on two similar series of ten aluminium–silicon alloys, one being used for the casting experiments and the other for the preparation of sheet for welding. Each series consisted of super-pure aluminium, 99·5% aluminium, and eight alloys containing 0·25, 0·6, 1·0, 1·5, 2, 4, 8, and 12% silicon, respectively. With the exception of the first-mentioned material, all were prepared

from aluminium of 99·5% purity. A 50% silicon temper alloy was used for the last three alloys mentioned and a 20% temper alloy for the remainder. The aluminium was melted in a Salamander crucible heated in a gas-fired furnace. Before adding the temper alloy the temperature was increased to about 750° C. and the melt was fluxed with a 2 : 1 mixture of sodium chloride and sodium fluoride. Prolonged contact of a 12% silicon alloy with this type of flux may result in modification, but no such effect took place in the experiments described. The charge of super-pure aluminium was melted in a crucible lined with Alundum cement which was free from silicon and iron and so contamination of the melt was negligible. The alloys were

TABLE I.—*Chemical Analysis of Alloys Used in Ring Casting Tests and in Clamped Weld Tests.*

Nominal Composition.	Ring Casting Tests.		Clamped Weld Tests.	
	Silicon, %.	Iron, %.	Silicon, %.	Iron, %.
Super-pure aluminium	<0·01	<0·01	<0·01	<0·01
99·5% aluminium	0·12	0·27	0·10	0·15
0·25% silicon	0·21	0·29	0·28	0·17
0·6% silicon	0·66	0·20	0·61	0·21
1·0% silicon	1·08	0·27	0·92	0·16
1·5% silicon	1·62	0·25	1·57	0·16
2% silicon	2·08	0·28	2·03	0·17
4% silicon	3·87	0·27	4·07	0·24
8% silicon	7·65	0·27	8·04	0·28
12% silicon	11·83	0·23	12·40	0·45

not degassed and, as the melting time was short, no elaborate precautions were taken against gas absorption. None of the ring castings which were sectioned showed any sign of porosity, and the melting procedure appeared to be quite satisfactory.

The dimensions of the slabs for the preparation of the sheet were 8 in. × 4 in. × $\frac{9}{16}$ in. The slabs were cast in an inclined cast-iron mould, and they were preheated to 400° C., hot rolled in a cross-wise direction to 0·35 in. and then lengthwise to 0·18 in. thickness, and afterwards cold rolled to a thickness of 0·12 in., annealed at 380° C., and finally rolled to 0·080 in. thickness. The results of chemical analyses for silicon and iron are given in Table I. Spectrographic analyses showed that other elements were present in negligible quantities.

IV.—Casting Experiments.

The test employed consisted of casting a ring in an open cast-iron mould made up of a flat plate on which rested concentrically a ring and core, thus leaving an annular space between. A mould having the dimensions shown in Fig. 1 proved to be most satisfactory. The molten alloy was poured radially into the mould to a height of about ¾ in. and, on freezing, tensile stresses were set up by contraction round the core which caused cracking in brittle or hot-short alloys. An advantage of this type of casting was that the whole process of solidification of an alloy could be observed visually.

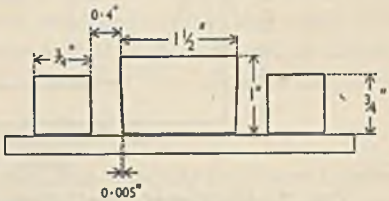

Fig. 1.—Mould for Ring Castings.

The results were influenced considerably by altering the pouring temperature, which was therefore maintained throughout at 100° C. above the liquidus. The mould was used uncoated so that the chilling effect would be uniform, and was kept at a temperature of approx. 150° C.; the mould temperature was found not to be critical. After pouring and cooling, the ring and core were lifted out together. The slight taper of 0·010 in. on the cores enabled them to be separated easily in a screw press.

From 4 to 14 ring castings were poured from each alloy of the series and an examination was made of the extent and nature of the cracks. Wide differences of behaviour between certain alloys were observed, but good agreement could be obtained between a number of rings in any one alloy. The severity of cracking was expressed numerically as the total length of cracks on all surfaces. This procedure has the disadvantage that no account is taken of the width or depth of the cracks, but it has the merit of simplicity and appears to work quite well.

Experimental Results.

The average length of cracking per ring for each of the ten alloys is shown in Fig. 2. The severity of cracking increases sharply with the addition of silicon to a maximum at 0·7% and then decreases rather less rapidly, reaching zero at about 3% silicon. It is worth noting that the curve begins to rise rapidly at approx. 0·25% silicon.

The cracks ranged in size from fine hair-cracks to those extending from top to bottom of the ring and affecting the whole section. The

fine cracks were most numerous on the top surfaces of castings in alloys containing 1·5 and 2% silicon, where they accounted for most of the cracking. The maximum scatter of the results occurred in the

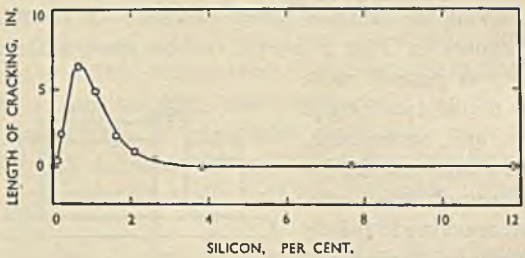

Fig. 2.—Cracking of Ring Castings in the Aluminium–Silicon Alloys.

0·6% silicon alloy in which the extreme limits of the 14 values were lengths of 4·5 and 8·9 in. Typical rings of each alloy are shown in Figs. 4 and 5 (Plate XIII) and show the way in which the severity of cracking varies with silicon content.

V.—Welding Experiments.

1.—*Apparatus.*

Of the two types of welding test already referred to, a clamped weld test was used in preference to welding a complex structure in order to be able to express the results numerically and to prevent slipping a single corrugation was pressed into one end of each sheet. The method was first used by Bollenrath and Cornelius [6] in testing aircraft steels, but for that purpose a much more substantial jig was required than is necessary for aluminium alloys. The details of the jig used in the present investigation are shown in Fig. 6 (Plate XIV). The end of the sheet was gripped between two steel blocks which were bolted to a 1-in. steel base-plate. The corrugation fitted into a groove in the lower block, and a corresponding groove in the upper block held a steel rod which pressed on the inside of the corrugation. These grooves were designed so that steel rods of different diameters could be used according to the thickness of the sheet, and the jig was therefore applicable to sheet of from 10 to 18 gauge, although welding experiments were made only on 14-gauge material.

2.—*Welding Procedure.*

After wire-brushing the scarves and applying to them a paste of Magnotectic welding flux, the sheets were bolted in the jig leaving a

gap of approx. $\frac{1}{16}$ in. to prevent buckling during welding. The weld was made for a length of 3 in. of the total of 4 in. by the leftward method with an oxy-acetylene torch, using a filler rod cut from the parent sheet. To make the results of different tests comparable a neutral oxy-acetylene flame of a standardized size was used. The time of welding was then roughly constant, the 3-in. weld taking approx. 20 sec. to complete. A 7-in. gauge-length was marked on the sheets before welding, after the completed weld had cooled, and again after removal from the jig so that the amount of slipping should be known, and to enable a calculation to be made of the approximate stress developed.

3.—*Experimental Results.*

All the completed welds were examined carefully and those showing defects, such as inadequate penetration or misalignment of the sheets, were discarded. From two to four wholly satisfactory welds were made in each of the ten alloys. Cracking tended to occur preferentially at the point of finishing of the weld, especially when the reinforcement at this point was insufficient. Most of the cracking was at the centre

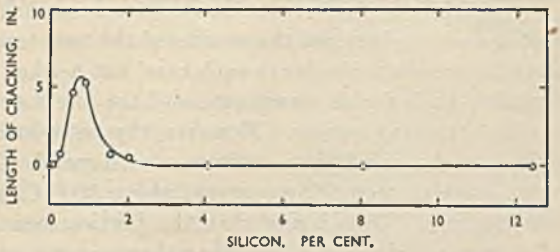

Fig. 3.—Cracking of Welds in the Aluminium–Silicon Alloys.

of the weld bead, and tended to be more extensive on top than beneath. Flux residues made it difficult to observe when cracking began, but it is certain that there was very little interval between welding and the appearance of the first crack. No appreciable porosity was observed in any of the welds.

Slipping during welding was less than 0·005 in. in every case, representing less than 10% of the total thermal expansion. The stress in the welded sheets when cool was calculated from the relaxation which occurred on loosening the bolts. In the absence of severe cracking the stress approximated to the elastic limit of the alloy in question, ranging from about 2 tons/sq.in. for pure aluminium to about 8 tons/sq.in. for the 12% silicon alloy.

The average length of cracking in each alloy is shown in Fig. 3,

in which the values refer to the total length of cracks on both sides of the sheet. The results are remarkably similar to those obtained in the ring casting experiments, cracking reaching a maximum at about 0·8% silicon and decreasing on either side. In the 0·6 and 1% silicon alloys the whole length of the weld was usually affected, and in some cases the sheets fell apart when removed from the jig.

The practical conclusion is that pure aluminium containing approx. 0·2% iron which is to be welded into complex structures should contain less than 0·25% silicon. Although the effect of iron was not determined, it seems quite likely that the welding properties depend on the iron content and this fact would probably have to be taken into account in specifying the maximum content of silicon. The alloys within the range 0·25 to 3% silicon appear to be of limited value for casting or welding, but those containing more than 3% silicon should have good properties from the point of view of freedom from cracking.

VI.—The Cracking Process and its Relation to Structure.

The good agreement between the results of the two tests suggests that the cracking process is similar in each case, but neither test seems to form a suitable basis for an investigation of the physical conditions prevailing when cracking occurs. However, by introducing a fine thermocouple into the solidifying casting or weld-metal of hot-short alloys, it was shown that cracking occurred above 500° C., confirming previous observations. Considering that the precise location of the cracks is not known beforehand, and that they are not visible until they have opened to a considerable extent, it appears that cracking may begin at a considerably higher temperature. Although no further study was made on these lines there was thus a strong indication that cracks first formed at a temperature at least approaching that of incipient fusion for the alloy concerned, a conclusion that is in agreement with the work of Lees.[4]

It is important to distinguish between hot-shortness and a different phenomenon in which cracking occurs at temperatures well below the solidus. Although no "cold-cracking" was found in the aluminium–silicon alloys, it is frequently met with in less ductile materials. The eutectic aluminium–copper alloy shows no hot-short tendencies in the ring test but cracks severely at much lower temperatures, and Lees noted that test castings of "Y" alloy crack at about 200° C.

1.—*Structure of the Ring Castings.*

A sample ring of each alloy was sectioned, polished, and etched to reveal the macrostructure (see Fig. 7, Plate XV). Alloys containing up to 1·5% silicon were composed of columnar crystals, but further additions of silicon caused a gradual transition to a finer equi-axed structure. The 2% silicon alloy contained both columnar and equi-axed crystals, but the structures of the 4, 8, and 12% silicon alloys were entirely equi-axed.

The composition at which the transition occurred depended on the degree of superheat at which the rings were cast. When the pouring temperature was decreased the transition occurred with a smaller percentage of silicon, and was moved back to 0·6% by using a pouring temperature of only 20° C. superheat. The severity of cracking was considerably reduced by pouring at a lower temperature, and the onset of a fine grain equi-axed structure was accompanied by a sudden decrease in hot-shortness. This was less apparent when casting at 100° C. superheat, as cracking had already reached a fairly low value by the time that sufficient silicon had been added to cause the structural change. The rapid decrease in hot-shortness found by Verö at about 1·7% silicon may have been associated with the change to a finer structure.

Horizontal sections were prepared through several ring castings which showed a large number of cracks, in order to determine their location in relation to the structure. The cracks were almost invariably along the grain boundaries and thus pursued a zig-zag course across the casting. A typical crack is shown in Fig. 8 (Plate XV) and it can be seen that instead of crossing a grain the crack has stopped on either side of it, and the movement of the neighbouring portion has been accommodated by a slight turning of the barrier grain.

2.—*Structure of the Welds.*

Each of the welds in the aluminium–silicon series was etched to reveal the macrostructure and some were sectioned, polished, and etched at varying depths from the top surface. The welds in superpure aluminium, one of which is illustrated in Fig. 9 (Plate XVI), were particularly remarkable. The structure was the same in the underbead as in the top surface layers and consisted entirely of large curved columnar crystals, starting almost perpendicularly to the line of the weld and sweeping round into the welding direction. A similar type of columnar structure was shown by all the alloys containing less than 1·5% silicon, although the crystals were smaller and straighter. The

2% silicon alloys showed a transitional columnar structure in the top surface layers, but the crystals in the lower layers were mainly equi-axed. The welds in the 4, 8, and 12% alloys were composed entirely of fine grain equi-axed crystals similar to those shown in Fig. 11 (Plate XVI).

All the observed cracks in the welds were intercrystalline, most of them occurred in the middle of the weld where the columnar crystals met at the centre line, as illustrated in Fig. 10 (Plate XVI), which shows a columnar crystal that grew along the centre line of the weld, later forming a connecting link between the two separated halves. Some welds cracked at the edge of the melted zone, while in the less hot-short alloys cracking occurred preferentially at the finishing end. Small cracks running between the columnar crystals and extending from the edge to the centre of the weld were commonly found towards the finishing end, sometimes linking the edge-cracks with those in the centre.

VII.—Discussion.

1.—*Present Theory of Cracking.*

A theory accounting for the cracking observed in certain alloys of aluminium with silicon was put forward by Verö [2] who postulated that cracking was caused by the contraction of the primary crystals during cooling between the liquidus and solidus. He suggested that in the presence of more than a certain critical proportion of liquid any incipient cracks between the primaries were healed by liquid flowing into them as they formed. When less than the critical proportion of liquid remained the healing process was prevented by the narrowness of the inter-dendritic channels. Verö assumed that crack formation could occur only during contraction of the dendrites and argued that when the proportion of liquid freezing at constant temperature—the eutectic temperature—was greater than the critical value no cracking took place. Taking the effective solid solubility of silicon in aluminium at the eutectic temperature to be approx. 0·4%, Verö calculated that the critical proportion of liquid was 12–13%.

2.—*Modified Theory.*

On closer examination it is evident that the sudden decrease in hot-shortness found by Verö cannot be explained by his theory as it stands. Fig. 12 shows part of a phase diagram of a eutectic system in which, for simplicity, the boundaries are drawn as straight lines. The diagram is characteristic of any eutectic system whether equi-

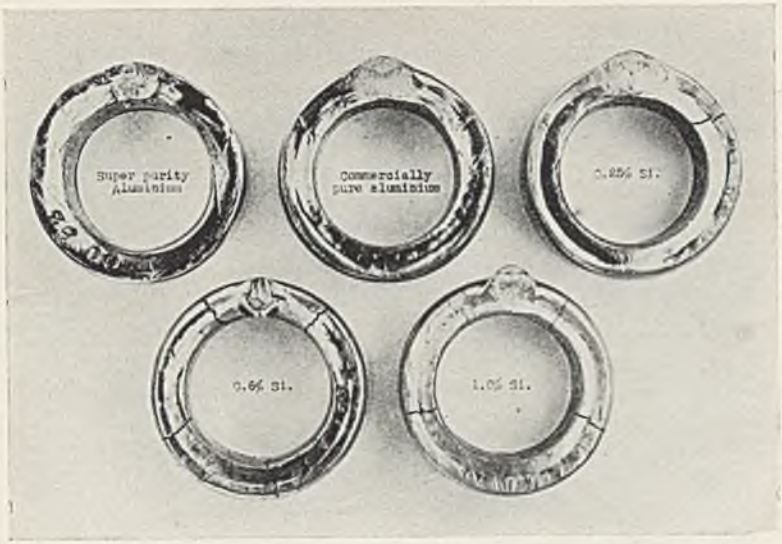

FIG. 4.—Cracking of Ring Castings in the Aluminium–Silicon Alloys. × ½.

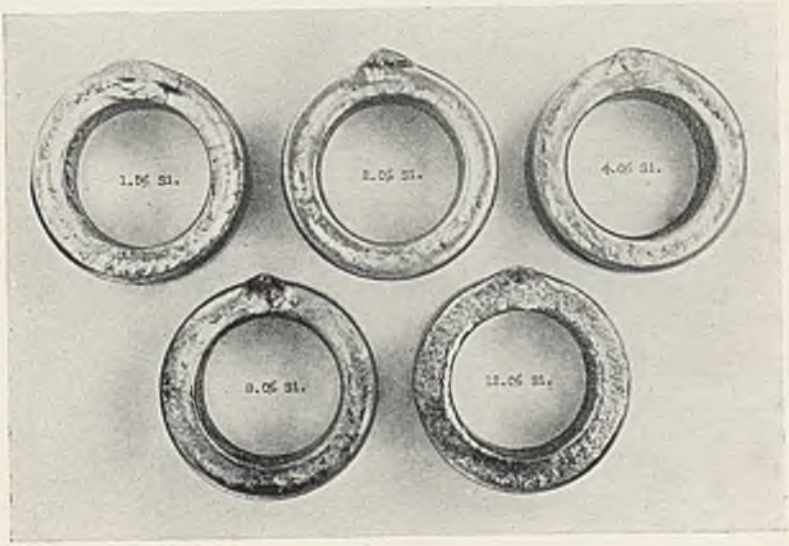

FIG. 5.—Cracking of Ring Castings in the Aluminium–Silicon Alloys. × ½.

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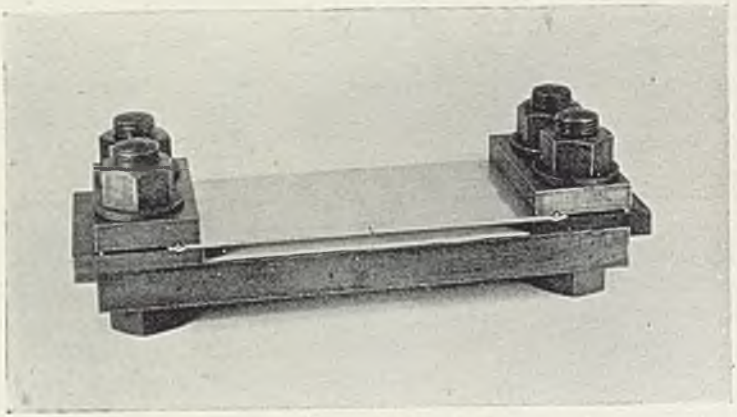

FIG. 6.—Jig Used for Clamped Weld Experiments.

(a) (b) (c)

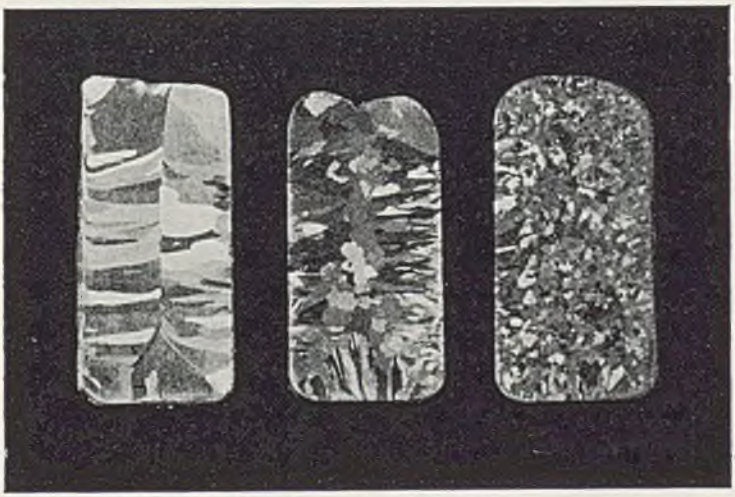

FIG. 7.—Macrostructure of Ring Castings in (a) Super-Pure Aluminium; (b) 2% Silicon Alloy; and (c) 8% Silicon Alloy.

FIG. 8.—Macrostructure of Part of Cracked Ring Casting in 1% Silicon Alloy.

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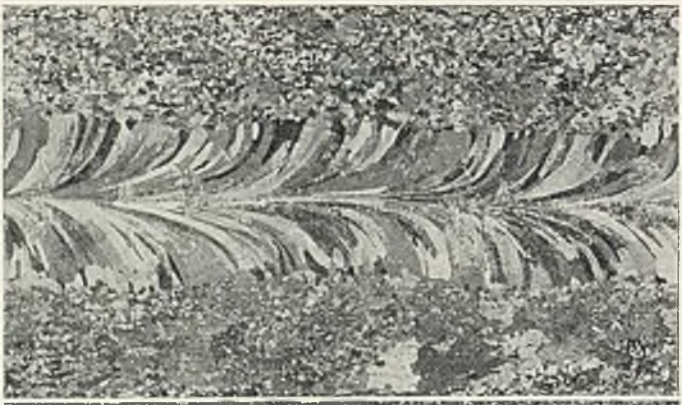

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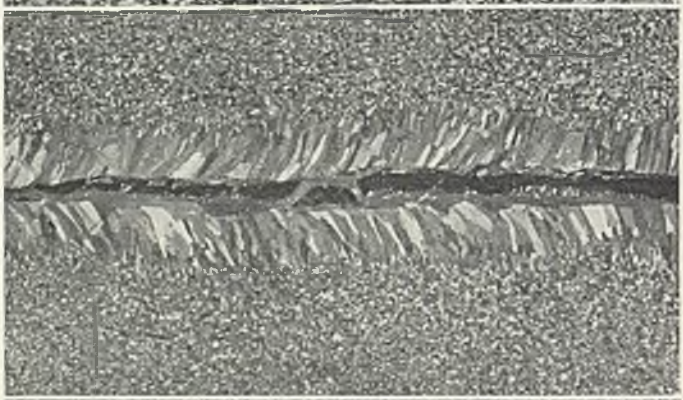

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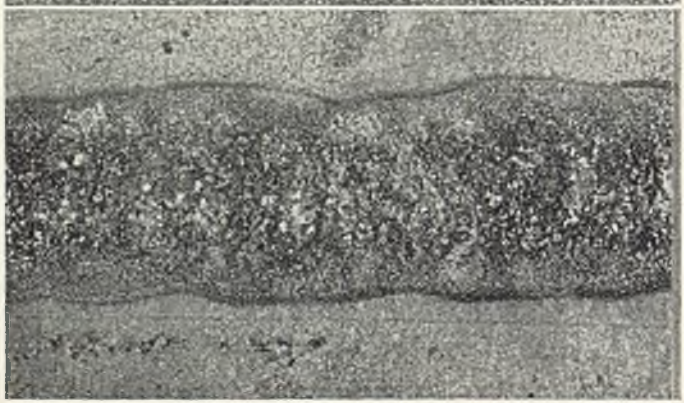

FIG. 9.—Macrostructure of Restrained Weld in Super-Pure Aluminium.
FIG. 10.—Macrostructure of Restrained Weld in 1% Silicon Alloy.
FIG. 11.—Macrostructure of Restrained Weld in 8% Silicon Alloy.

librium has or has not been attained. The point B is such that $\frac{AB}{AE}$ is the critical proportion of liquid necessary to heal cracks. Thus, in alloys whose compositions are to the left of B, less than the critical

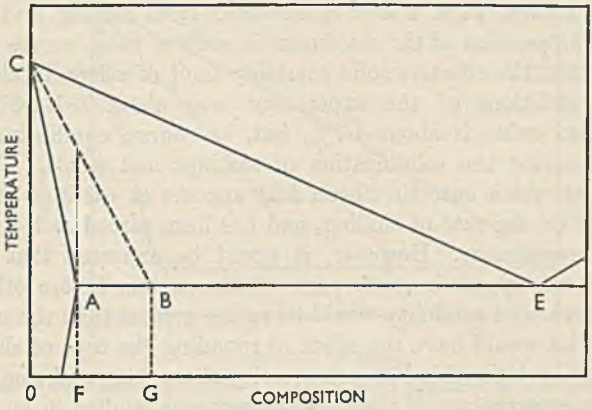

Fig. 12.—Phase Diagram of Eutectic System.

proportion of liquid freezes at the eutectic temperature. Healing would not then be possible in any system represented by a point within the triangle CAB. In other words, effective healing ceases when in cooling the line CB is crossed. The severity of cracking would be

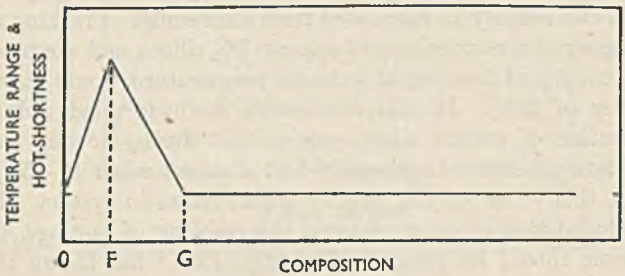

Fig. 13.

expected to depend on the amount of contraction that takes place during cooling from the appropriate point on CB to the solidus and would be approximately proportional to this temperature range, the extent of which is plotted in Fig. 13. Accordingly, Fig. 13 should give an indication of the degree of hot-shortness, which would reach a

maximum at the composition *F* coincident with the limit of solid solubility at the eutectic temperature. On either side of *F* the hot-shortness would diminish to zero at *O* and *G*.

Some measure of agreement between this theory and the experimental results is suggested by the similarity between Fig. 13 and the cracking curves, Figs. 2 and 3, obtained from casting and welding tests. The position of the maximum in each of these curves seems to indicate that the effective solid solubility limit of silicon in aluminium in the conditions of the experiment was about 0·7–0·8%. The equilibrium value is about 1·7%, but, of course, equilibrium is not attained during the solidification of castings and welds. The composition at which eutectic silicon first appears in castings depends a great deal on the rate of chilling, and has been placed as low as 0·2% by one investigator. However, it would be expected that eutectic silicon would appear in some parts of the casting before others and the effective solid solubility would be rather greater than the minimum value. This would have the effect of rounding the tops of the curves showing the relationship between severity of cracking and composition.

The microstructure of the ring castings was studied in an attempt to correlate the composition of maximum cracking with the first appearance of appreciable quantities of eutectic silicon, but the results were indefinite owing partly to the non-homogeneous nature of the castings, and partly because the extremely small size of the intermetallic compounds makes their identification difficult.

Assuming that the effective solid solubility of silicon in aluminium under the conditions of experiment is 0·75%, the critical proportion of liquid can roughly be calculated from the results. Cracking appears to disappear at a composition of approx. 3% silicon and the proportion of residual liquid freezing at eutectic temperature would then be of the order of 20%. In this connection Bochvar [9] deduced from a consideration of several alloy systems that during cooling from the liquid state coherence is generally first attained when 10–15% liquid remains, this value varying greatly from system to system. Later,[10] he concluded that in order to avoid the cracking of castings, 15–20% of eutectic should be present. Recently, Lees [4] has shown that the volume proportion of eutectic (the eutectic index) necessary to ensure freedom from cracking is approx. 10% for a particular sand mould and 30–50% for a more severe test in copper dies.

3.—*Correlation of Hot-Shortness with Properties at High Temperatures.*

In a study of the tensile properties of the aluminium–silicon alloys at high temperatures, Singer and Cottrell [11] showed that a hot-short

temperature range exists above the solidus, and concluded that the extent of this range may be a principal factor in determining the casting and welding properties of the aluminium–silicon alloys. For ease of reference some of the results of this investigation are repro-

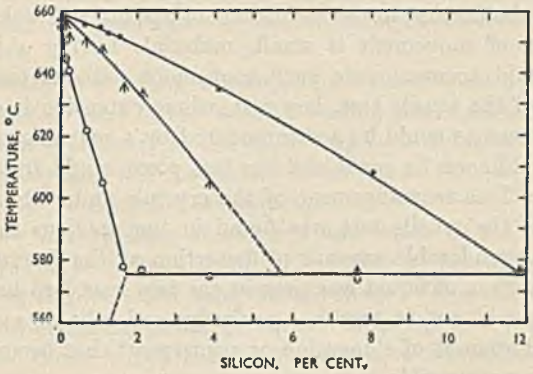

FIG. 14.—Constitutional Diagram of the System Aluminium–Silicon (Singer and Cottrell).

duced in Figs. 14 and 15. Fig. 14 shows part of a constitutional diagram in which the solidus was determined from the sudden decrease in strength on the first appearance of liquid. The liquidus was obtained

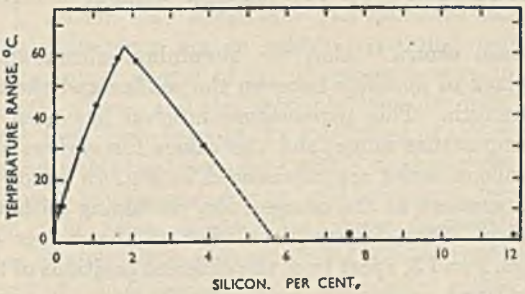

FIG. 15.—Hot-Short Temperature Range of the Aluminium–Silicon Alloys (Singer and Cottrell).

from cooling curves, and the intermediate line denotes the highest temperature for each alloy at which the strength was perceptible.

The strength reached a negligible value when the liquid content was about 40%—a value well in excess of the critical proportion of liquid necessary for healing incipient cracks, which in the present casting and welding experiments has been found to be about 20%.

This apparent contradiction can be explained by assuming that under tensile stress, with a proportion of liquid of the order of 20–40%, some movement can be accommodated by a slight rearrangement of the crystals. The amount of adjustment thus obtainable would be limited and would be greater with the higher proportion of liquid. It seems probable that in the conditions of casting and welding, where the amount of movement is small, materials having a high liquid content would accommodate such movement without cracking. In conditions of the tensile test, however, where extension is continuous, such movement as could be accommodated by a rearrangement of the crystals would soon be spent and the test piece would fracture in the usual way. This rearrangement of the crystals under the continuous extension of the tensile test was found in the previous investigation to cause a considerable amount of distortion at the fracture. When a high proportion of liquid was present the two fractured halves of the test piece would not fit together perfectly, and reliable measurement of the small amount of elongation or adjustment that occurred during the test was not possible.

At the solidus there is a sudden increase in ductility and it can be assumed that below this point hot-cracking is no longer possible. Thus, it would be expected that the aluminium–silicon alloys would be most susceptible to hot-cracking at, or immediately above, the solidus temperature, for at this point the amount of movement which can be accommodated by the material without cracking is at a minimum.

It has been shown [11] that the aluminium–silicon alloys have a pronounced lack of ductility between the solidus and the temperature of losing strength. This temperature interval has been termed the hot-short temperature range, and the values for various alloys of the aluminium–silicon series are reproduced in Fig. 15 which shows that the range is greatest at the composition coinciding with the limit of solid solubility. This diagram is similar to the curves of cracking shown in Figs. 2 and 3, apart from the different positions of the maxima, already mentioned.

4. *Mechanism of Cracking.*

One of the simplest cases for consideration is the solidification of a small length of a butt weld between two restrained sheets. During welding the sheet adjacent to the weld expands and reduces the expansion gap left between the scarves. Shortly after welding the sheets begin to contract, but whilst a part of the weld is still mainly liquid the movement can readily be accommodated. After a time, however,

less than the critical proportion of liquid is available and cracking occurs provided that enough contraction takes place before the weld is completely frozen.

This reasoning can also be applied to castings, for freezing will almost invariably be complete in one place before another and the solid portions will undergo thermal contraction in much the same way as above.

The severity of cracking will depend on the amount of contraction while the hottest part of the weld or casting passes through the hot-short range, and contrary to the opinion of Verö it appears that cracking is possible, and will frequently occur, even though the residual liquid solidifies at constant temperature.

Thus, the hot-cracking of castings and welds in the aluminium–silicon alloys can be accounted for theoretically by one principal factor, the extent of the hot-short temperature range. This single factor, of course, incorporates in modified form the conceptions of freezing range and eutectic index which had previously been advanced to explain the phenomenon of hot-shortness.

VIII.—Conclusions.

In commercially-pure aluminium–silicon alloys containing approx. 0·2% iron, there is a hot-short composition range extending roughly from 0·25–3% silicon. No appreciable hot-shortness has been found in super-pure aluminium nor in alloys containing more than 3% silicon. The greatest degree of hot-shortness occurs in alloys containing 0·7–0·8% silicon, and this probably coincides with the effective solid solubility limit pertaining to the conditions of experiment.

Castings and welds made in alloys within the hot-short composition range are subject to cracking during solidification if free contraction is prevented. The compositions of the most frequently used commercial alloys of aluminium with silicon lie beyond this range, but an undue amount of silicon in commercial aluminium makes it hot-short and may cause much trouble during welding.

Acknowledgements.

The authors are indebted to Professor D. Hanson, D.Sc., under whose general direction this research was carried out, and to the Wrought Light Alloys Association for permission to publish this paper.

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A RAPID METHOD FOR THE ANALYSIS OF LIGHT ALLOYS, BASED ON ELECTRICAL RESISTIVITY.* 1044

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SYNOPSIS.

A study was made of the variation of electrical resistivity with composition in light alloys corresponding to the specifications D.T.D. 300 and 59A; in one case correlating resistivity with magnesium content and in the other with aluminium content. It was found that the results obtained depended on porosity, microstructure, and details of the casting procedure, but that, with careful control, a straight-line relationship between alloy content and resistivity could be obtained. In the case of the specification D.T.D. 300-type alloys, a change of resistivity of 0·53 microhm-cm. per 1% magnesium was obtained, while a spread of points about a line of this slope corresponded to a standard deviation of 0·16% magnesium. For the alloys of the type D.T.D. 59A, a slope of 0·75 microhm-cm. was obtained, the corresponding standard deviation being 0·13% aluminium. It is suggested that these relationships offer the possibility of an extremely rapid method of foundry analysis control, as, with simple equipment, electrical resistance can be quickly measured with a high degree of accuracy. The accuracy of the method under suitable conditions would be greater than that of accepted (*e.g.*, spectrographic) methods.

I.—INTRODUCTION.

WAR-TIME experience of the spectrographic analysis of light alloys has shown that the method is not sufficiently accurate to justify its extended use in estimating the alloy content of the richer alloys, such as those conforming to specifications D.T.D. 300 or D.T.D. 59A. Density and electrical resistivity are alternative physical properties which, it was thought, might form a suitable basis for a rapid method of analysis. The experiments described in this paper were carried out to study the possibility of using these methods in estimating magnesium in alloys conforming to specifications D.T.D. 300 and aluminium in those conforming to D.T.D. 59A.

1.—*Relationship of Density to Magnesium Content (Aluminium Alloy D.T.D.* 300).

Results of density measurements on specimens prepared from chill-cast test bars, of both experimental and foundry origin, are plotted

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against composition in Fig. 1. The decrease of density with increase in magnesium content was about 0·01 g./ml. per 1% magnesium, but the correlation was poor, mainly because of the interference of porosity. The slope of the line density–magnesium % might be considered to indicate sufficient sensitivity provided that porosity is

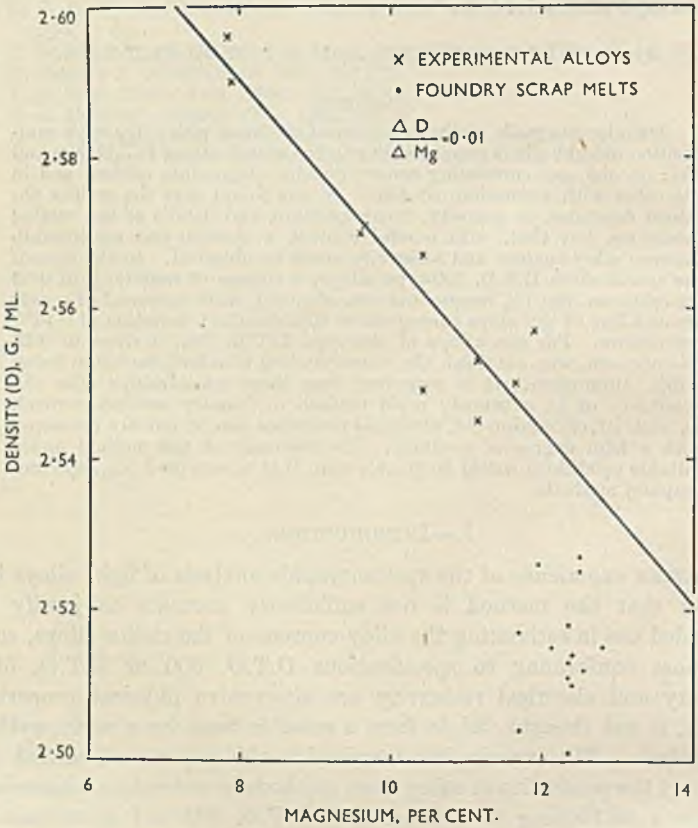

Fig. 1.—Aluminium Alloys. Density of chill-cast specimens.

avoided, but no further work on density was carried out as electrical conductivity proved to be about 15 times more sensitive to composition changes.

2.—*Relationship of Electrical Resistivity to Composition* (*Aluminium Alloy D.T.D.* 300 *and Magnesium Alloy D.T.D.* 59A).

It was immediately obvious that any correlation which might be established between conductivity and a major alloying element would

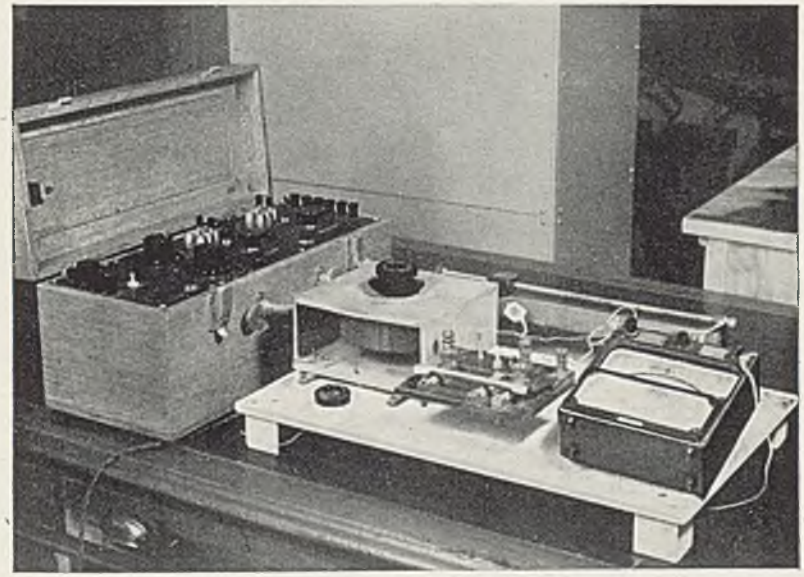

FIG. 3.—Apparatus Used for Measurement of Electrical Resistivity.

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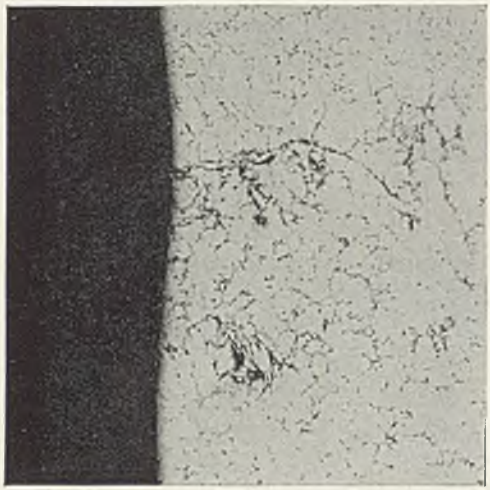

FIG. 4.—Entrapped Oxide Films in Specimen with High Resistivity Giving Apparent Error in Magnesium Estimation of 0·7%. × 50.

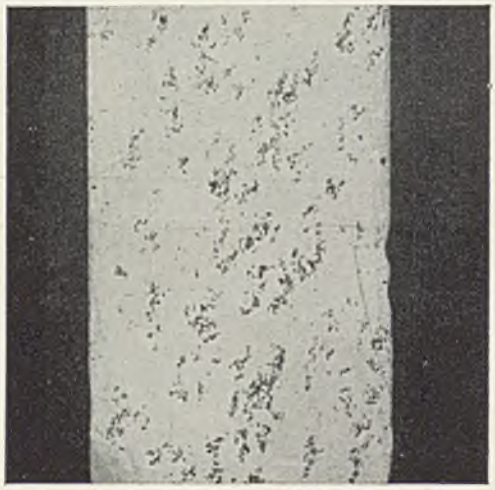

FIG. 5.—Porosity in Specimen with High Resistivity Giving Apparent Error in Magnesium Estimation of 0·4%. × 6.

be subject to a number of disturbing factors other than the accuracy of the actual measurements. Amongst these were vagaries of composition in respect of impurities and minor alloying elements, the soundness and microstructure of test pieces, and the solid solution concentration as influenced by cooling rate. There were grounds for optimism (on the score of compositional influences) in the cases of the alloys to specifications D.T.D. 300 and D.T.D. 59A, the impurities in which are—of necessity—already closely controlled and in which, in the case of the magnesium alloy, the small additions of zinc and manganese are known to vary within very narrow limits. Moreover, it was thought possible that, by attention to casting technique, a measure of consistency in the soundness and microstructure of the specimens might be attained. The extent of the variation to be expected in the rates of cooling after casting, and its influence on solid solution concentration, were factors which had not been studied closely enough to permit supposition.

II.—Experimental Procedure.

Electrical resistivity measurements were made on cylindrical specimens machined from test bars cast in an iron mould of the type

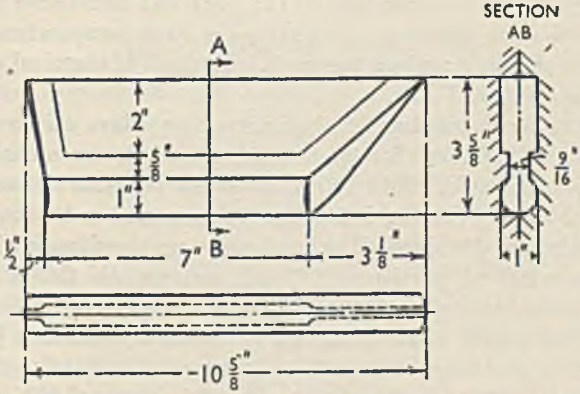

Fig. 2.—Cast Iron Mould. Minimum wall thickness, 1¾ in.

shown in Fig. 2. No heat-treatment was given prior to testing. The specimens, ¼ in. in dia. and 5 in. long, were supported in a jig with two knife-edge tappings 10 cm. apart, to give the required gauge length. Potentiometer measurements were made of potential decrease when passing a known current. Values for resistivity were then calculated, using the mean potential difference of two tests at different current values, and the mean diameter from 10 micrometer readings along the

gauge length. The apparatus used is shown in Fig. 3 (Plate XVII). To ease the arithmetical work involved in numerous determinations, a simple formula was found which relates resistivity with potential decrease by standardizing various current values for each specimen diameter in the range of variation encountered. By this means, with a current (amp.) equal to ten times the cross-sectional area of the specimen (sq.cm.), a potentiometer reading of 1·0 mV. corresponded to a resistivity value of 10 microhm-cm. In this way electrical resistivity could be determined in 2 or 3 min. Resistivity values so determined were plotted against chemical analyses of millings from separate test bars of the same casts or, as in the final experiments, of the actual electrical test pieces after use.

The resistivity determinations were carried out in an underground laboratory, to minimize errors due to fluctuation of room temperature. To give some idea of the reproducibility of the resistance measurement, the results of three replicate determinations on each of nine test pieces at different periods were examined by analysis of variance technique. The standard deviation between replicate determinations was 0·05 microhm-cm. and the mean resistivity about 8·7 microhm-cm. The maximum variation of room temperature between the different periods at which checks were taken was 6° C.; this was considered to be a sufficient indication that expected changes in room temperature would introduce no serious error into the work. Methods of chemical analysis used were as detailed below.

To determine magnesium in aluminium-base alloys conforming to specification D.T.D. 300, dissolve a 2·184 g. sample by additions of 50% hydrochloric acid. Add 10 ml. hydrogen peroxide (20 vol.) and evaporate to salts. Take up in 5% hydrochloric acid and water. Boil until the salts are dissolved, filter, and make up the filtrate with cold water. To a 100-ml. portion add 15 ml. tartaric acid (500 g./l.) and 20 ml. di-ammonium phosphate (10% aqueous solution). Neutralize to bromcresol purple and add 25 ml. ammonium hydroxide (*d* 0·88) excess. After standing for 2 to 3 hr., filter, and redissolve the precipitate with hot 50% hydrochloric acid. Add 2 ml. of 50% tartaric acid, 5 ml. di-ammonium phosphate (10%), and one drop of bromcresol purple indicator. Allow 10% excess of ammonium hydroxide in the final solution. Filter, and ignite the precipitate and pad at a low temperature until most of the carbon is removed and then at 1000° C. until pure white. Weigh as magnesium pyrophosphate ($Mg_2P_2O_7$).

$$\text{wt. of } Mg_2P_2O_7 \times 50 = \%\ \text{Mg in sample.}$$

To determine the aluminium content of magnesium-base alloys

conforming to specification D.T.D. 59A, dissolve a sample of 1·25 g. in boiling hydrochloric acid. Add a few drops of nitric acid, cool, and dilute to 500 ml. Neutralize a 100-ml. fraction with 50% ammonium hydroxide, using methyl orange indicator, and add 3 ml. B.P. acetic acid and 20 ml. ammonium benzoate (10% aqueous solution). After boiling, filter off the residue and dissolve it in hydrochloric acid. Neutralize with 50% ammonium hydroxide, using bromcresol purple indicator. Add 5 ml. 50% hydrochloric acid and boil. Dilute to 300 ml., adding 8-hydroxyquinoline solution in slight excess, and 40 ml. ammonium acetate solution. Collect the precipitate, and dissolve from the pad with 50% hydrochloric acid. Add potassium bromate-bromide solution (6·193 g. $KBrO_3$, 50 g. KBr per litre) in two stages, with indigo-carmine indicator, until finally the solution is pure yellow. Stand for 5 min. and add 10 ml. 20% potassium iodide solution. Titrate with sodium thiosulphate solution until the turbidity is almost discharged. Add a little starch solution, and titrate further until the blue colour of starch iodide disappears.

$$\% \text{ Al} = \frac{\text{vol. bromate-bromide (corrected)} - \text{vol. sodium thiosulphate (corrected)}}{5}$$

III.—Details of Investigation.

Preliminary experiments on specially-cast test pieces covering the ranges 8–12% magnesium in specification D.T.D. 300 and 6–10% aluminium in specification D.T.D. 59A indicated a straight-line relationship between conductivity and the above-mentioned alloying elements, but when the results of more than one experiment were considered some displacement was noted between the curves. In two series of measurements on each alloy this amounted in one case to 0·14% magnesium, and in the other alloy to about 0·26% aluminium. The residual standard deviations on any one experiment, however, in no case exceeded 0·10% alloying element. The slopes were 0·54 microhm-cm. per 1% magnesium and 0·70 microhm-cm. per 1% aluminium, indicating a much greater sensitivity than for density and composition.

The next step, therefore, was to discover the extent of variability in results from a large number of castings made in the foundry. Results obtained from 66 specimens of aluminium alloys over the range 10–12·5% magnesium gave a slope of 0·45 microhm-cm. per 1% magnesium, as compared to 0·54 on laboratory castings, but showed a residual standard deviation as great as 0·43% magnesium. The first set of 64 magnesium alloy specimens from the foundry, containing

6–8% aluminium, proved no better, the standard deviation in respect of composition being 0·27% aluminium.

A metallurgical examination of specimens giving the greatest displacements indicated three sources of error, all of which had a bearing on sampling procedure. The first two of these appeared most serious in the case of the aluminium alloys.

(a) *Unsound Specimens.* Entrapped oxide films and shrinkage porosity of the types shown in Figs. 4 and 5 (Plate XVIII) were found in 6 cases out of 7, where the resistivity was apparently much too high. These defects were not found in a random selection of other specimens representing the majority grouping.

(b) *Unrepresentative Chemical Analyses.* Check chemical analyses, obtained on actual resistivity specimens, showed serious divergence in several instances from the analyses obtained on separate specimens from the same castings and used for purposes of correlation in the early experiments. The biggest discrepancies were found in cases of extreme displacement.

(c) *Variation of Cooling Rates in the Mould.* In view of the greater sensitivity of the conductivity/composition relationship for magnesium alloys than for aluminium alloys, any errors due to differences in cooling rates would be most noticeable with the former. To investigate the extent of this effect, 24 specimens of magnesium alloys, previously used for the electrical tests, were heat-treated together at 405° C. for 20 hr., and then quenched in hot water. Precautions were taken to ensure a uniform rate of cooling to room temperature and the whole batch was then re-tested, with an interesting result. Instead of a standard deviation of 0·27%, as obtained on the original 64 specimens, this group of 24 of the same specimens now gave a value of 0·09%, suggesting that an appreciable improvement in consistency is obtained simply by heat-treatment and standardized cooling. Other experiments showed the extent of variation in cooling to be expected from differences in the initial temperature of the mould. For instance, bars cast at 680° C. in a mould at 150° C.—cooled to 170° C. in 9 min. after casting, whereas, with an initial mould temperature of 320° C., the bar temperature after 9 min. was 310° C. This difference naturally had a pronounced influence on resistivity. The time in the mould before stripping was also shown to be an important variable, the resistance of bars stripped 3 min. after casting being up to 6% greater than for similar bars left in the mould for 20 min. before air-cooling.

From these preliminary experiments it was clear that a greater degree of standardization in the sampling procedure was necessary if more consistent results were to be obtained. The final series of

specimens in the actual investigation were taken from the foundry, as before, but this time with laboratory supervision. Particular attention was paid to the under-mentioned points, the last three of which had not previously applied :

(*a*) Casting temperature 680° C.
(*b*) Pouring time, approx. 10 sec.
(*c*) Adequate skimming during pouring.
(*d*) Initial mould temperature, 100° C.
(*e*) Time in the mould before stripping, 5 min.
(*f*) Chemical analyses of millings from conductivity specimens.

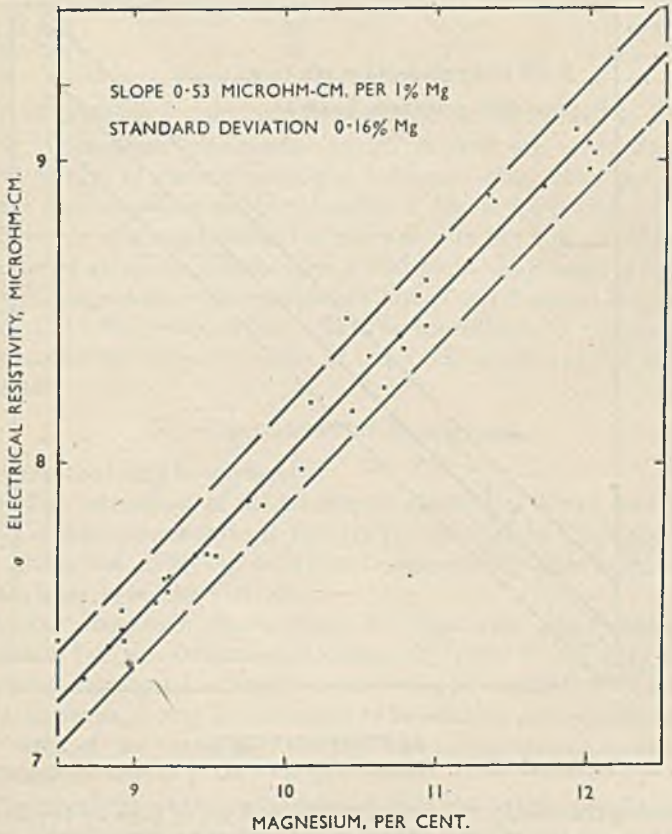

FIG. 6.—Aluminium Alloys. Relationship of resistivity to aluminium content.

The materials used were representative of normal foundry castings, a number of reliable scrap melts being included to increase the composi-

tion ranges. Maxima and minima of the compositional variations encountered were:

	Mg.	Al.	Zn.	Mn.	Cu.	Si.	Fe.
Aluminium alloys .	8·5/ 12·0	bal.	...	trace	trace	0·11/ 0·17	0·15/ 0·18
Magnesium alloys .	bal.	7·0/ 9·5	0·53/ 0·62	0·16/ 0·23	0·06/ 0·09	0·08/ 0·21	...

The results are shown in Figs. 6 and 7, in which resistivity is plotted against magnesium or aluminium content. The most suitable line

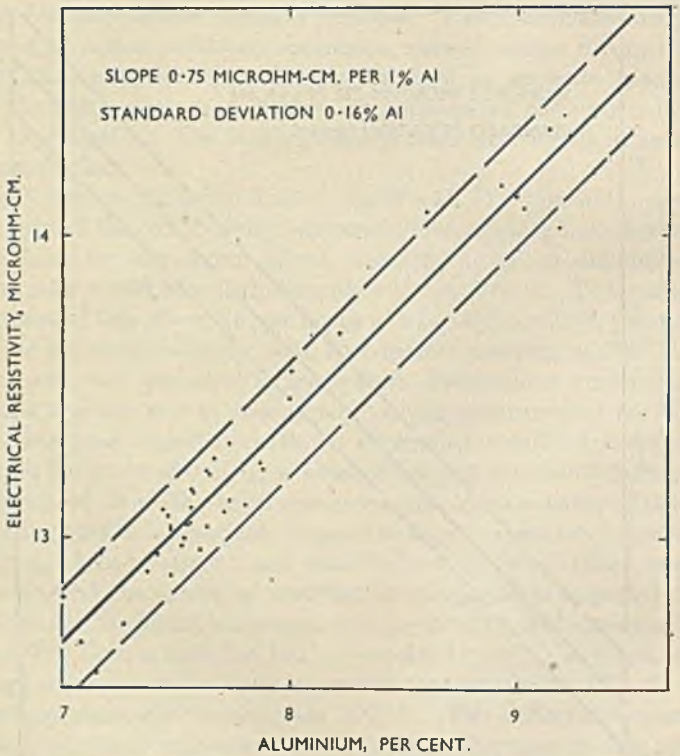

FIG. 7.—Magnesium Alloys. Relationship of resistivity to magnesium content.

expressing the relationship was fitted to each set of data by the method of least squares. Two regression lines are possible (depending on the form of expression used) which approach each other as the variability in the data becomes less. In general, the composition determined by chemical analysis was regarded as the independent variable and only

one regression line is shown in Figs. 6 and 7. However, for the sake of clarity, the standard deviations given are those of the residual variability in composition, which are a more direct indication of the potential accuracy of a method of analysis based on electrical resistivity. Owing to the high correlations obtained in the later experiments, such estimates do not differ appreciably from those based, more correctly, on resistivity.

The results obtained were :

Alloy Type.	Number of Specimens.	Slope. Michrom-cm. per 1% Added Element.	Residual Standard Deviation.
D.T.D. 300 . . .	36	0·53	0·16% Mg
D.T.D. 59A . . .	44	0·75	0·13% Al

The 0·95 probability limits of the relationships are marked in Figs. 6 and 7. Correlation coefficients as high as 0·98 are proof that, by careful control of casting technique, influences other than the major element of composition can be reduced to a degree compatible with the requirements of a rapid method of analysis. In the final experiments, the order of accuracy indicated, on a 0·95 probability basis, is approx. ± 0·30% magnesium or aluminium in alloys of specifications D.T.D. 300 and D.T.D. 59A, respectively. This is considered to represent an improvement on the performance of the spectrograph applied to these elements.

IV.—Recommended Procedure.

The method may be applied to :

(*a*) The estimation of magnesium in aluminium alloys containing 9–11% of this element (type D.T.D. 300) in cases where alloys are made from aluminium of 99·7% purity and commercially-pure magnesium, or from scrap of similar derivation.

(*b*) The estimation of aluminium in magnesium alloys containing aluminium 7–9, zinc 0·5, and manganese 0·2% (type D.T.D. 59A), where the purity corresponds to that of virgin ingot material. With these alloys, however, it may be necessary to re-establish the correlation for each batch of raw material if the zinc and manganese contents differ appreciably.

The actual relationships determined from the final series of castings are applicable only if the casting procedure described above is scrupulously followed, but it is not necessary to do this, of course, as any suitable technique may be standardized provided that a new correlation is established. Once this is done a periodical chemical analysis is all

that will be required to check the consistency of sampling procedure, and only when the check results are outside the range of tolerance indicated by the 0·95 or other chosen probability limits will further enquiry be necessary.

The measurement of resistivity takes only a few minutes and requires no elaborate equipment. As-cast specimens, machined to size, may be used. If particular values of current are chosen for each specimen diameter within the range of variation expected, then the millivolt scale of the potentiometer can be factored directly to resistivity, as in the present investigation, giving greater speed and a possible direct reading instrument calibrated in percentage composition.

ACKNOWLEDGEMENTS.

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A NOTE ON THE INFLUENCE OF ADDITIONS OF THORIUM TO MAGNESIUM-BASE ALLOYS.* 1045

By F. A. FOX,† M.Sc., Member.

Synopsis.

It has been found that, although it resembles zirconium, additions of thorium to magnesium do not produce the grain-refining effects caused by zirconium. Up to about 1·2% thorium can be introduced into magnesium–zinc alloys, but the alloys are weak and show intercrystalline fractures.

Thorium will not alloy with magnesium alloys containing aluminium, but it has some effect in reducing the iron content of such alloys.

I.—Introduction.

Zirconium is known to have a remarkable effect as an alloying addition to magnesium, producing strong grain-refinement and consequent considerable improvement of the mechanical properties.[1] It was thought that thorium, which is also a group IV element and the size factor and relative valency effect for which are not unfavourable, might also produce remarkable results when alloyed with magnesium.

This paper gives a brief account of a rough, exploratory examination of the effects of additions of thorium on magnesium and on two magnesium-base alloys.

II.—Experimental Work.

1.—*Alloying Tests.*

Preliminary tests were carried out, using a batch of thorium chloride which was later found to contain some oxy-chloride. Additions of 0·53% thorium to commercially-pure (99·8%) magnesium were successfully made in a steel crucible at 900° C., using a "diving-bell" type of tool. The alloying medium was a mixture of two parts of commercially-pure magnesium powder and one part of thorium chloride, compressed into pellets, and the same thorium content was obtained whether 2 or 10% thorium was added. The die-cast alloy had a coarse-grained, columnar structure.

As it had been found possible to alloy thorium with magnesium, the effect of thorium additions on magnesium-base alloys could be more closely examined, and other methods of alloying attempted.

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For these experiments a different batch of thorium chloride of greater purity (approx. 99·5% $ThCl_4$, with 0·5% oxy-chloride) was used.

By means of the technique described above, additions equivalent to 2% thorium were made to charges of commercially-pure magnesium, magnesium plus 3% zinc, and magnesium plus 5% aluminium. Analyses of test bars of the D.T.D.-type are given in Table I.

TABLE I.—*Analyses of Some Magnesium Alloys Containing Thorium. (Addition of* $ThCl_4$ *equivalent to* 2% Th.)

Actual Contents, % by wt.		
Thorium.	Zinc.	Aluminium.
1·1	...	...
1·21	2·9	...
...	...	4·8

An attempt was then made to prepare a mixed or double salt, $2NaClThCl_4$, which could be fused and alloyed as cast lumps, thus eliminating briquetting. Suitable proportions of sodium and thorium chlorides were well mixed and then slowly heated in a graphite crucible. The mixed salts melted at about 550° C. The molten mass was stirred with a carbon rod and then cast in the form of thin plates in a clean, thickly-dressed ingot mould. The salt so produced was grey in colour and hard and brittle. Very little fuming took place during the production of the mixed salt, and it is unlikely that there was any contamination or appreciable loss of thorium.

An alloying test with this mixed salt, using commercially-pure magnesium and an addition equivalent to 2% thorium, produced an alloy containing 1·22% thorium. Attempts were made to prepare alloys with the greatest possible thorium content and it was found that, with an addition equivalent to as much as 10% thorium, a thorium content of 1·22% was again obtained.

The similarity of these results suggests that molten magnesium will not take much more than about 1·2% thorium into true solution. This is to be expected, irrespective of the purity of the basis magnesium used, since the addition of as much as 10% thorium in the form of mixed salt can be expected to produce its own effective purification of the magnesium by preliminary precipitation from the melt of impurities which will form insoluble compounds with thorium. This mechanism operates, for example, in the case of alloying with zirconium salts, in which small traces of impurities (like aluminium and silicon) in the magnesium are precipitated by part of the zirconium salt addition before the rest supplies zirconium for effective solution in the melt.

2.—*Microstructures.*

Thorium apparently has no grain-refining effect on magnesium and all the binary alloys had a coarse columnar structure, similar to that of magnesium of ordinary purity. The microstructures showed a second phase, well-marked grey-blue in colour, which appeared in the grain boundaries in a serpentine form—suggesting a degenerate eutectic —and also as small precipitated particles within the grains; Fig. 1 (Plate XIX) shows a typical structure. The precipitation was "crystallographic" in form and was distributed at random within the grains. The precipitated particles were very small, and could be resolved only at a magnification of approx. × 1000, but at low magnifications the particles could be seen as faint parallel streaks. Thorium apparently has some slight solid solubility in magnesium, but the amount which can be held in solution is evidently small. Samples heated for 24 hr. at both 420° and 500° C. and quenched in cold water showed no signs of any solution of the small precipitated particles.

The second phase would appear to be a magnesium–thorium phase rather than to consist mainly of thorium metal. This supposition is based partly on the well-marked blue colour of the phase, whilst metallic thorium (of which a sample was available) is silvery white as seen under the microscope.

3.—*Tensile Properties.*

The tensile strengths of die-cast test bars of a binary magnesium–thorium alloy with a thorium content of 1·1% were found to be very low—less than 2 tons/sq.in. Examination of the fractures was difficult because of the large grain-size, but they seemed to be intercrystalline.

An addition of 2% thorium as mixed chlorides was made to a magnesium–zinc alloy containing 3% zinc, and four sand-cast D.T.D.-type test bars were made from the melt. The tensile properties were low, being less than those for the simple binary magnesium–zinc alloy. This comparison is shown in Table II below.

TABLE II.—*Average Tensile Properties of Alloys Containing Zinc and Thorium.*

Alloy.	0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.
Mg + 3% Zn + 1·2% Th .	2·5	6·8	5·5
Average properties of an alloy of Mg with 3% Zn . .	2·4	8·7	6·5

The alloy showed an almost complete network of a serpentine intercrystalline phase with some duplex lamellar areas (Fig. 2, Plate XIX). No precipitated thorium phase was seen within the grain and no magnesium–zinc phase was detected. This thorium-containing phase was identical in colour with that in the binary magnesium–thorium alloy, but, although the thorium content (1·2%) was the same as in the binary alloys, more thorium-containing phase could be seen. This suggested that the apparently limited solubility of thorium in magnesium may be reduced even further by the presence of zinc. The fracture of the broken test bars was almost completely intercrystalline, which helped to explain the poor tensile properties.

4.—*Magnesium–Aluminium–Thorium Alloys.*

A melt of a binary alloy containing 5% aluminium was made from commercially-pure magnesium and commercial (99·7%) aluminium, 2% thorium being added as thorium chloride. The mean results of tensile tests are given in Table III.

TABLE III.—*Properties of a Magnesium–Aluminium Alloy after Addition of Thorium.*

Alloy.	0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.
Mg + 5% Al + addition of Th .	2·7	8·9	8·5
Typical test values for the binary alloy containing 5% Al .	4·2	13·7	10

These results for the thorium-containing alloy were low and the test bars had coarse fractures, almost similar to that of magnesium of ordinary purity. Micro-examination confirmed that the test bars were exceptionally coarse-grained: columnar grains reached almost to the centre of the test bar, while the central area consisted of three or four grains of dentritic formation with an average diameter about 3 mm. (Fig. 3, Plate XX). No trace of thorium could be detected in the microstructure, and analysis showed that, while the aluminium content was 4·8%, the thorium content was nil.

A considerable amount of pasty residue was recovered from the melting pot and a section cut from this contained large irregular inclusions of a hard compound (Fig. 4, Plate XX). This was presumed to be a thorium–aluminium compound, the formation and precipitation of which was likely to be the reason for the failure to introduce thorium into the alloy.

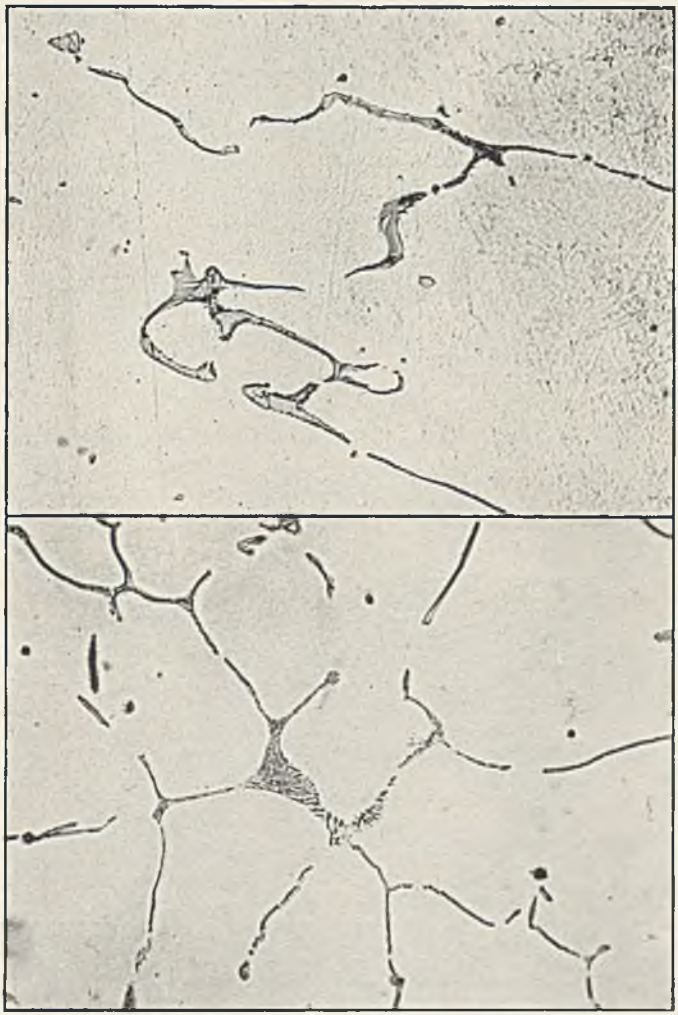

FIG. 1.—Section from Die-Cast Test Bar in Alloy Mg + 1·2% Th, showing Thorium Phase in Grain Boundaries. × 600.

FIG. 2.—Section from D.T.D.-Type Sand-Cast Test Bar in Alloy Mg + 3% Zn + 1·2% Th, showing Thorium Phase in Grain Boundaries. × 350.

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FIG. 3.—Cross-Section of D.T.D.-Type Sand-Cast Test Bar in 5% Aluminium Alloy Treated with Thorium. Macro-etched. × 2.

FIG. 4.—Aluminium–Thorium Compound Found in Residue from Melt of 5% Aluminium Alloy Treated with Thorium. × 350.

5.—*Grain-Coarsening Effect of Thorium Additions.*

The extraordinary coarseness of the aluminium-containing test bars suggested that thorium might be a general grain-coarsener of the magnesium–aluminium alloys, acting in a similar way to zirconium and beryllium,[2] but more powerfully. To check this, additions of thorium were made to Elektron A8 (a magnesium-base alloy containing about aluminium 8, zinc 0·4, and manganese 0·3%), to supplement the data already obtained on the 5% aluminium alloy. 10 lb. of Elektron A8 ingot was melted in a mild steel crucible and superheated for 5 min. at 900° C. The crucible was then allowed to cool in air to a temperature of 760° C., at which three D.T.D.-type test bars were poured. The remaining metal was then reheated to 850° C. and 2% thorium added in the form of the mixed chlorides. The melt was allowed to stand for 5 min. at 850° C. It was then cooled in air to 760° C. and three more D.T.D.-type test bars were cast. Grain-size determinations and analyses for iron were carried out on both series of bars. The test bars were then given a solution-treatment for 24 hr. at 420° C. and tests made of their tensile properties; mean results are given in Table IV.

As can be seen, the addition of thorium caused a distinct increase in grain-size. Micro-examination also showed the presence of typical "superheated" structures before adding the thorium and typical unsuperheated structures after adding the thorium.[2]

The thorium addition evidently removed some iron, but this was considerably less than the amount which can be removed by zirconium

TABLE IV.—*Effect of Thorium Additions on the Tensile Properties of Solution-Treated Elektron A8.*

Samples.	Grain-size, mm.	Iron, %.	Thorium, %.	0·1% Proof Stress, tons/sq.in.	Ultimate Tensile Strength, tons/sq.in.	Elongation, % on 2 in.
Solution-treated, cast before addition of thorium . .	0·07	0·047	...	4·8	15·6	10
Solution-treated, cast after addition of thorium . .	0·12	0·026	nil	4·7	15·3	11

from the aluminium-containing alloys if added under the same conditions. The grain-coarsening effect was also less than that produced by additions of zirconium to alloys containing aluminium.

The experiments with Elektron A8 did not produce the remarkable grain-coarsening effects which were obtained with the 5% aluminium

alloy. This marked difference in grain-coarsening effect is rather interesting, and it may be that a somewhat different mechanism operates in the case of thorium additions from that for beryllium and zirconium, the grain-coarsening effects of which are independent of the aluminium content of the alloys.

III.—Conclusions.

(*a*) Up to about 1·2% thorium can readily be introduced into magnesium and magnesium–zinc alloys.

(*b*) The thorium additions produce no grain-refining action, but give rise to a serpentine grain-boundary phase.

(*c*) The alloys are weak, and have intercrystalline fractures.

(*d*) Thorium will not alloy with magnesium alloys containing aluminium, but forms insoluble aluminium–thorium compounds.

(*e*) Like zirconium and beryllium, thorium tends to remove or decrease the iron content and coarsens the grain of magnesium–aluminium alloys, but its effect in both cases is not so powerful as that of the former elements.

(*f*) The binary magnesium–thorium alloys and the magnesium–zinc–thorium alloys are not likely to be technically useful. The possible utility of thorium in other combinations or more complex magnesium-base alloys, however, is not excluded, as, if effectively combined with a hardening and grain-refining element, it might confer some useful properties.

Acknowledgements.

The author's thanks are due to the Directors of Magnesium Elektron, Ltd., for permission to publish this paper and to Mr. E. Lardner, B.Sc., formerly of the laboratories of the firm, under whose direct supervision the investigation described in this paper was carried out.

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INVESTIGATIONS ON THE EFFECT OF ZINC ON THE CORROSION OF SOME MAGNESIUM CASTING ALLOYS.* 1046

By F. A. FOX,† M.Sc., Member.

Synopsis.

Corrosion tests have been carried out on unprotected magnesium–8 and 9·5% aluminium alloys with varying zinc contents, both in high-purity and in normal-purity material; immersion in 3% sodium chloride solution was mainly employed, but some atmospheric-exposure tests were made also.

For the material of normal purity it was found that zinc additions were beneficial to the corrosion-resistance as tested by immersion, provided that the zinc content was not appreciably below 0·4%. It was not, however, of much value to add zinc in amounts much above approximately 0·5%, especially in the case of fully heat-treated material, although for the as-cast and the solution-treated states, the higher-zinc alloys were rather better than the lower-zinc alloys.

In the case of atmospheric exposure, the varying zinc content of the alloys did not greatly affect the results, but the state of heat-treatment had a different effect on the corrosion-resistance from that during total immersion.

For the unprotected magnesium–5% aluminium alloys of higher purity, the addition of zinc reduced the resistance to salt-water attack.

Corrosion-potential determinations were made on the alloys of higher purity, and it was found that the addition of zinc resulted in an elevation of the potential. It was concluded that the zinc reduced cathodic polarization, probably by increasing the available cathodic area.

I.—Introduction.

The compositions of magnesium-base alloys used in this country and in the U.S.A. are generally similar, but the zinc contents have differed, the Americans usually favouring higher zinc contents than ourselves. The reasons for the use of the higher-zinc alloys (2–3% zinc) are usually given as greater corrosion-resistance, better castability, and somewhat improved mechanical properties. The points in favour of a lower zinc content (about 0·4%) are commonly stated as greater freedom from microporosity, more uniform response to heat-treatment, and greater freedom from hot-cracking troubles in the foundry.

There is evidence,[1, 2] that American technicians are now tending to abandon the higher-zinc alloys and to prefer alloys of lower zinc content, at least for applications in which best properties and reliability are important.

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This paper deals with the results of corrosion investigations carried out in the laboratories of Magnesium Elektron, Ltd., over a period of some years. This work has had the object of throwing light on the part played by zinc in the corrosion of magnesium–aluminium–zinc alloys, both of normal and of higher purity.

The data on this subject are rather meagre. Mutchler [3] states that the addition of zinc to magnesium–aluminium alloys results in an increase in corrosion-resistance. Some corrosion tests carried out by Wray,[4] using intermittent immersion (tide-water) on painted specimens, showed that metal containing about 6% aluminium and 3% zinc was more corrosion-resistant than other aluminium-containing alloys of lower zinc content.

Peloubet [5] describes the results of two-year atmospheric-corrosion tests at a location 800 yards from the Atlantic Ocean; his results show a slight but distinct advantage for the lower-zinc alloys, whether of normal or of high purity. His results also indicate no material improvement in the performance of high-purity material over that of corresponding alloys of normal purity, in these conditions of test.

Hanawalt and his associates [6, 7] found that the advantage of high zinc contents in magnesium-base alloys was that the "tolerance" for iron and nickel was raised considerably. High zinc contents might, therefore, be expected to be beneficial in cases where the impurity limits are becoming dangerously high. The value of zinc in high-purity alloys is not clear from their researches.

The description of the investigation is divided into two parts, corresponding roughly to a chronological gap: the work described in Section II of the paper was also of a preliminary and exploratory character.

II.—"Normal"-Purity Alloys.

This part of the research dealt exclusively with alloys of "normal" purity, that is with casting alloys with an iron content above 0·005%, and, in practice, more usually above 0·01%. The basic alloys examined first consisted of two ternary alloys: (*a*) aluminium 8 (approx.), manganese 0·3% (approx.), magnesium remainder; (*b*) aluminium 9·5 (approx.), manganese 0·3% (approx.), magnesium remainder. To these basic alloys differing amounts of zinc were added, up to 1·0% (nominal) in four steps in the former case (Series *A*), and up to 1·5% (nominal) in four steps in the latter case (Series *B*). Including the basic alloys themselves, this made a total of ten alloy melts.

1.—*Experimental.*

The test materials, commercial magnesium ("Melpure"), 99·5% aluminium, and G.O.B. spelter, were melted in steel crucibles in 10-lb. lots under the usual proprietary fluxes, alloyed at 780° C., superheated to 900° C., cooled rapidly to 760° C., and cast, each melt yielding six vertically cast die bars of 1-in. dia.

Two bars from each melt were retained in the as-cast state; the other four were solution-treated as follows:

(i) Metal containing less than 0·8% zinc was heated for 8 hr. at 385° C. and then for 16 hr. at 420° C.

(ii) Metal containing 0·8% zinc or more was maintained at 350° C. for 8 hr.; the temperature was then increased to 405° C. and held constant for 16 hr.

The bars were quenched in water after solution-treatment, and two were then given a precipitation treatment (14 hr. at 200° C.). Each bar was machined to give three, standard, cylindrical, corrosion test pieces of the type described in earlier papers.[8]

All the corrosion tests were of the standard type: the specimens were prepared on IF emery paper, degreased in carbon tetrachloride vapour, weighed, and immersed in 3% sodium chloride solution at 17°–20° C. saturated with magnesia. After a suitable time interval (50–100 hr.), the samples were removed, washed in warm water, cleaned in boiling chromic acid, washed, dried, and reweighed. The loss in weight of the specimens was taken as a measure of the mean corrosion rate over the time of exposure.

In this and the later work described in this section of the paper it will be noted that IF emery paper was used to prepare the samples: in a paper describing later studies,[9] it is shown that such a method of preparation is not satisfactory if the best corrosion results are to be obtained. However, experience has also shown that the results obtained in this case are not likely to be materially affected, as the IF-emery preparation has significant adverse effects only in the case of high-purity material.

2.—*Results.*

The analytical data are given in Table I, and the corrosion-test results in Figs. 1–3, in which the ordinates show the mean corrosion rate reduced to g./sq.dm./100-hr. exposure. Each point on the graphs represents the mean of six results; the scatter between individual results was not great.

The iron contents are rather higher in all three series of melts than is normal in large-scale alloying operations; this is not un-

expected in laboratory melting and is attributable to the more effective stirring action (during flux refining) which takes place in small crucibles. The iron contents are not particularly important in these specimens,

TABLE I.—*Analytical Data for Aluminium-Containing Alloys with Varying Zinc Content (Corrosion Test Pieces).*

Series *A*.					Series *B*.				
Nominal Zinc Content, %.	Mean Analytical Results, %.				Nominal Zinc Content, %.	Mean Analytical Results, %.			
	Al.	Mn.	Fe.	Zn.		Al.	Mn.	Fe.	Zn.
0	...	0·45	0·032	0·05	0	...	0·28	0·041	0·05
0·2	7·9	0·46	0·035	0·20	0·3	9·10	0·32	0·048	0·27
0·4	to	0·47	0·031	0·32	0·6	to	0·27	0·027	0·43
0·6	8·4	0·47	0·033	0·59	1·0	9·80	0·27	0·028	0·86
1·0	...	0·38	0·040	1·18	1·5	...	0·34	0·049	1·40

Nickel contents in all cases $<0{\cdot}002\%$.

however, since they are not "high-purity" materials, and in the range of iron contents in the melts there is sufficient manganese present [8] to render negligible the effects of the observed analytical differences.

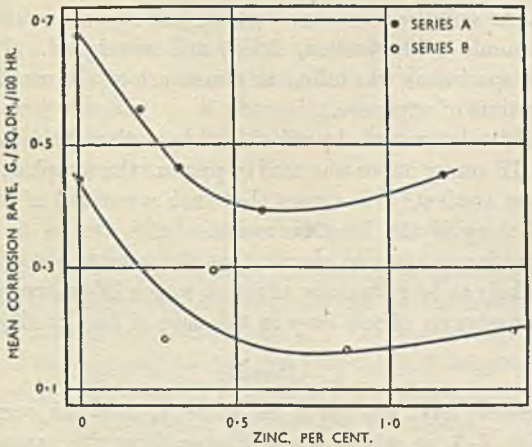

FIG. 1.—Mean Corrosion Rates of Chill-Cast Magnesium–Aluminium–Zinc Alloys Series *A* and *B*.

From the curves in Figs. 1–3, it appeared that zinc additions improved the resistance of the unprotected metal on immersion in sodium chloride solution, provided that the zinc content was not much

below about 0·4%. It also seemed unnecessary to add zinc appreciably above about 0·5%.

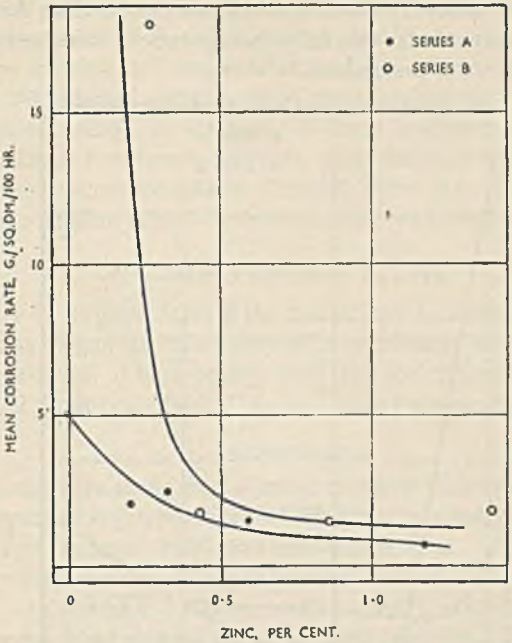

FIG. 2.—Mean Corrosion Rates of Solution-Treated Magnesium–Aluminium–Zinc Alloys Series *A* and *B*.

Further similar tests were made to compare the immersion behaviour of as-cast, and of heat-treated, Elektron A8, Elektron AZ91, and two other alloys, one containing 6% aluminium and 3% zinc, and the other

TABLE II.—*Immersion Corrosion Tests on Four Magnesium–Aluminium–Zinc Alloys.*

Alloy Designation or Mark.	Composition, %.				Mean Corrosion Rate, g./sq.dm./100-hr. exposure.		
	Al.	Mn.	Fe.	Zn.	Chill-Cast State (168-hr. exposure).	Solution-Treated State (161-hr. exposure).	Fully Heat-Treated State (92-hr. exposure).
Elektron A8	8·1	0·47	0·031	0·32	0·464	2·48	0·731
" AZ91	9·5	0·27	0·027	0·43	0·296	1·81	0·394
Alloy "S"	9·6	0·29	0·028	1·83	0·256	1·33	0·672
" "T"	6·0	0·33	0·027	2·9	0·382	0·368	4·44

Nickel content in all cases $<0·002\%$.

Each entry for corrosion rate is the mean of six results.

9·5% aluminium and 2% zinc. The results are given in Table II. In the chill-cast and in the solution-treated states the higher-zinc alloys behave rather better in the immersion test than do those with lower zinc content. In the fully (precipitation) heat-treated state, a lower zinc alloy was preferable.

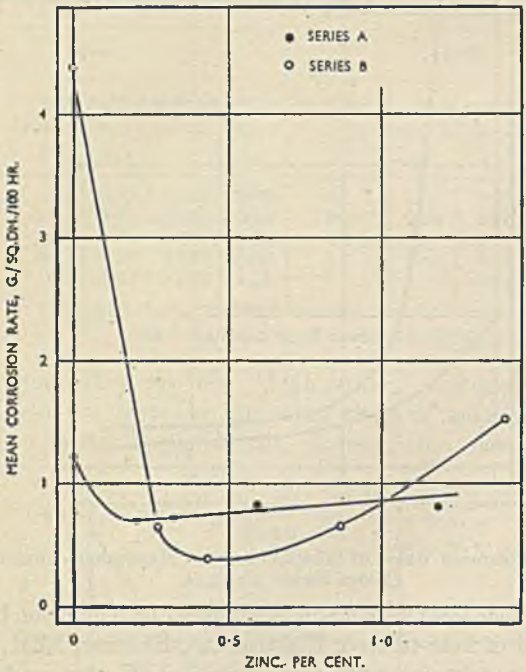

FIG. 3.—Mean Corrosion Rates of Fully Heat-Treated Magnesium–Aluminium–Zinc Alloys Series *A* and *B*.

TABLE III.—*Atmospheric Corrosion Tests on Four Magnesium–Aluminium–Zinc Alloys.*

Alloy Designation or Mark.	Mean Corrosion Rate, g./sq.dm./100-days exposure.		
	Chill-Cast State (100-days exposure).	Solution-Treated State (84-days exposure).	Fully Heat-Treated State (84-days exposure).
Elektron A8 . .	0·581	0·367	0·276
„ AZ91 . .	0·552	0·319	0·290 *
Alloy "S" . .	0·485	0·424	0·319
„ "T" . .	0·511	0·333	0·329

Each entry is the mean of six results, except for the specimen marked *, which is the mean of three.

Atmospheric corrosion tests were also carried out on the alloys mentioned in Table II, and the results are given in Table III. These results are of interest as they show, not only that the composition and varying zinc content of the alloys do not greatly affect corrosion rate (in spite of the varying iron concentrations from alloy to alloy), but also that fully heat-treated metal is more corrosion-resistant than solution-treated metal, which, in its turn, is more resistant than chill-cast material. These results are, however, quite different from those under salt-water-immersion conditions. In the latter case, if the zinc content is low, corrosion is most severe in the alloys in the solution-treated state.

III.—Higher-Purity Alloys.

In order to explore further the indications described in Section II, research was begun on the effect of zinc content on the corrosion-resistance of alloys of high purity, with iron and nickel contents below the so-called " tolerance limits " for the binary magnesium alloys.

1.—*Experimental.*

Four melts were made from a stock of ingots of binary magnesium–5% aluminium alloy (prepared from " Melpure " electrolytic magnesium, and with iron approx. 0·003 and nickel less than 0·001%) and zinc (99·99% purity) was added to give nominal zinc contents of 0·3, 1·0, 2·0, and 3·0%. In addition, a melt of magnesium–5% aluminium alloy was made using sublimed magnesium as the basis material. Three chill-cast bars were poured from each melt, and from each bar three corrosion specimens of the usual cylindrical type were machined. In addition, some of the ingot stock of the magnesium–5% aluminium alloy was remelted and cast into two die bars, from which four corrosion specimens were machined. All melting was carried out in graphite crucibles, using graphite stirring rods, so no contamination of the material by iron or nickel could occur. Analyses of the melts are given in Table IV.

Table IV.—*Analyses of High-Purity Melts of Magnesium–Aluminium–Zinc Alloys.*

Melt No.	Magnesium Stock Used.	Composition, %.				
		Al.	Mn.	Zn.	Fe.	Ni.
1	" Melpure "	4·7	0·26	Nil	0·001	0·001
2	Sublimed metal	4·9	0·30	Nil	0·0032	0·001
3	" Melpure "	5·1	0·50	0·39	0·0024	0·001
4	"	4·9	0·51	0·91	0·0027	0·001
5	"	4·8	0·48	2·4	0·0035	0·001
6	"	4·6	0·50	3·2	0·0032	0·001

The specimens were prepared for the corrosion tests by gentle abrasion with moist pumice powder. They were then degreased in carbon tetrachloride vapour, weighed, and immersed in 3% sodium chloride solution, saturated with magnesium hydroxide. After a suitable time interval, the samples were removed, washed in warm

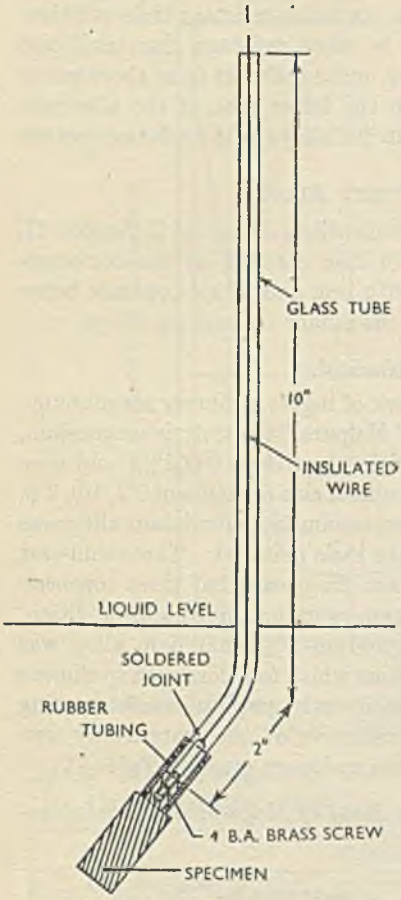

FIG. 4.—Method of Mounting Specimens for Measurement of Electrode Potential.

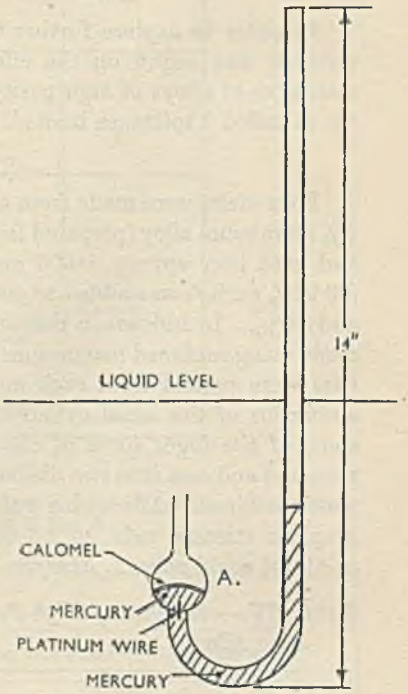

FIG. 5.—Diagram of Calomel Electrode.

water, cleaned in boiling chromic acid, washed, dried, and reweighed. The loss in weight of the specimens was taken as a measure of the mean corrosion rate.

In addition to calculating the corrosion rates of the alloys, the corroding potentials were also measured, in the hope that this might

throw some light on the mechanism of corrosive attack. For these measurements, the spigot on the specimen was drilled and tapped to carry a 4-B.A. brass screw, and at the outer end of the screw an insulated wire was soldered leading up through a glass tube which rose above the surface of the liquid for about ten in. The specimen was attached to the glass tube by a piece of rubber tubing, and the general arrangement is shown in Fig. 4.

As a reference electrode, a calomel electrode was used, of the design shown in Fig. 5. The mercury surface in the bulb *A* was covered with a paste made of calomel and the corroding solution, and the bulb was then filled with the same solution. This eliminated significant liquid-junction potentials, and the troubles likely to be caused by appreciable diffusion at such junctions. The potential of this electrode, relative to the saturated calomel electrode, was + 0·045 V. at 20° C. The potentials of the specimens were measured on a Cambridge electrometer valve potentiometer, using a Cambridge Weston cell in opposition to the potential to be measured. This last step was necessary because the potential of the specimen relative to the calomel electrode is about — 1·6 V., and the potentiometer had a range of only 1·4 V.

2.—*Results.*

The results of the corrosion tests are given in Fig. 6. With the exception of the specimens made from remelted magnesium–5% aluminium alloy, to which no zinc had been added, the specimens of each alloy were removed in two batches, after 15 and 30 days, respectively. The specimens of the binary alloy without zinc were removed after 24 days, as they were included in another experimental programme.

In Table V are recorded the mean daily potentials for each batch of specimens. The scatter in any group of specimens was very small and justifies the recording of mean potentials only.

From the corrosion results shown in Fig. 6 it is seen that:

(*a*) The zinc-free alloys, made from sublimed magnesium and "Melpure" magnesium, possess equal corrosion-resistance and corrode at the rates found by Hanawalt [6] for high-purity alloys (0·15 ± 0·05 mg./sq.cm./day).

(*b*) The addition of zinc to these high-purity materials results in an increase in mean corrosion rate, which is quite marked with the first small additions. The increase is not, however, uniformly maintained at higher zinc concentrations.

(*c*) There is a slight indication from Fig. 3 that, while the corrosion rate of the zinc-free alloy decreases with time, the corrosion

rates of the alloys containing zinc are approximately constant. With the few results available, however, it is impossible to say whether this apparent relation with time of the corrosion rate of the zinc-free alloy is significant.

TABLE V.—*Mean Daily Potentials (Volts Hydrogen Scale) of Higher-Purity Alloys Tested.*

Day No.	Melt No.					
	1.	2.	3.	4.	5.	6.
1	1·515	1·337	1·320	1·322	1·324	1·321
2	1·405	1·324	1·303	1·300	1·299	1·297
3	1·389	1·326	1·303	1·299	1·300	1·294
4	1·383	1·329	1·299	1·293	1·291	1·286
5	1·382	...	...	...	...	...
6	...	1·338	1·295	1·292	1·284	1·281
8	1·367	1·341	1·295	1·292	1·281	1·278
9	...	1·341	1·297	1·291	1·282	1·278
10	1·346	1·336	1·294	1·290	1·279	1·276
11	1·345	1·325	1·291	1·289	1·279	1·275
12	1·344	1·332	1·293	1·288	1·277	1·275
14	...	1·324	1·296	1·286	1·274	1·276
15	1·338	1·332	1·296	1·288	1·278	1·277
16	1·334	1·322	1·290	1·283	1·272	1·272
17	1·328	1·323	1·293	1·284	1·269	1·272
18	1·325	1·334	1·292	1·285	1·273	1·271
19	1·322	...	...	...	...	...
22	1·313	1·336	1·293	1·279	1·272	1·273
23	...	1·333	1·291	1·281	1·272	1·270
24	...	1·332	1·298	1·278	1·274	1·270
25	1·297	1·325	1·293	1·279	1·268	1·271
26	...	1·329	1·291	1·288	1·273	1·271
28	...	1·329	1·288	1·281	1·271	1·273
29	...	1·325	1·292	1·277	1·272	1·271
30	...	1·325	1·290	1·274	1·272	1·272
31	...	1·327	1·290	1·276	1·269	1·270

The results in Table V show that the zinc-free alloys corrode at more negative potentials than do the alloys containing zinc; in fact, the addition of zinc tends to ennoble the corroding metal. Also, the zinc-free alloy made from sublimed magnesium is slightly less noble than that made from "Melpure" magnesium.

In order to relate the electrode-potential determinations to the corrosion results, it is convenient to refer to the type of diagram popularized by U. R. Evans [10] and his school (see Fig. 7).

The corrosion of the metal by the aqueous solution proceeds by an electrolytic mechanism, which is dependent on the existence of anodic and cathodic areas on the metal surface. At anodic areas, metallic ions pass into the solution, and at cathodic areas, reactions occur

which remove electrons from the metal. In the case of magnesium alloys corroding in salt solutions, the cathodic reaction merely consists of the discharge of hydrogen ions, with the ultimate formation of hydrogen molecules, which are evolved as gas bubbles. If no current

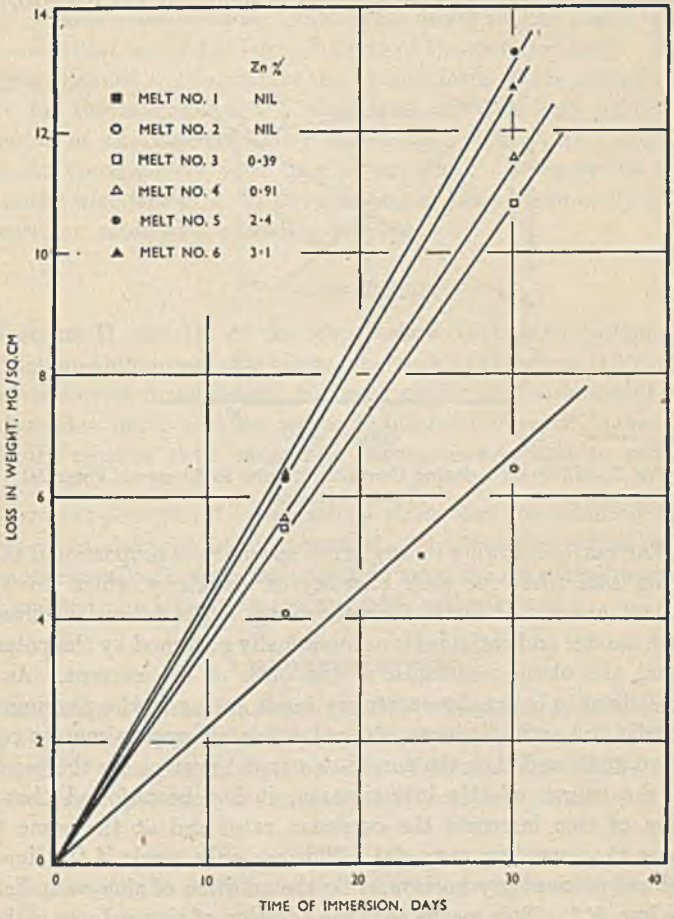

FIG. 6.—Corrosion–Time Curves for Specimens of Magnesium–5% Aluminium Alloy Containing Varying Amounts of Zinc.

were flowing and the reactions at the anodes and cathodes were truly reversible, the potential of the cathodes would be that of the reversible hydrogen electrode in the solution used. This value is indicated by the point *A* in Fig. 7. Similarly, the potential of the anodes would be that of the reversible magnesium–magnesium-ion electrode (slightly

modified owing to the alloying additions), as indicated by point *B*. The flow of current, however, results in considerable polarization of the anodic and cathodic areas. This depresses the cathodic potential, and increases the anodic potential. In Fig. 7, plotting potentials as ordinates and currents as abscissæ, this is shown by the lines *AC* and

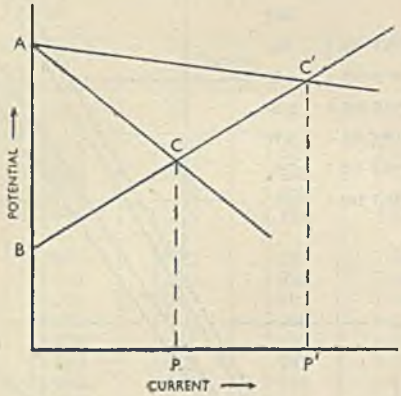

FIG. 7.—Diagram Relating Corrosion Results to Electrode-Potential Determinations.

BC. The current flowing in any given specimen is proportional to the corrosion rate (thus for each Faraday of electricity which flows, an equivalent amount of metal corrodes away). The potential difference between anodes and cathodes is automatically governed by the polarization and the ohmic resistance of the path of the current. As the ohmic resistance is usually extremely small, owing to the proximity of the anodic and cathodic areas, the potentials are approximately equal, as shown at *C*, and thus the corroding current is given by the point *P*.

In the course of this investigation, it has been found that the addition of zinc increases the corrosion rate, and at the same time increases the corroding potential. This can only result if the line *AC* is rendered more nearly horizontal by the addition of zinc, as indicated by the line *AC'*. This means that the addition of zinc reduces cathodic polarization, with a consequent increase in the corroding current as indicated by *P'*. As the polarization at the anodes and cathodes is a function of the current density at these areas, it is reasonable to assume that the addition of zinc increases the area of the cathodes available, rather than causing some fundamental difference in the nature of the cathodes. It is, however, impossible to decide finally between these two possibilities with the few results available.

The potentials recorded in Table V show that there is initially a sharp increase in potential, after which the values are approximately constant. This constancy of the corroding potentials during the greater part of the test suggests that the corrosion rates are also constant. These considerations throw some doubt on the slight apparent decrease with time of the corrosion rate of the zinc-free alloy. Further study is planned, to determine the precise form of the corrosion–time curve for the magnesium–5% aluminium alloy of high purity. The potential of the zinc-free alloy made from "Melpure" magnesium increased continuously with time of exposure. However, as all four specimens were tested for 24 days, no sound comparison could be made of corrosion rates with corroding potentials.

IV.—Conclusions.

Sections II and III of the paper show that, with normal-purity magnesium–aluminium–zinc alloys, the presence of about 0·5% of zinc improves corrosion-resistance. However, zinc in itself is undesirable from the corrosion point of view, as its addition to alloys of higher purity markedly reduces their resistance (when unprotected) to salt-water attack.

Corrosion-potential determinations show that the addition of zinc results in an elevation of the potential. It is concluded that, in view of the increased corrosion rates, the zinc must reduce cathodic polarization, probably by increasing the available cathodic area.

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The author's thanks are due to the Directors of Magnesium Elektron, Ltd., for permission to publish the results of this investigation, and also to Mr. C. J. Bushrod, M.Sc., formerly of Magnesium Elektron, Ltd., under whose supervision the experimental work was carried out.

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

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METALLURGICAL ABSTRACTS

AUTHOR INDEX TO ABSTRACTS

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 13 DECEMBER 1946 Part 12

I.—PROPERTIES OF METALS

***The Mechanical Properties of Copper at High Temperatures.** A. A. Bobylev and A. I. Chipizhenko (*Tsvet. Metally*, **1945**, (3), 62–65).—[In Russian]. Annealed wires, 6 mm. in dia., were tested at three rates of extension (1, 20, and 300 mm./min.) at temp. from 20° to 900° C. With increase in the rate of extension, the strength and plasticity of copper become greater. The deleterious effect of the ambient atmosphere is connected with its action on the grain boundaries, which results in the formation of intercrystalline cracks and leads to a sharp decrease in plasticity.—N. A.

***The Influence of Small Iron Contents on the Properties of Copper and Alpha Brasses.** (Shpichinetsky and Rogel'berg). See p. 412.

Lithium, the Lightest Known Metal. G. Fitzgerald-Lee (*Aircraft Eng.*, 1946, **18**, (203), 32).—A brief note on the properties, applications, and economics of lithium.—H. S.

Cavitation in Centrifugal Pumps. A. H. Stepanoff (*Trans. Amer. Soc. Mech. Eng.*, 1945, **67**, (7), 539–552; *Corr. Abs.*, 1946, **2**, (3), 45).—The present state of information on cavitation of centrifugal pumps is presented, with a method for determining cavitation conditions from velocity considerations. The model-test laws as applied to cavitation are deduced, with their limitations. The presence of gases in liquids does not affect the cavitation of pumps, except that vaporization starts at a higher absolute pressure, due to the law of partial pressures. Drop in head capacity may appear earlier because of liberation of gases under reduced pressure, and the water-hammer effect of collapsing vapour bubbles is cushioned. Penetration of metals by water under repeated stresses furnishes a logical explanation for the origin of local destructive high pressures found during cavitation, and also for the cases of metal failure from fatigue in presence of liquids. 32 references are given.

***The Influence of Rate on the Resistance of Metals to Plastic Deformation.** L. D. Sokolov (*Zhur. Tekhn. Fiziki*, 1946, **16**, (4), 437–442).—[In Russian]. Static compression tests (at rates of 0·01 and 1·0 mm./sec.) and dynamic tests (at an average rate of 2000 mm./sec.) were carried out in the cold and at elevated temp. on 20-mm.-high cylinders of lead, copper, and steels of various carbon contents. True-stress curves were constructed from the results. The rate coeff. (*i.e.*, the ratio of the change in true stress to change in rate) increases with rise in temp. and with diminution of the m.p. of the metal, and has a single-order value for an increase in rate in the ranges indicated above.—N. A.

***Examination of the Wood and Smith Effect [in Aluminium].** N. N. Davidenkov and M. I. Timofeeva (*Zhur. Tekhn. Fiziki*, 1946, **16**, (3), 283–290).—[In Russian]. Experiments were made to measure the residual stresses of the first order in the outer layers of stretched aluminium specimens. Negative results were obtained in all cases, and no residual stresses were found.—N. A.

The Surface Strain of Metals. A. Kh. Breger and A. A. Zhukovitsky (*Zhur. Fiz. Khim.*, 1946, **20**, (4/5), 355–362).—[In Russian]. On the basis of Sommerfeld's model, it is shown that the dispersion of a metal leads to an increase in the kinetic energy of the electrons, and this is the fundamental physical cause of the large surface strain of metals. A formula is deduced

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

for calculating surface strain, which gives accurately its order of magnitude and its relation to the density of the electron gas. In the case of a linear model it is shown that surface strain may also be determined by the method of molecular orbits.—N. A.

The Theory of Fatigue Strength Under Complex Stresses. N. N. Afanas'ev (*Zhur. Tekhn. Fiziki*, 1946, **16**, (4), 443–454).—[In Russian]. A theory has been worked out for real polycrystalline metals, based on the probability of finding the crystals most favourably orientated in relation to the max. shear stresses acting in the metal.—N. A.

***Hydrogen and Proton Gas in a Metal.** A. I. Krasnikov (*Izvest. Akad. Nauk S.S.S.R.*, 1946, [Tekhn.], (1), 133–140).—[In Russian]. An experimental spectrographic study was made of the state of hydrogen in a metal, the action of X-rays, and the structure of the lines of the $K\alpha_1\alpha_2$ doublet. It is shown that hydrogen in the form of protons is a factor determining the structure of the doublet and also the properties of the material. The linkage of the atoms of the material is determined by the energy state of its proton gas. The state of the electron gas is a function of the state of the proton gas. The reaction oxidation–reduction can be described in terms of the redistribution of protons.—N. A.

***The Gyromagnetic Effect in Supraconductors [Lead].** I. K. Kikoin (*Zhur. Tekhn. Fiziki*, 1946, **16**, (2), 129–154).—[In Russian]. The existence of the Einstein–de Haas effect in supraconductors was demonstrated by experiments on supraconducting lead. The numerical value of the Lande factor was found to be $1 \pm 0{\cdot}03$, indicating that the gyromagnetic effect is due to short-circuit currents.—N. A.

Semi-Conductors and Their Application. A. F. Joffe (*Izvest. Akad. Nauk S.S.S.R.*, 1946, [Fiz.], **10**, (1), 3–14).—[In Russian]. Delivered at a session of the Physico-Mathematical Division of the Academy of Sciences of the U.S.S.R., during the celebration of the 220th anniversary of the founding of the Academy. A review is given of the work at the Physico-Technical Institute relating to these questions: the determination of the number and mobility of conductivity electrons; electrical conductivity in strong fields; the mechanism of electrical conductivity; boundary layers; photo-electric phenomena; and the application of semi-conductors.—N. A.

***Secondary Electron Emission from Oxide-Coated Cathodes.—II.** Martin A. Pomerantz (*J. Franklin Inst.*, 1946, **242**, (1), 41–61).—Apparatus and experimental procedure are described for an investigation of electron emission from oxide-coated cathodes. It is concluded that the high secondary electron yields may not be attributed to some modification of the Matter effect.

—H. J. A.

II.—PROPERTIES OF ALLOYS

***Report of the Automobile Research Committee on Contraction of Aluminium Alloy Bearings.** L. Farkas and H. Ludicke (*J. Inst. Automobile Eng.*, 1946, **14**, (9), 205–228).—The nature and causes of the contraction of aluminium alloy bearings in steel housings were investigated, earlier (unpublished) work having indicated that contraction was due to plastic straining of the bearing metal. Tests were carried out in a machine in which the conditions existing in a connecting-rod big end were simulated, and the following factors were investigated: (*a*) strength of the bearing material, (*b*) interference fit, (*c*) bearing wall thickness, (*d*) bearing size, and (*e*) connecting-rod wall thickness. The effect of temp. on bearing clearance was also considered. The results show that, owing to the interference fit in the housing and the differential expansion between the bearing and the connecting rod, a compressive hoop stress exists which may exceed the elastic limit of the aluminium alloy and so lead to plastic

strain and contraction of the bearing across internal and external dia. Contraction can be prevented, however, by suitable choice of alloy and proper design of the bearing. The alloy should have a high limit of proportionality in compression at temp. usually encountered in bearings, and should not soften on exposure to such temp. for long periods. Fully heat-treated, high-strength aluminium alloys appear to satisfy these conditions; a satisfactory alloy is one containing copper 2·12, nickel 1·13, silicon 0·65, zinc 0·06, magnesium 0·93, manganese 0·07, titanium 0·07, iron 1·2, and tin 0·2%. As regards design, it is essential to make the interference fit as small as possible in order to keep the max. stress in the bearing low. The max. stress can be calculated by simple equations, and if the strength properties of the alloy are known, the highest temp. to which the bearing can be subjected without contraction can be estimated. Provided that contraction is prevented, bearing clearance remains practically const. at all operating temp.—N. B. V.

***Investigation of the Equilibrium Diagram of the System Aluminium–Copper–Magnesium.** G. G. Urazov and D. A. Petrov (*Zhur. Fiz. Khim.*, 1946, **20**, (4/5), 387–398).—[In Russian]. The aluminium corner of the system was studied by the thermal and microstructural analysis of alloys on five sections: 80, 70, and 60% aluminium, part of the 20% copper section, and the section from aluminium to the newly discovered ternary compound *S*. Three invariant reactions were established in the region investigated: (*a*) a ternary eutectic liq. $\rightleftharpoons$ Al + $CuAl_2$ + *S* at aluminium 63·1, magnesium 7·2, copper 29·7%, 500° C.; (*b*) a peritectic reaction liq. + *S* $\rightleftharpoons$ Al + *T* at aluminium 64·4, magnesium 25·6, copper 10%, 465° C.; (*c*) a ternary eutectic liq. $\rightleftharpoons$ Al + *T* + Al_3Mg_2 at aluminium 65·5, magnesium 33·0, copper 1·5%, 445° C. There is also a peritectic reaction liq. + *U* + *S* $\rightleftharpoons$ *T* at aluminium 51·1, magnesium 34·0, copper 15%, 520° C. Approx. compositions of the compounds found in the region investigated are as follows: *U*: aluminium 13·7, copper 66·0, magnesium 20·3%; *S*: aluminium 38, copper 44·8, magnesium 17·2%. In conformity with these compositions the formulæ $Al_2Cu_4Mg_3$ and Al_2CuMg may be provisionally ascribed to the compounds *U* and *S* respectively. Vogel's formula Al_6CuMg_4 can be retained for the phase *T* (*Z. anorg. Chem.*, 1919, **107**, 265; *J. Inst. Metals*, 1919, **22**, 354). The phase *U* differs in composition from Bastien's phase with the formula $Al_2Cu_3Mg_2$ (*Publ. sci. et tech. Ministère de l'Air*, No. **20**, 1933, 1–9; *J. Inst. Metals*, 1933, **53**, 623), but doubtless the two are the same. The composition of *S* differs from the phase designated $Al_5Cu_3Mg_2$ by Laves and Witte (*Metallwirtschaft*, 1936, **15**, (1), 15–22; *Met. Abs.*, 1936, **3**, 353) and also from $Al_{13}Cu_7Mg_8$ (Nishimura (*Nippon Kinzoku Gakkai-Si*, 1937, **1**, 8–18; *Met. Abs.*, 1938, **5**, 208)). The max. solubility of magnesium in $CuAl_2$ probably does not exceed 1–1·5%. The phase *S* was mistaken by Vogel for the solid solution of Al_3Mg_4 in $CuAl_2$.

—N. A.

***On the Structure and Properties of Commercial Aluminium Alloys of High Iron and Manganese Content.** S. M. Voronov and V. I. Dobatkin (*Tsvet. Metally*, 1945, (5), 63–67).—[In Russian]. Ternary aluminium–iron–manganese solid solutions in slowly cooled commercial aluminium alloys tend to give rise to brittle crystals. Primary crystals of an iron–manganese phase begin to appear in alloys containing 0·7% manganese and 0·8% iron. The brittle particles of this phase decrease the plasticity of the alloy in hot working under pressure, and reduce the static and dynamic mechanical properties. With a high iron content (0·6–0·8%) in the alloy "D6" (copper 4·8–5·2, magnesium 0·75–1·0, manganese 0·8–1·2, silicon 0·7%), the manganese content should be close to the lower limit.—N. A.

***The Mechanical Properties of Aluminium–Magnesium–Zinc Alloys in the Region of the Aluminium-Rich Solid Solution.** T. A. Badaeva and F. I. Shamray (*Izvest. Akad. Nauk S.S.S.R.*, **1946**, [Tekhn.], (4), 611–618).—[In

Russian]. It is established that the greatest strength is possessed by alloys lying on sections in the region of increasing relative magnesium content between the section Al–$MgZn_2$ and that corresponding to the ratio Mg : Zn = 1 : 1. This shows that the increased strength of the alloys is due not only to the $MgZn_2$ phase but also to the ternary phase $Al_2Mg_3Zn_3$, which exists in regions corresponding to Mg : Zn ratios of 1 : 3 to 1 : 1, and imparts max. strength to them. Aluminium–magnesium–zinc alloys have a high resistance to corrosion by sea water, but are susceptible to stress-corrosion. Suitable choice of composition and heat-treatment can minimize this deficiency however.—N. A.

Aluminium Foundry Alloys. Their Selection and Preparation. (Carrington). See p. 432.

***The Action of Small Quantities of Magnesium on the Allotropic Modification of Metallic Cerium.** (Mlle.) Françoise Mahn (*Compt. rend.*, 1946, **223**, (2), 78–79).—The coeff. of magnetization and the elongation of various cerium–magnesium alloys containing 0–4% magnesium were determined at ascending and descending temp. from 78° to 290° abs. The object was to find out if the free cerium phase, as indicated by Vogel (*Z. anorg. Chem.*, 1915, **91**, 277; *J. Inst. Metals*, 1915, **13**, 326) and Guertler ("Metallographie," Band I, Teil 2, Berlin: 1921; *J. Inst. Metals*, 1921, **26**, 682 (review)) could assume the allotropic states that characterize the pure metal. Both quenched and slowly cooled alloys were studied. The limits of existence of the allotropic state of cerium were greatly modified by the presence of small quantities of magnesium, and the γ-phase becomes unstable. Although the cycle of dilatation, $\gamma \rightleftharpoons \alpha$, diminishes at from 0 to 1% magnesium, the corresponding magnetic cycle reaches a very marked max. at about 0·2% magnesium.—J. H. W.

†Copper and Copper-Base Alloys. Review of American Research During 1945–46. J. W. Donaldson (*Metal Ind.*, 1946, **69**, (8), 157–160; (9), 171–173; (10), 195–198).—A comprehensive review of researches, carried out in the U.S.A. in 1945–46, on the melting and casting, working, brazing and welding, testing, structure, powder metallurgy, stress-corrosion cracking, and damping of copper and copper-base alloys. A *bibliography* of 54 references is given.—J. H. W.

***The Influence of Small Iron Contents on the Properties of Copper and Alpha Brasses.** E. S. Shpichinetsky and I. L. Rogel'berg (*Tsvet. Metally*, **1946**, (1), 54–60).—[In Russian]. S. and R. studied the effect of small quantities of iron (0·005–0·5%) on the mechanical properties after deformation and annealing, the grain-size, and the corrosion-resistance of copper and of brasses containing 5, 10, 15, 20, and 28% zinc. The effect of iron on the mechanical properties of the alloys "L80," "L68," and "L62" at elevated temp. was also examined. Iron in copper and copper–zinc alloys increases the hardness and strength, decreases the elongation, and inhibits grain growth. Iron markedly affects the plasticity of brasses at elevated temp. Up to 0·3% iron in copper and α-brasses does not appear to be a harmful impurity. After annealing at 600°–650° C., alloys containing up to 0·15% iron have properties practically identical with those of iron-free alloys.—N. A.

***Study of the Anisotropy of Melchior [Nickel Brass] in Relation to Its Mechanical Properties.** I. A. Mendelev (*Tsvet. Metally*, **1945**, (6), 56–61).—[In Russian]. The temp. of the preliminary anneal appears to be the most important factor determining the degree of anisotropy of nickel-brass strip in relation to the mechanical properties for a given reduction. Anisotropy is least when preliminary annealing is carried out at 700°–800° C. and final annealing at 700°–900° C.—N. A.

New Magnesium Die-Casting Alloy [Eclipsaloy]. R. F. Hauser (*Modern Metals*, 1946, **2**, (2), 8–10).—The need for a magnesium-base die-casting alloy having a small tendency to hot-cracking led to the development of Eclipsaloy

130, which contains aluminium 1·0–1·5, manganese 0·5–1·5, iron 0·005 max., nickel 0·005 max., copper 0·05 max., silicon 0·3 max., total other elements 0·3% max., remainder magnesium. After a special heat-treatment (the details of which are not disclosed), the alloy has the following properties: tensile strength 32,000, yield strength 21,000 lb./sq.in., elongation on 2 in. 9%, Charpy impact value 10 ft.lb., hardness 56 (Rockwell E). Corrosion-resistance is comparable with that of the best magnesium die-casting alloys at present in use. The use of Eclipsaloy 130 is said to permit the die-casting of articles which would not otherwise be possible on account of hot-cracking. The alloy has the disadvantages, compared with the usual alloys, of decreased apparent fluidity, greater tendency towards apparent internal shrinkage porosity, and greater tendency to form flow marks on the surface of the castings. Measures can, however, be taken to minimize these shortcomings.
—N. B. V.

***The Cause and Control of Microporosity in Magnesium Alloys.** (Liddiard and Baker). See p. 434.

Modern Permanent-Magnet Materials. Helmer Nathorst (*Jernkontorets Ann.*, 1942, **126**, (10), 471–525).—[In Swedish]. A detailed review of the development of alloys for permanent magnets, with particular reference to progress made in the 1930–1940 decade. N. discusses the theory of ferromagnetism and considers the properties of materials used for permanent magnets, from the early martensitic steels to the later aluminium–nickel–cobalt–titanium high-alloy steels, and such non-ferrous alloys as Alconit 5·2. The manufacture, treatment, properties, and applications of these alloys are discussed, and the Zumbusch system of classification explained. A list of Swedish patents and a *bibliography* are appended.—M. A. V.

†Modern Hard Magnetic Materials. K. Hoselitz (*Metal Treatment*, 1946, **13**, (47), 213–222).—See *Met. Abs.*, this vol., p. 289.

Selecting Non-Ferrous Bearing Material. Norman E. Woldman (*Iron Age*, 1946, **158**, (10), 54–57; (11), 60–64).—The structure, physical properties, and proper applications of non-ferrous bearing alloys are discussed, including the characteristics of babbitts, the copper–lead group, single-phase metals such as pure lead, tin, cadmium, and bismuth, and the recently developed aluminium-base alloys. A comparison is made with other standard-type bearing materials, and the advantages and disadvantages of the various aluminium alloys for specific purposes are described. A *bibliography* is appended.—J. H. W.

Bearing Metals. Mechanism and Fundamentals of Performance. E. Wood (*Metal Ind.*, 1946, **69**, (14), 277–280).—Describes the manner in which bearing metals work and, in particular, the fundamental advantages of soft metals for bearings. These alloys depend principally on their ability to cope with breakdowns in the oil film and periods of boundary lubrication. Tin-base alloys offer the best all-round combination of properties for bearing metals. For very high-duty applications, silver–lead–indium bearings may be better.—J. H. W.

Bearing Developments. P. T. Holligan (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B26–B31; discussion, B31–B36).—See *Met. Abs.*, 1945, **12**, 248.

On the Dependence of the Mechanical Properties of Alloys on Composition and Structure. A. A. Bochvar (*Izvest. Akad. Nauk S.S.S.R.*, **1946**, [Tekhn.], (5), 743–752).—[In Russian]. B. points out the inadequacy of determining the properties of alloys from composition–property diagrams, without taking into account other factors which influence the properties of alloys. Data are given regarding the change of hardness in the aluminium–silicon alloys; values calculated from the law of additivity are distinctly higher than the experimental values. The enhanced plasticity of the alloy of zinc with 20% alu-

minium at 100°–300° C. is also pointed out. (Cf. *ibid.*, 1945, [Tekhn.], (9), 821; *Met. Abs.*, this vol., p. 318).—N. A.

***The Behaviour Under Tensile Stress of Metals Deformed by Compression.—II.** Friedrich Körber, Anton Eichinger, and Hermann Möller (*Mitt. K.-W. Inst. Eisenforschung*, 1943, **26**, (6), 71–89).—Cf. *Met. Abs.*, 1943, **10**, 67. Continuing their researches on embrittlement, the authors investigated the effect of temp. up to 700° C. Embrittlement generally increased with upsetting temp., but disappeared in specimens upset at 700° C.—M. A. V.

***Internal Friction of Metallic Alloys.** Albert Portevin and Léon Guillet (*Compt. rend.*, 1946, **223**, (6), 261–263).—The internal friction of alloys was measured by Chevenard's torsion micropendulum, precautions being taken to obviate errors caused by the very different grain-sizes, heterogeneity of the solutions, and the residual strain in the specimen after working. This test gives damping curves of the specimen, which functions as an oscillator. The conclusions of previous investigators, that the decrement of solid solutions is much smaller than that of pure metals, and that it diminishes rapidly at first and then slowly as the concentration increases, were confirmed. In the case of order–disorder transformations, gold–copper alloys afford two examples: (*a*) On quenching the alloy of equi-atomic composition from 650° C. in cold water, a disordered cubic solid solution results; on slow cooling and reheating for 100 hr. at 380° C., an ordered structure with a tetragonal lattice results. The decrement of the ordered alloy is 50 times greater than that of the disordered alloy. (*b*) On the other hand, the order–disorder transformation without change of lattice of Au_3Cu shows no change of decrement. Due to experimental difficulties, the results for intermediate solid solutions are meagre. For $Cu_{31}Sn_8$ the decrement is very small and corresponds to a min. on the decrement–composition curve for an electronic concentration of 21 : 13. In the case of CuZn, however, the decrement is appreciable and corresponds to a max. at an electronic concentration of 3 : 2. A general conclusion and an explanation of the practical points are advanced.—J. H. W.

***Catalytic Effect of Metals and Light on Fats and Oils.** N. W. Zeils and W. H. Schmidt (*Oil and Soap*, 1945, **22**, (12), 327–330; *Corr. Abs.*, 1946, **2**, (3), 32).—Presented to a conference on problems related to fat deterioration in foods, held by the Committee on Food Research of the U.S. Office of the Quartermaster-General. Aluminium and nickel were the only metals among those tested found absolutely free of any pro-oxidant effect on hydrogenated vegetable oils during the de-odorizing process. Inconel and Rezistal were the best of the alloys tested, while Monel was the poorest, probably because of its high copper content. As a rule the metal effect became more noticeable with increasing temp. Metals used were lathe turnings or 10-mesh granules; in no case was powder employed.

Russian Metallography. Kurnakov's "Daltonides" and "Berthollides." G. Stanley Smith (*Metal Ind.*, 1946, **68**, (23), 451–454; (24), 471–474; (25), 495–498; (26), 516–518).—A full description of the basic principles of Russian work on metallic systems, with particular reference to the investigations embodying a combination of geometry and physics with chemistry, carried out by Kurnakov and his school. These involve the introduction of the conception of "daltonides" and "berthollides." Briefly, the former is a phase with singular points on the property–composition curves; the latter is a phase of variable composition with an "irrational" max. m.p. The application of these conceptions to the transformations that take place in the copper–gold and other solid solutions is discussed, and order and disorder transformations generally are examined and illustrated. The ability of berthollides to change their properties as equilibrium conditions alter is of importance in dispersion-hardening. The study assists in the choice of suitable age-hardening alloys, such as occur in the aluminium–magnesium, aluminium–copper, and alumin-

ium–magnesium–zinc systems. S. correlates these Russian theories with the electron-atom ratios and characteristics formulated by Hume-Rothery and others. 21 references are appended.—J. H. W.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

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

Nature-Printing Aluminium Alloy Forgings. —— (*Metallurgia*, 1946, 34, (204), 335).—Cf. *Met. Abs.*, this vol., p. 49. In the light of further experience, the etching procedure previously described has been considerably altered. The etchant finally evolved is composed of ferric chloride 40 and cupric ammonium chloride 13 g. in 1 l. of water. This etchant is used at 80°–95° C., the section being immersed for two-minute periods; after which it is washed, immersed in 45% nitric acid until the adherent brown deposit has dissolved, and rewashed.—J. W. D.

***The Structure of Aluminium [and Aluminium Alloy] Spot Welds.** H. Hug (*Schweiz. Arch. angew. Wiss. Techn.*, 1946, **12**, (8), 250–257).—[In German]. Metallographic examination of spot welds, made under carefully controlled conditions in pure aluminium, Anticorodal, Avional, and Aluman, revealed the existence of four principal zones in the welded sheet: (1) unchanged structure, with crystals oriented in the direction of rolling; (2) a similar structure in which some of the constituents had melted; (3) cast structure containing very fine constituents which had separated from the melt and were oriented at right angles to the lens-shaped edge of the spot weld; and (4) randomly-oriented cast structure. 16 photomicrographs of welds are reproduced and described in detail.—N. B. V.

***On the Structure and Properties of Commercial Aluminium Alloys of High Iron and Manganese Content.** (Voronov and Dobatkin). See p. 411.

***The Electrolytic Polishing and Etching of Copper and Copper Alloys.** V. I. Lainer (*Tsvet. Metally*, **1946**, (3), 54–66).—[In Russian]. Copper and its alloys were successfully polished by the electrolytic method in phosphoric acid solutions. The addition of other constituents to the solutions did not lead to any improvement. The decisive factor in the electropolishing was the concentration of phosphoric acid, to which was related the degree of anodic polarization. On strengthening the acid concentration the optimum c.d. decreased, and the duration of the process increased; on increasing the temp. and stirring the electrolyte, the time was shortened and the c.d. increased.—N. A.

***Crystal Lattice Constants of the Iron-Rich Solid Solutions of Iron, Silicon, and Aluminium.** Ya. P. Selissky (*Zhur. Fiz. Khim.*, 1946, **20**, (7), 597–604).—[In Russian]. The lattice const. of alloys containing up to 13 wt.-% aluminium and 18 wt.-% silicon were determined by Preston's method, using Fe radiation. Curves showing the change of lattice const. with composition exhibit inflections, the presence of which is explained by the formation of superstructures of the type $Fe_3(Si,Al)$. The boundary of the superstructure field extends from the straight line joining the compositions of the binary alloys Fe_3Si and Fe_3Al with the alloy containing aluminium 10, silicon 5 wt.-%.—N. A.

***On the Question of the Structure of Eutectic Alloys.** K. Bunin (*Izvest. Akad. Nauk S.S.S.R.*, **1946**, [Tekhn.], (2), 305–310).—[In Russian]. The behaviour of liquid eutectic alloys when centrifuged was studied. Specimens of eutectic bismuth–tin alloy were placed in a crucible, heated to 200°±5° C., and rotated at 3000 r.p.m. for 10–30 min. The crucible was then quenched

in water and broken, and the cylindrical specimens (1–8 mm. dia. × 50 mm. long) were subjected to chemical analysis at three points. The results showed that the bismuth content in the regions farthest from the axis of rotation differed on an average by 10 at.-% from the regions nearest to it. In specimens which were not rotated, no gravity segregation was observed. From his results, B. draws conclusions regarding the absence of molecular mixing in alloys of the eutectic type.—D. A.

Recent Publications on Electrolytic Polishing and Its Applications. —— (*Métaux et Corrosion*, 1946, **21**, (245), 18; (246), 27, 32).—Extension to the *bibliography* of P.-A. Jacquet, *Métaux, Corrosion–Usure*, 1943, **18**, 1–21.—W. G. A.

The Structure and Growth of Passivated Films. (Dankov). See p. 420.

X-Ray Analysis. Developments During the War Years. —— (*Metal Ind.*, 1946, **69**, (5), 87–90; (6), 119–120).—A report of papers read at the international conference on X-ray analysis organized by the Institute of Physics. *Wyckhoff* surveyed the development of the electron microscope, and the technique developed in America for specimen preparation since 1946. (Mrs.) *K. Lonsdale* discussed thermal and other perturbations of crystal structure. *Wyart* reviewed the work done at the Sorbonne, and indicated that the present tendency was to develop monochromatic rays and to increase the actual power of X-ray tubes to give greater definition to the radiograms. *Zachariasen* gave an account of the crystalline character of the rare-earth elements and of thorium, uranium, neptunium, and plutonium; *L. Bragg* described the method of illustrating plane, close-packed crystal structures by using a layer of bubbles on the surface of a liquid to represent individual atoms; and *Bijvoet* dealt with X-ray researches in Holland. *Homes* outlined the work done in Belgium, and *R. C. Evans* reviewed X-ray crystallography in Germany. *McLachlan* described a Fourier-series machine in which sand is made to fall in a sinusoidal manner; *Trillat* gave a description of French designs of the electron microscope, and (with (Mlle.) *Moiroud*) discussed electronic radiography and microradiography. *Guinier* surveyed new and improved methods of X-ray analysis, while *Harker* reviewed American developments in the study of the crystallography of metals. *Brockway* referred to the types of equipment and apparatus at present in use in America; *Hassell* gave an account of electron diffraction in Norway; *Waller* and *Sillen* outlined optical methods of Fourier summation; *Wasartjernia* briefly summarized the work being done in Finland; and *Krishnan* discussed the diffuse scattering of electrons in metals and alloys in relation to their resistivities. *Kochanovska* gave an account of an investigation of different types of tungsten and tungsten–titanium cemented carbide by the Debye–Scherrer method.—J. H. W.

Quality Control. III.—Metallography. A. Hone and E. Pearson (*Canad. Metals*, 1945, **8**, (8), 24–28, 45).—Cf. *Met. Abs.*, 1945, **12**, 405; this vol., pp. 428, 429, 431. An elementary introduction to the results obtained by microscopic metallography.—H. J. A.

V.—POWDER METALLURGY

Spectrographic Analysis of Powdered [Aluminium] Alloys. (Rudnevsky). See p. 427.

Two New Methods of Using Powdered Metal. —— (*Ironmongers' Weekly*, **1946**, (1745), 572–573).—Two powdered-metal products are described: (*a*) A copper-base bearing alloy containing nickel 2·4, silicon 0·8, and phosphorus 0·3%. The powders are sintered in hydrogen or cracked-ammonia atmospheres at pressures of 25–40 tons/sq.in. (*b*) A sintered mass of pulverized steel impregnated with a molten copper alloy containing 15% tin in addition to silicon, chromium, and other constituents. The compacted steel is heated in

contact with the copper alloy to just above the m.p. of the latter. The product has good bearing qualities and can be brazed directly to other metals.—P. R.

Alloys of the Heavy Metals. G. Fitzgerald-Lee (*Aircraft Eng.*, 1946, **18**, (209), 239–241).—The preparation of aggregates by powder metallurgy is described briefly, and some particulars of G.E.C. Heavy Alloy are given.
—H. S.

***The Theoretical Basis of the Fritting Process in Powders.** G. F. Hüttig (*Metallwirtschaft*, 1944, **23**, (40/43), 367–372).—Describes the changes that a homogeneous, powdered chemical substance undergoes when the temp. is gradually increased. A thermodynamic approach to the subject is made on the basis of the theories of Maxwell, Planck, and van Liempt; the results are applied to the changes taking place on heating single crystals and two or more single crystals in contact with each other. From this a theory of fritting of metal powders is developed. Fritting takes place in successive stages, and there is a direct relationship between the absolute m.p. T_F and the temp. at which these changes occur T_Z, represented by $T_Z = \alpha T_F$. The process of fritting runs, in general, thus: period (*a*), below $\alpha = 0{\cdot}23$, progressive uncovering of the surface layers, viz., reduction of surface activity by adhesive forces. Period (*b*), $\alpha = 0{\cdot}23$–$0{\cdot}36$, mainly activation as a result of surface diffusion and a loosening or escape of gases in the superficial layers. Period (*c*), $\alpha = 0{\cdot}33$–$0{\cdot}45$, de-activation due to completion of molecular re-arrangements in the surface layers, and the resultant conditional stabilization as increased adhesion takes place. Period (*d*), $\alpha = 0{\cdot}37$–$0{\cdot}53$, activation as new atomic groupings occur inside the crystals. Period (*e*), $\alpha = 0{\cdot}48$–$0{\cdot}8$ and above, de-activation due to lattice diffusion as well as surface contraction caused by collective recrystallization. Period (*f*), $\alpha > 0{\cdot}8$, a new activation which, although not fully investigated, appears to be a preliminary to melting and may be fusion of the surface layers. Generally, the formation and orientation of new crystals begins at $\alpha = 0{\cdot}33$ for metals, 0·52 for metal oxides, 0·54 for metal salts, and 0·90 for carbonaceous materials. The results are given of measuring many physical and chemical properties of the powders at various temp., and it is shown that all values decrease sharply at $\alpha = 0{\cdot}8$–$0{\cdot}9$. The powders examined included most of the common metals and metal oxides.—E. N.

The Explosibility of Metal-Powder Dust Clouds. Irving Hartmann and H. P. Greenwald (*Min. and Met.*, 1945, **26**, (463), 331–335).—The greatly extended use of metals in powder form in recent years has necessitated investigations into the explosibility of powders. H. and G. summarize work carried out by the U.S. Bureau of Mines (cf. *U.S. Bur. Mines Rep. Invest.* No. 3751) and discuss preventive measures for reducing the explosion hazard. The hazard is greatest for zirconium, magnesium, aluminium, titanium, and some of their alloys.—N. B. V.

British Powder Metallurgy. Its History, Development, and Commercial Future. W. D. Jones (*Metal Ind.*, 1946, **68**, (22), 431–434).—A lecture to the Stevens Institute of Technology, New York. The past, present, and future of powder metallurgy are discussed.—J. H. W.

VI.—CORROSION AND RELATED PHENOMENA

***Scaling of Some Metals in Pure Steam [Copper, Iron, Nickel, Zinc].** W. Baukloh and F. Funke (*Korrosion u. Metallschutz*, 1942, **18**, (4), 126–130; *Corr. Abs.*, 1946, **2**, (3), 26).—Experimental data are presented on scaling resistance of iron, nickel, copper, zinc, and cast iron (grey and white) in steam and in dry air. In contrast with the behaviour of iron, the scaling resistance of nickel is greater in steam than it is in air. When exposed to steam, copper

shows only minute signs of scaling up to a temp. of 1000° C. Pure zinc offers about the same resistance in air as it does in steam; the surface of the pure metal undergoes marked passivation.

Corrosion-Resistant Materials [Brasses and Bronzes] in the Atmosphere of Acid Vapours of Sulphite–Alcoholic. N. K. Grigor'eva (*Korroziya i Bor'ba s Ney*, 1941, **7**, (1), 40–43).—[In Russian]. For parts exposed to the atmosphere of acid vapours of sulphite–alcoholic, various types of brasses and bronzes may be used, especially those containing aluminium or aluminium, iron, and manganese.—N. A.

Corrosion of Inserts. Results of Tests on a Magnesium Casting Alloy. A. J. Ferko (*Metal Ind.*, 1946, **68**, (24), 467–468).—Owing to its extremely negative galvanic properties, magnesium is very susceptible to corrosion by dissimilar-metal contact. F. describes an investigation to determine the best coating to apply to a magnesium casting alloy in order to suppress galvanic corrosion between the alloy and a number of different metals in the form of screwed inserts.—J. H. W.

Processing with Magnesium [Alloys]. Avoiding the Breakdown of Corrosion-Resistance. (Simpson). See p. 437.

Bimetallic Double-Wall Tubing for Combating Corrosion. —— (*Product Eng.*, 1946, **17**, (2), 102–103; *Corr. Abs.*, 1946, **2**, (3), 31).—Bimetallic tubing is suitable for withstanding two different and simultaneous types of corrosive attack in heat exchangers, oil refineries, synthetic-rubber manufacture, ammonia refrigeration systems, and chemical plants. Metals and alloys that may be combined include steel, stainless steel, aluminium, Monel, Admiralty copper, aluminium brass, Muntz metal, bronze, and copper–nickel alloy. For oil-refinery service and synthetic-rubber manufacture, steel is used outside to resist corrosive oil vapour and copper inside facing the fresh water. Other applications call for combinations such as copper–nickel outside, red brass inside; stainless steel outside, aluminium or brass inside.

***Measuring the "Existent Corrosivity" of Used Engine Oils.** R. G. Larsen, F. A. Armfield, and L. D. Grenot (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 19–24).—Describes a test for determining the "existent corrosivity" of used engine oils, independently of previous history. Test strips of copper, electroplated with lead or other metals in graduated thicknesses from 0·00003 to 0·001 in., are immersed in the hot oil and examined after an interval. The extent to which the deposited metal has been stripped from the copper demonstrates visually the corrosiveness of the oil. The test has a practical application in determining the cause of bearing failures and indicating necessary oil drainage.—E. N.

***Bearing-Corrosion Characteristics of Lubricating Oils: Indiana Stirring-Corrosion Test.** C. M. Loane and J. W. Gaynor (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (2), 89–95).—Details are given of the Indiana stirring-corrosion test, and the results obtained are compared with those of the Chevrolet 36-hr. test. The limitations of both tests are discussed; like any other laboratory test, neither can duplicate engine conditions.—E. N.

***Corrosion by Hydrofluoric Acid.** W. Z. Friend and H. O. Teeple (*Oil and Gas J.*, 1946, **44**, 87; *Corr. Abs.*, 1946, **2**, (3), 33).—Laboratory corrosion data are given for Monel, 70 : 30 copper–nickel alloy, copper–aluminium alloy, fine silver, carbon steel, nickel, Inconel, lead, stainless steel, Ni-Resist, Hastelloy B, and Hastelloy C in acid concentrations varying from 10 to 100%, at temp. from 70° to 240° F. (21°–116° C.). F. and T. present data from test spools containing most of the above metals and from other metals situated in operating hydrofluoric acid alkylation units and acid-storage tanks. The character of the attack on the various metals is discussed. The effect of silicofluoric acid as an impurity is examined.

***Corrosion of Metals and Alloys in the Tanning Industry.** A. H. Winheim and R. A. Mills (*J. Amer. Leather Chemists' Assoc.*, 1945, (Dec.), 441–478; *Corr. Abs.*, 1946, **2**, (3), 29).—Corrosion-resistance of 1729 test specimens, representing 56 different metals and alloys, was studied in 11 different factories. Alloys tested included Inconel, Ni-Resist, Illium G, Durimet, Hastelloy A and C, and cast iron. A spool-type specimen holder made of Monel was used. Complete results are tabulated for all parts of the process and equipment.

***Investigation of the Processes of Corrosion on a Model of a Local Element. I.—The Field in the Electrolyte Above Short-Circuited Models Situated in One Plane.** G. V. Akimov and A. I. Golubev (*Zhur. Fiz. Khim.*, 1946, **20**, (3), 303–308).—[In Russian]. A. and G. studied the distribution of the equipotential surfaces and lines of force above short-circuited electrodes situated in one plane. Electrodes of copper and zinc were investigated in a solution of 3% NaCl + 0·06*N*-HCl, and electrodes of copper and magnesium in 0·1*N*-NaCl solution. As a rule the field of the local element was distorted, being displaced in the direction of the anode or cathode in accordance with their polarization characteristics and the ratio of their areas. The general potential was not equal to the boundary potential; it was electropositive to the latter when displacement of the field was in the direction of the anode and electronegative when in the direction of the cathode. The greater the displacement of the field, the greater was the difference between the general and boundary potentials. The height of the field was equal to approx. half the sum of the lengths of the anode and cathode.—N. A.

***Investigation of the Processes of Corrosion on a Model of a Local Element. II.—Current Distribution and Variation of Resistance on Short-Circuited Models.** A. I. Golubev and G. V. Akimov (*Zhur. Fiz. Khim.*, 1946, **20**, (3), 309–314).—[In Russian]. Cf. preceding abstract. The current distribution over the surface of the electrodes of the model was calculated from the polarization curves and the curves showing the distribution of potentials over the surface of the model. Near the edges of contact of the electrodes, the c.d. on the anode was usually different from that on the cathode. The magnitude of the current in the copper–zinc model studied in a solution of 3% NaCl + 0·06*N*-HCl + 0·24% H_2O_2, varies in direct proportion to the area of the cathode. The current strength is greatest where the cathodic inclusions are greatest. The resistance of the electrolyte does not vary linearly from the edge of contact to the periphery of the model.—N. A.

***The Theory of the Corrosion of Metals. III.—On the Uniformity of Corrosion.** V. S. Daniel-Bek (*Zhur. Fiz. Khim.*, 1946, **20**, (6), 567–573).—[In Russian]. Cf. *ibid.*, 1944, **18**, 247; *Met. Abs.*, 1945, **12**, 185. A model of a micro-element was made in the form of a bimetallic (copper and zinc) plate, the reverse side of which was covered with a layer of insulating material. The plate was put into a vessel filled with one of four electrolytes (0·05 and 0·01*N*-KCl and 0·2 and 0·05 *N*-$KClO_3$), and served as a partition dividing the vessel into two parts. The surface of the anode (zinc) was provided with a series of holes which enabled the potentials of different parts of the anode surface to be measured. The uniformity of corrosion of a metal increases with rise in the conductivity of the electrolyte and with the polarization of the corroding micro-element.—N. A.

Laboratory Tests to Predict the Performance of Metals [Zinc, Aluminium] Under Service Conditions. (Sawyer and Mears). See p. 430.

Cathodic Protection. Use of Magnesium for Preventing Corrosion. —— (*Metal Ind.*, 1946, **68**, (24), 474).—Describes the use, for preventing corrosion by cathodic protection, of a magnesium alloy containing aluminium 5·3–6·7, manganese 0·15, and zinc 2·5–3·5%.—J. H. W.

VII.—PROTECTION

(Other than by Electrodeposition.)

***Modified Chromic Acid Anodizing Process for Aluminium.** C. J. Slunder and H. A. Pray (*Indust. and Eng. Chem.* (*Indust. Edn.*), 1946, **38**, (6), 592–596).—On the basis of laboratory tests, a chromic–sulphuric anodizing bath appears to offer an attractive saving in chromic acid. The attendant difficulties and modifications of technique required are discussed. In particular, the new solution has a marked corrosive action on steel tanks such as are normally used for the straight chromic acid process.—H. J. A.

Chromic Acid Anodic Solution. The Effect of Sulphuric Acid Additions [for Aluminium Alloys]. —— (*Metal Ind.*, 1946, **68**, (24), 477).—Cf. preceding abstract. A summary of the results of a recent investigation in the U.S.A. The addition of sulphuric acid to a chromic acid anodic solution produced a coating on an aluminium alloy (composition: copper 4·6, manganese 0·6, magnesium 1·5%, aluminium remainder) which had better corrosion-resistance than the film produced by the standard chromic acid bath. Unfortunately, this solution has a severely corrosive effect on the linings, other than lead, of steel tanks.—J. H. W.

Anodic Oxidation of Aluminium and Its Alloys. R. F. C. Calder (*Elect. Eng. and Merchandiser*, 1946, **23**, (3), 83–85).—A review of the chromic acid anodizing process, and a description of a simple device for checking film thickness.—H. J. A.

The Structure and Growth of Passivated Films. P. D. Dankov (*Izvest. Akad. Nauk S.S.S.R.*, **1946**, [Tekhn.], (2), 137–142).—[In Russian]. A review of the development of the film theory of passivity (the work of V. A. Kistenevsky and his school).—N. A.

Research on Metallic Surfaces Organized in France. (Portevin). See p. 449.

Non-Ferrous Metals Aid in Steel's Use. [Tin, Zinc, Nickel, Chromium, &c.] J. Levin (*Domestic Commerce*, 1945, **33**, (12), 37–40; *Corr. Abs.*, 1946, **2**, (3), 35).—The rôle of non-ferrous metal coatings on steel is described. L. gives a general summary of the use of tin, zinc, nickel, chromium, and other metals that are plated, sprayed, or clad on steel.

"Dry" Galvanizing. Effect of Aluminium Additions to the Zinc Bath. H. Bablik (*Metal Ind.*, 1946, **68**, (25), 487–489).—Small additions of aluminium to the zinc bath and a low working temp. result in an improved galvanized coating, reduction of wastage, and decreased dross formation. This "dry" process is said to have a considerable range of application for the galvanizing of shaped products.—J. H. W.

Hard-Surfacing Light Metals. [Metal Spraying]. (Reid). See p. 439.

"Dyed Metal" (Metal Finishes). (——). See p. 439.

Surface Finishes for Aluminium [and Its Alloys]. (Mason). See p. 439.

Spray-Finishing and Drying Aluminium Fabrications at Woodall Industries. (——). See p. 439.

The Preservative Qualities of Aluminium Paint. —— (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (7/9), 38, 40, 42).—The properties of aluminium paint are described, and its applications in a wide variety of industries are reviewed.—N. B. V.

Paint Manual—With Particular Reference to Federal Specifications. [Methods of Surface Preparation]. Percy H. Walker and Eugene F. Hickson (*U.S. Nat. Bur. Stand. Build. Mat. Structures Rep.*, 1945, (**105**), pp. 165).—Recommendations by the U.S. National Bureau of Standards for the most effective use of painting materials which satisfy Federal specifications. Methods of surface preparation and application of the coating are considered,

the failure of painted surfaces is discussed, and data on many paints and paint products are presented.—H. J. A.

American Corrosion-Preventive Materials. James A. Richardson (*Petroleum*, 1945, **8**, 29; *Corr. Abs.*, 1946, **2**, (3), 34).—Corrosion preventives are defined as materials which are applied to unpainted metal surfaces for their protection, and which are removable with petroleum solvent to leave the surface in as good a condition as when the material was applied. These are classified as thick-film type (usually petrolatum or mineral jelly), thin-film type (compounds diluted with volatile solvent), and fluid type (mineral oils with corrosion inhibitor added). Specifications are given for a general description of these types, together with a brief explanation of the control tests required to characterize each material.

VIII.—ELECTRODEPOSITION

Cadmium Plate and Passivated Cadmium-Plate Coatings. E. E. Halls (*Metallurgia*, 1946, **34**, (204), 295–297).—Specimens of mild steel, copper, and brass, degreased, cleaned, and cadmium-plated by an industrial process, were either dipped in a hot solution of 5% plater's compound or immersed in a passivating solution for 10 sec. at room temp. Two types of test were applied after both after-treatments, one consisting of heat and humidity cycles and the other a standard salt-spray exposure. The results of these tests showed that chromate-passivation treatment ensures much improved serviceability for the cadmium finish.—J. W. D.

Improved Chromium Plate. Increased Resistance to Distortion and Impact. A. L. Peach (*Metal Ind.*, 1946, **69**, (1), 14–16).—P. discusses a number of measures that provide a more resistant and better chromium-plated article from the engineer's point of view. In particular, he describes a method which considerably improves the resistance of hard chromium plate to the effects of distortion and impact, and to some extent increases the field in which thicker deposits may be used. The method is one in which two chromium baths are used to provide a composite deposit, comprising a "soft," adherent, and impact-absorbing undercoat, and a very hard, wear-resisting outer layer. —J. H. W.

***The Problem of the Hydrogen Embrittlement of Steel in Galvanic Processes. [Deposition of Zinc, Copper, Cadmium, Brass, or Silver].** H. Fischer and H. Bärmann (*Korrosion und Metallschutz*, 1940, **16**, (12), 405–417).—The deposition of zinc, copper, cadmium, brass, or silver on spring steel from cyanide baths leads to marked embrittlement. The embrittlement takes place in the early stages of plating, and little or no further effect is observed once the steel has a sufficient protective coating. Thus, greater c.d. lessens embrittlement. Increased temp. has a deleterious effect. Cyanide-free baths are much less harmful. Small additions of zinc to a caustic soda bath increase the embrittlement, but do not do so in the presence of cyanides. Large concentrations of metal in cyanide baths are beneficial, especially cadmium. Weakly acid zinc, nickel, and lead plating baths are without harmful effect. In strongly acid zinc baths, there is a marked initial embrittlement, but prolonged treatment leads to a recovery, due apparently to the hydrogen diffusing back through pores in the coating. By the correct choice of an electrolyte, it is possible in most cases to reduce the effect to harmless proportions. No theoretical explanation can be advanced to account with certainty for the harmful effect of cyanide baths and zinc in caustic soda.—M. A. V.

Plating on to Hardware. Herbert Chase (*Iron Age*, 1946, **158**, (12), 59–60). —C. describes the plating of motor-car fittings in a plant in which full use is made of conveyors. Rocking procedures, and solution and c.d. for copper

cyanide strikes are outlined, as well as the methods used for bright nickel, copper, and chromium plating. Various rinses are discussed in detail.

—J. H. W.

***Dry Rectifiers in Electroplating. (Investigation of the Influence of Polarization on the Shape of the Current and Voltage Curves.)** Julius Steiner (*Z. Elektrochem.*, 1944, **50**, (8), 186–200).—Unloaded, dry, single-phase rectifiers, supplied with sine-wave A.C., give a voltage of almost sine-form half-cycles. When the rectifiers operate plating baths, polarization causes both the voltage and current curves to deviate from the sine form. By means of the oscillograph, S. studied the influence of the electrolyte and polarization phenomena on the current curves in acid copper, zinc, and nickel baths as well as in cyanide copper baths. It is shown that deviations from the sine form depend mainly on the ratio of polarization potential to rectifier voltage. Polarization potentials were approx. ascertained from oscillograms of bath potentials, and the assumption of their approx. linear form is closely confirmed for nickel baths, and somewhat less closely confirmed for the other baths. On this assumption, formulæ are developed for the chief variables of the current curves, and, as oscillographs are not always available, methods are given for measurement of the form factors, by means of D.C. and A.C. instruments, on the basis of these formulæ. The current form can also be obtained from measurements of the terminal voltage of the unloaded rectifier and the average value of the polarization potential of the bath.—E. N.

Economics of Electroplating. Optimum Current Density for Mass Production. T. F. O'Connor (*Metal Ind.*, 1946, **69**, (5), 97–100; (7), 140–142).—In designing a plant for the successful production of electroplated articles, it is necessary to consider the number of cells and the c.d. A low c.d. involves a large number of cells, but is cheap in electrical cost; a higher c.d., if technically satisfactory, reduces the capital sunk in equipment, but is more expensive electrically. *A priori*, a balance can be struck to give the most economical results, and C. describes the use of a mathematical equation to determine the equilibrium point.—J. H. W.

Polarographic Method for the Control of [Brass] Electroplating Baths and Electrodeposits. (Vyakhirev). See p. 426.

***Spectrophotometric Determination of Nitrates in Plating Baths.** (Dolance and Healy). See p. 427.

Surface Finishes for Aluminium [and Its Alloys]. (Mason). See p. 439.

" Dyed Metal " (Metal Finishes). (——). See p. 439.

Glycerine in Metal Treatment. (Leffingwell and Lesser). See p. 439.

Aspects of Finishing Processes Applicable to Automobile Engines and Chassis. (Jackson). See p. 439.

XI.—ANALYSIS

***Separating and Detecting Cupric and Cadmium Ions in the Copper Sub-Group of Group II.** Gerald F. Grillot and Jerry B. Kelley (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1945, **17**, (7), 458).—The ammoniacal solution from the separation of $Bi^{\cdot\cdot\cdot}$ is acidified with HNO_3 to 5 drops excess, evaporated to dryness, and heated until all NH_3 salts decompose. Cool, add 1–2 drops of 6*N*-HNO_3 and 1 c.c. of H_2O, followed by 10 drops of 6*N*-NaOH and 1 c.c. of 0·5*M* Rochelle salt solution, which prevents precipitation of $Cu^{\cdot\cdot}$. Centrifuge; a white, gelatinous precipitate of $Cd(OH)_2$ confirms the presence of Cd.—E. N.

***The Reduction of Sexivalent Molybdenum and Its Application.** Folke Lindstrand (*Trans. Chalmers Univ. Technol., Gothenburg, Sweden*, **1945**, (41), 3–12; *C. Abs.*, 1946, **40**, 1417).—A rapid and accurate volumetric method for detecting Mo. Fe–Mo and Mo ores are attacked by fusion with Na_2O_2 and

$KNaCO_3$, and Mo slags by HCl. Reduction of Mo^{VI} is accomplished in a cadmium reductor with a solution containing 20 c.c. of 12*N*-HCl per 0·2 g. sample. The reduced Mo is titrated with $KMnO_4$ in the presence of $MnSO_4$ and H_3PO_4. Substitution of H_2SO_4 for HCl leads to incomplete reduction of the Mo.

***A Specific Spot-Test for Vanadium.** Gilbert Ashburn and J. H. Reedy (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 63).—A drop of the solution to be tested (the V must be in the form of vanadate, vanadous compounds being oxidized with Br_2 and warming) is mixed, on a spot plate, with a drop of H_3PO_4 and allowed to stand for a few sec. to allow the acid to form complexes with any interfering ions. A drop of 10% Na_2WO_4 solution is then added. The appearance of a yellow to orange colour indicates the presence of V. There is little or no interference by common metallic ions or by the anions Cl, Br, SO_4, NO_3, CH_3COO, and ClO_3.—E. N.

***Observations on the Rare Earths. Extraction of Ytterbium from Rare-Earth Mixtures with Sodium Amalgam.** Therald Moeller and Howard E. Kremers (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (12), 798–800).—The recovery of Yb, from rare-earth fractions, by the use of Na amalgam is described, together with a new test for its identification. To 5 c.c. of the nearly neutral rare-earth chloride solution add 5 c.c. of 0·1% Na amalgam, shake for 15 sec., add 10 drops of conc. HCl, and shake for several sec. to remove the bulk of the Na from the amalgam. As soon as the evolution of H_2 diminishes, an apple-green colour appears if 0·002 g. or more of Yb_2O_3 is present.—E. N.

***New Method for the Separation of Small Amounts of Zn, Ni, Co, Mn, Cd, Cu, and Ti from Large Amounts of Iron.** I. V. Tananaev and E. N. Deichman (*Zavod. Lab.*, 1946, **12**, (1), 30–37).—[In Russian]. The new method of separation is based on the precipitation of the double salts: $5NaF.2FeF_3$ or $2KF.FeF_3.H_2O$ and $11KF.4FeF_3.12H_2O$. The completeness of the separation of the metals enumerated depends on the acidity of the solution (1–3 ml. conc. HCl or H_2SO_4 in 100 ml. of solution). The precipitate of crystalline double fluorides of Fe occupies a small vol., and on precipitation from hot solution it is well filtered.—N. A.

***Rapid Volumetric Method for [Determination of] Aluminium.** L. J. Snyder (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 37–38).—A rapid and accurate method for the determination of Al in the presence of 1–10% of impurities such as Ca, Cu, Cr, Fe, Mg, Mn, and Zn. $Al(OH)_3$, formed by the neutralization of an Al salt to the phenolphthalein end point, reacts with KF to form the neutral salt $AlF_3.3KF$ which, in the presence of Rochelle salt, liberates, practically instantaneously, three molecules of KOH per molecule of Al present. The acid used to titrate the liberated base is a direct measure of the Al present. An analysis can be performed in 5–10 min.—E. N.

***A Method for the Determination of Alumina in Anodic Baths and Other Solutions Containing Hexavalent Chromium.** Winslow H. Hartford (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (4/6), 33–34).—Reprinted from *Metal Finishing*, 1944, **42**, 72; *Met. Abs.*, 1945, **12**, 285.—N. B. V.

***Colorimetric Reaction for the Determination of Antimony.** A. I. Kokorin (*Zavod. Lab.*, 1946, **12**, (1), 64–68).—[In Russian]. K. points out the possibility of using the reduction of phosphomolybdic acid with Sb^{+++} as a reaction for the quantitative colorimetric determination of Sb.—N. A.

***Potentiometric Determination of Beryllium.** V. M. Tarayan (*Zavod. Lab.*, 1946, **12**, (6), 543–546).—[In Russian]. The complex Na_2BeF_4 is sufficiently stable to make possible the potentiometric determination of Be with NaF. The stability of Na_3AlF_6 is of the same order, however, so that the presence of Al interferes with the potentiometric titration of Be and vice versa. Mg does not interfere with the determination of Be. A description of the scheme of analysis is given.—N. A.

***Silver Sulphide Method for the Determination of Cadmium.** N. N. Lapin (*Zavod. Lab.*, 1946, **12**, (2), 158–160).—[In Russian]. A new method for the volumetric determination of Cd has been evolved, using the values of the solubility products of a series of sulphides. Cd is precipitated from HCl solution by means of H_2S, and the precipitate is treated by titration with $AgNO_3$ solution. A definite amount of Ag passes into the precipitate and an equivalent amount of Cd passes into solution. The quantity of Ag is determined by back titration and the Cd calculated. The accuracy of the method depends on the completeness of the reaction between the sulphide precipitate and the $AgNO_3$ solution.—N. A.

***Volumetric Determination of Calcium in the Presence of Silica, Iron, Aluminium, Magnesium, Phosphorus, Titanium, and Manganese.** James J. Lingane (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 39–41).—A volumetric oxalate–permanganate method, which permits the direct determination of Ca in the presence of Si, Fe, Al, Mg, and PO_4, and also in the presence of small amounts of Ti and Mn. Dissolve 0·4 g. of the sample in 5 c.c. of H_2O and 10 c.c. of conc. HCl (36*N*), dilute to 50 c.c., and heat almost to boiling. Run in slowly 100 c.c. of hot (90° C.) 5% solution of $(COONH_4)_2.H_2O$, add a few drops of a 0·1% indicator solution of methyl orange, followed by a dropwise addition of 1 : 1 NH_4OH over 5–10 min., which precipitates the Ca as oxalate, the neutralization being stopped when the methyl orange changes to a pinkish-yellow colour (*p*H 3·5–4·5). Stand for not longer than 20–30 min., filter the precipitate into a Gooch, and wash 8–10 times with $\not>$ 100 c.c. of ice-cold H_2O. Dissolve the precipitate in 5–6 c.c. of conc. H_2SO_4 (36*N*) and 100 c.c. of H_2O, heat to 90° C., and titrate with 0·1*N*-$KMnO_4$, keeping the temp. above 60° C. Duplicate assays can be completed in 2 hr., and the accuracy compares favourably with the more laborious classical methods. Details of the applications of the method are given.—E. N.

***Rapid Method of Determining Minute Quantities of Carbon in Metals.** J. K. Stanley and T. D. Yensen (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (11), 699–702).—A combustion method for the determination of $<$0·01% C with an accuracy of $\pm$0·0005% in soft magnetic materials, Ni, and Cr–Ni alloys is described. The milled sample, at -20 and $+100$ mesh, is heated for 10 min. at 1100° C., or 5 min. at 1200° C., in a stream of pure O_2. The gaseous products are collected, the H_2O and SO_3 frozen out with dry ice, and the CO_2 frozen out with liquid air. The C is then determined by heating the solid CO_2 to room temp., expanding into an evacuated known vol., and noting the pressure. S. and Y. discuss the effects of preheating the sample, temp. and time of oxidation, the effect of O_2 pressure on oxidation, the formation of CO, the effect of S, adsorbed CO_2, C in the residues, and the preparation of the sample. As increase of time and temp. does not remove the last traces of C from pure Ni and Cr–Ni alloys, they must be mixed with four times as much of an easily oxidizable material, such as Si–Fe alloy of known C content. —E. N.

***Determination of Iron in the Presence of Cobalt. Two-Component Colorimetric Method.** Ernest A. Brown (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (4), 228–230).—A description of a colorimetric thiocyanate method for determining 0·07–0·5 mg. of Fe in the presence of up to 90 mg. of Co, although no serious deviations occur when the amount of Co exceeds this figure. A filter-type photometer with two colour filters overcomes the interference due to the colour of Co ions, while fading of the $Fe(CNS)_3$ colour is not serious if the time taken in making the final solution and adjusting the photometer is $<$8 min. The method is rapid and accurate to $\pm$3%; it is suitable for determining traces of Fe in a large range of Co salts.—E. N.

***Rapid Polarographic Method for the Determination of Lead in Smelter Products.** William Hered and Grace R. Hered (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (12), 780–781).—Fuse 0·2 g. of the sample with 2·3 g. of Na_2O_2,

cool, and break the tube into a beaker. Add 50 c.c. of H_2O and stand for 15 min. so that the material separates completely from the glass fragments. Add, rapidly, 25 c.c. of conc. HCl, obtaining a clear yellow solution to which 3 g. of tartaric acid is added to prevent precipitation of SbOCl on dilution; dilute to 100 c.c. Determine the Pb polarographically in an aliquot portion, adding gelatine to suppress maxima if the supporting electrolyte is *N*-HCl. Each smelter product presents a distinct problem as far as the supporting medium is concerned; suitable electrolytes are: 0·1*N*-KCl, 1*N*-HCl, 1*N*-HNO_3, 1*N*-NaOH, or alkaline tartrate. The method is more accurate and takes only half the time required for the molybdate titration method.—E. N.

***Polarographic Analysis of Aluminium Alloys.** I. M. Kolthoff and George Matsuyama (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (10), 615–620).—The determination of Fe, Cu, Pb, Ni, and Zn in Al alloys is described in detail. Dissolve the sample in NaOH, acidify with dil. HNO_3, and, in the absence of Cl′, measure the Fe‴ and Cu waves, reducing the Fe‴ with $NH_2OH.HCl$ if the Fe : Cu ratio is large. Reduce the Fe‴, precipitate the Cu as $Cu_2(CNS)_2$, adjust the *p*H, and measure the Pb wave. Ni and Zn are determined after adjustment of the *p*H of the original solution of the alloy and addition of $NH_2OH.HCl$, CNS′, sodium citrate, and pyridine. The behaviour of Ni in CNS′ and CNS′–citrate solutions is discussed, and typical current–voltage curves are given. Determination of all five elements takes approx. 45 min., and the method is suitable for routine analysis.—E. N.

***Colorimetric Determination of Copper in Aluminium Alloys.** Robert F. Patridge (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (7), 422–424).—Dissolve 0·2 g. of the alloy in a solution of H_2SO_4, HNO_3, and HCl and evaporate to fumes. Cool, add 60 c.c. hot H_2O, boil until the residue is dissolved, cool, and dilute to 100 c.c. To 10 c.c. of this add 10 c.c. citric acid, 5 drops of dimethylglyoxime, and 10 c.c. dil. NH_4OH, stand for 3 min., and filter off any Ni present, washing well with hot water. Transfer the filtrate to a separating funnel, add 20 c.c. of a 0·1% solution of sodium diethyldithiocarbamate, and extract with 2–25 c.c. portions of CCl_4, in which the copper complex dissolves to form a yellow solution. Drain off the lower layers of CCl_4, make up to 50 c.c. with CCl_4, transfer an aliquot to a colorimeter, and match the colour against standards in the usual way, using a green filter with a max. transmission of 540 mμ. The method can be applied to all commercial Al alloys containing $\not>$8% Cu; it is rapid and accurate to within ±0·03% Cu. Mn, Fe, Zn, Ni, Si, Mg, Pb, Cr, Sn, Bi, and Ti do not interfere.—E. N.

Determining Iron Content. A New Method for Aluminium Alloys. —— (*Metal Ind.*, 1946, **69**, (6), 112).—A method for determining the iron content of aluminium alloys, based on the colour reaction between the iron and orthophenanthroline. The latter turns orange when it unites with ferrous iron.

—J. H. W.

***Photocolorimetric Determination of Bismuth in Copper.** A. I. Kokorin and I. G. Dermanova (*Zavod. Lab.*, 1946, **12**, (1), 59–63).—[In Russian]. The method, which is based on the reaction of Bi with NH_4CNS, permits the determination of 0·0005–0·003% Bi in 5 g. of Cu.—N. A.

Copper and Lead Estimation. Speedy "Spekker" and Centrifuge Method [for Brasses]. C. E. Gubbins (*Metal Ind.*, 1946, **68**, (16), 312).—Lead in brasses containing copper 55–60, lead 1–3·5% was determined by precipitation with H_2SO_4 in HNO_3 solution containing urea, and centrifuging in a flask fitted with a "milk-sedimentation capillary" for 5 min. at 300 r.p.m. The percentage of precipitated $PbSO_4$ is read off directly on the tube, which is graduated so that 2 mm. = 0·5% lead, thus giving the lead content to 0·25%. The copper solution is transferred to a Spekker, specially mounted on a spring platform to obviate vibration from heavy machinery. Traces of tin are filtered off before measuring, as neither citric nor tartaric acid may be used.

—J. H. W.

***Analysis of Manganese Bronze.** Harold Ravner (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 41–43).—With the use of a single sample wt., Cu, Pb, Sn, Fe, and Ni may be accurately determined in Mn bronze. Cu and Pb are plated out in the presence of HF, which serves to hold Sn in solution; care must be taken that the Cu is completely deposited or it follows Sn through the subsequent separation, causing low Sn values. Pb is usually high due to Mn contamination, and this can be corrected by transferring the anode, with the PbO_2 deposit, to a previously boiled 20% HNO_3 solution, reversing the current for a few sec., and then replating for 1 hr. Sn is subsequently separated from the Fe and Ni with H_2S, reduced with Pb, and titrated with KI–KIO_3 solution. The H_2S separation also serves to reduce $Fe^{\cdot\cdot\cdot}$ to $Fe^{\cdot\cdot}$, in which state it is determined with $CeSO_4$ solution. Ni is precipitated from the resultant solution with dimethylglyoxime. The results check closely with longer conventional methods.—E. N.

Polarographic Method for the Control of [Brass] Electroplating Baths and Electrodeposits. D. A. Vyakhirev (*Zavod. Lab.*, 1946, **12**, (3), 276–278).—[In Russian]. V. describes a polarographic method for determining Cu and Zn in brass-plating baths and brass electrodeposits, using an ammoniacal solution.—N. A.

***Potentiometric Methods for Determining Aluminium in Elektron-Type Magnesium Alloys.** L. Ya. Polyak (*Zavod. Lab.*, 1946, **12**, (3), 268–275).—[In Russian]. A method is described for determining Al by titration with NaF and another, very rapid, method by titration with NaOH.—N. A.

***Determination of Hydrogen, Carbon, and Nitrogen in Magnesium Alloys.** E. G. Bobalek and S. A. Shrader (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (9), 544–553).—The determination of H_2, CO, CO_2, and N_2 in Mg alloys was studied by various methods: helium extraction, vacuum extraction, electrical degassing by ionic bombardment, combustion in O_2, and Kjeldahl (for N_2 only). The He extraction was specific for H_2, H_2O vapour, and oxides of C, but needed careful purification of the He at the source, and analysis of the gases in the He after it has passed through the molten metal. Vacuum extraction, when done in a twin-type sublimation furnace, was the best for speed and precision, as large samples (10 g.) could be handled, thus minimizing errors. For pure Mg, the extraction was complete in 2–3 min. at 600° C., but the time and temp. increased with complex alloys, and the removal of the last traces was slow and could be confused with the blank degassing of the furnace. Degassing by ionic bombardment, making the specimen the cathode in a discharge tube, was too complicated to provide a convenient analytical procedure. The combustion method, burning in pure O_2 and measuring the H_2O and CO_2 liberated, needed a high degree of refinement in manipulation and was tedious, but gave the most consistent and accurate results for oxides of C. The Kjeldahl method was most accurate for N_2 determination. Although all three extraction methods gave consistent results, it is concluded that they are only of the greatest precision for the determination of H_2.—E. N.

***Electrodeposition of Zinc in Magnesium Alloys Employing Various Buffered Solutions.** Thomas F. Boyd, George Norwitz, and Sidney Weinberg (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (8), 472–473).—The electrodeposition of Zn from NH_4OH, NaOH, citric acid, tartaric acid, and formic acid solutions was studied and the results compared with gravimetric and volumetric methods of determination. Although Zn can be quantitatively deposited over a wide range of *p*H with acceptable precision, the best results are obtained with deposition from solutions containing formic acid. The recommended procedure is: dissolve 0·5 g. of the alloy in 40 c.c. dil. H_2SO_4 (1 : 9), add 2 c.c. of 25% tartaric acid solution and 7–8 g. of $(NH_4)_2SO_4$, dilute to 200 c.c. with H_2O, stir, make just ammoniacal using methyl red as indicator, add formic

acid (1 : 4) until just acid and then 5–6 drops in excess, electrolyse at 3 amp. for 25 min., agitating with air, wash, dry at 100° C., cool, and weigh.—E. N.

The Application of the Polarographic Method of Analysis to Production Control in Non-Ferrous Metallurgy. S. A. Pletnev, T. V. Aref'eva, E. M. Tal, and E. I. Dubovitskaya (*Zavod. Lab.*, 1946, **12**, (1), 38–58).—[In Russian]. Methods are described for : (1) determining Cu, Pb, and Zn in Cd, (2) the control of industrial solutions and products in Co production, (3) determining Cu, Bi, Pb, Cd, and Zn in Sn and Pb–Sn solders, (4) determining impurities in Pb, (5) rapid determination of Pb, Cd, and Zn in ores and tailings from enriched ores. In many cases, for the basis electrolyte, use was made of solutions of salts of the metals being analysed, thus enabling the necessary determinations to be carried out without the sample having to undergo any kind of chemical treatment, with consequent economy in time.—N. A.

***Evaluation of Spectrographic Analytical Data [of Aluminium Alloys].** H. V. Churchill and J. R. Churchill (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (12), 751–754).—Discusses statistical methods of handling data obtained from the spectrographic analysis of Si, Fe, Cu, Mn, Mg, Cr, and Ni in Al alloys, reference being made to the influence of random and systematic errors in manipulation and methods. It is concluded that regularly made spectrographic analyses are of high quality, and that the probable errors are not greater than those encountered in routine chemical analyses.—E. N.

Spectrographic Analysis of Powdered [Aluminium] Alloys. N. K. Rudnevsky (*Zavod. Lab.*, 1946, **12**, (2), 189–193).—[In Russian]. Conditions are given for the spectrographic analysis of alloys containing : Zn $<0{\cdot}5$, Mg $<0{\cdot}5$, Mn $<0{\cdot}5$, Fe $<1{\cdot}5$, Si 4·5–6·0, Cu 6·25–7·75%, aluminium the remainder.—N. A.

Quantitative Spectrographic Determination of Nickel in Copper Alloys. V. F. Vetoshkin (*Tsvet. Metally*, **1945**, (4), 58–60).—[In Russian]. A description of the method and of the construction of the calibration curves.—N. A.

***Spectrographic Analysis of Lead and Its Oxides.** K. I. Taganov (*Zavod. Lab.*, 1946, **12**, (4/5), 449–454).—[In Russian]. T. describes the apparatus, the preparation of standard specimens, and the method of analysis, and gives results obtained in control analyses.—N. A.

***Simultaneous Spectrophotometric Determination of Titanium, Vanadium, and Molybdenum.** Alfred Weissler (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (11), 695–698).—In 70% $HClO_4$ solutions the H_2O_2 complex of Ti is yellow, of V reddish-yellow, and of Mo a pale yellow. The complex of Mo can be intensified by additions of H_3PO_4, which also serves to eliminate extraneous colour due to Fe. The optical densities of the absorption spectra bear a linear relationship to concentration, and are additive at the various wave-lengths, 330 mμ for Mo, 410 mμ for Ti, and 460 mμ for V, thus enabling the three ions to be determined simultaneously in a Beckman spectrophotometer, using monochromatic light.—E. N.

***Spectrophotometric Determination of Nitrates in Plating Baths.** Albert Dolance and Paul W. Healy (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (11), 718–719).—NO_3' in silver-plating baths containing 0–120 g./l. KNO_3, together with AgCN, KCN, K_2CO_3, and KOH, may be determined with an accuracy of $\pm 2{\cdot}5$ g./l. by the method. 5 c.c. of the plating-bath solution are placed in a 100 c.c. beaker, and a precipitating solution (13·5 g. $HClO_4$, 93·6 g. $AgClO_4$, 258 g. $Ba(ClO_4)_2$/l.) added drop by drop until no further precipitation occurs. Stand for 1 hr., filter, and wash precipitate three times with distilled H_2O. Dilute the filtrate and washings to 50 c.c., and measure the absorption of light due to NO_3' at 305 mμ, using a Beckman quartz spectrophotometer. The precipitating solution removes CN', CO_3', and OH', as they show light absorption.—E. N.

Spectroscopy Applied to Ferrous and Non-Ferrous Materials. Wm. J. Pochlman (*Weld. J.* (*J. Amer. Weld. Soc.*), 1945, **24**, (11), 564–572S).—A brief account of the history, principles, and uses of the spectroscope in a modern metallurgical laboratory. Examples of its application, and some typical results, are given.—P. H.

***Device and Method for Quantitative Analysis [with X-Ray Diffraction Powder Camera].** Stanley Brosky (*Indust. Radiography Non-Destructive Test.*, 1946, **5**, (1), 36–39).—The unknown (*e.g.*, containing silica) is mixed with an equal quantity of a known reference substance (*e.g.*, NiO), and the mixture is used as the specimen in an X-ray diffraction powder camera. Part of the pattern is filtered by a wedge consisting of 1, 2, 3, . . . 10 thicknesses of aluminium placed in contact with the film. After calibration, the amount of the unknown present may be estimated by comparing the number of aluminium steps through which reference lines of the standard and unknown are visible.—L. M.

The Application of the Mass Spectrometer to Chemical Analysis. A. Keith Brewer (*Bull. Amer. Soc. Test. Mat.*, 1946, (**140**), 38–42).—A discussion of the use of the mass spectrometer in the analysis of hydrocarbon molecules, with suggestions as to how the technique may be applied to alloys.—H. J. A.

A Generator for a Multi-Crater Arc and a Set of Universal Accessories for Spectrographic Analysis. P. F. Lokhov (*Izvest. Akad. Nauk S.S.S.R.*, 1945, [Fiz.], **9**, (6), 753–758).—[In Russian]. By superimposing a magnetic field on the ordinary A.C. arc greater stability of the spectrum is obtained because a number of arcs are struck instead of one. A combined spark and arc source for use with a steelometer is described, with the aid of a circuit diagram; either form of excitation can be selected by means of two double-throw switches. In the determination of Mo in steel, better results were obtained with the multiple arc than with the spark source. A set of five gadgets for improving the efficiency of the steelometer is also described and illustrated.
—N. B. V.

Quality Control. II.—Chemical Laboratories. H. L. Collins and H. Shehyn (*Canad. Metals*, 1945, **8**, (7), 20–25, 38).—Describes the detailed layout and organization of a chemical laboratory for metallurgical analysis.
—H. J. A.

XII.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

The Kelvin Double Bridge for Measuring Surface Resistance of Aluminium Alloys. (*Weld. J.* (*J. Amer. Weld. Soc.*), 1945, **24**, (9), 458–459S).—The apparatus consists of two parts, namely, a press in which coupons are clamped together under known pressure, and a bridge. Circuit diagrams are given.
—P. H.

***A Photo-Electric Method of Measuring Damping in Metal Forks at Elevated Temperatures.** T. E. Pochapsky and W. J. Mase (*J. Appl. Mechanics*, 1946, **13**, (2), A157–A161).—Describes details of construction and tests performed to establish the accuracy of a new apparatus for measuring internal friction in metals. A photo-electric method of measuring amplitude decay was developed by using shutters on a vibrating fork to modulate light directed at a photocell. The apparatus works satisfactorily up to 1500° F. (815° C.).
—H. J. A.

Semi-Automatic Spectrographic Analysis. R. H. Zachariason (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (12), 749–750).—Spectrographic operations may be simplified and made more rapid by using semi-automatic devices, which are described and illustrated, for positioning the plate after each ex-

posure, focusing the electrodes, controlling the exposure, and changing the electrodes. 13 exposures may be made on one small plate.—E. N.

Time-Switching Apparatus. P. H. Keck (*Spectrochim. Acta*, 1944, **2**, (8), 389–395).—Details are given of a fully automatic delayed-action time switch, constructed throughout of standard commercial components. The beginning and duration of an exposure in spectrographic analysis can be accurately controlled.—M. A. V.

A Generator for a Multi-Crater Arc and a Set of Universal Accessories for Spectrographic Analysis. (Lakhov). See p. 428.

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

Questionnaire Relating to Machines and Apparatus for Mechanical Testing. F. P. Belyankin. N. N. Davidenkov. V. D. Kuznetsov. I. A. Oding and I. V. Kudryavtsev. S. V. Serensen. Ya. B. Fridman. E. M. Shevandin (*Zavod. Lab.*, 1946, **12**, (3), 328–362).—[In Russian]. Reports the answers given by the persons indicated above to questions on the prospects for the development and invention of improved machines and apparatus for the mechanical testing of materials.—N. A.

Quality Control. V.—Mechanical Testing. A. E. Hyde (*Canad. Metals*, 1945, **8**, (10), 26–29, 45).—Brief review of the principles of tensile and hardness testing.—H. J. A.

Micro-Hardness Testing. A Description of a Technique Developed in Sweden. E. Börje Bergsman (*Metal Ind.*, 1946, **69**, (6), 109–112).—B. describes a micro-hardness-testing apparatus, using an ordinary Vickers diamond for both scratch and indentation hardness. The technique is designed for use with any standard inverted microscope, with only slight modification in the attaching device to suit various types of stage and object holders.—J. H. W.

Method of Notching Impact-Test Specimens. S. E. Siemen (*Bull. Amer. Soc. Test. Mat.*, 1946, (139), 45–46).

***The Mechanics of the Tensile Test.** E. Siebel (*Wiss. Abhandl. deut. Materialprüfungsanst.*, 1944, (5), 1–4).—The stress distribution in the neck of a tensile test-piece is calculated theoretically, and the variation from the suface to the axis determined. The zone in which plastic flow takes place decreases with increased necking. This agrees with experiment.—M. A. V.

***Tension Testing at Elevated Temperatures [Aluminium].** T. M. Blackmon, P. R. Nourse, and E. H. Plesset (*Bull. Amer. Soc. Test. Mat.*, 1946, (140), 32–37).—Aluminium test bars have been satisfactorily heated to 550° F. (290° C.) by the resistance heating of a current flowing in the test bar. Two extensometers for measurement in the elastic and plastic regions have been developed, together with a technique for determining the true load at fracture.
—H. J. A.

***Tension Tests of Single-Row Spot-Welded Joints in 24S-T Alclad Aluminium Alloy Sheet.** (Della-Vedowa). See p. 443.

Calculation of the Elongation from One Length to Another. I. V. Kudryavtsev (*Zavod. Lab.*, 1946, **12**, (2), 233–235).—[In Russian]. Formulæ are deduced for calculating elongation in the tensile testing of metals.—N. A.

***Determination of the Modulus of Elasticity Using the Method of Coincident Oscillations of Conjugate Pendulums.** F. F. Vitman and B. S. Joffe (*Zavod. Lab.*, 1946, **12**, (4/5), 458–472).—[In Russian]. The phenomenon of coincident oscillations has been utilized in working out a method for the determination of the modulus of elasticity. The results obtained confirm in essentials the work of Le Rolland and Sorin (*Rev. Mét.*, 1933, **30**, 112; *J. Inst. Metals*, 1933, **53**, 518), although carried out independently. In conclusion, a description is given of the apparatus devised by V. and J.—N. A.

Proof-Stress Determination. R. A. Beaumont (*Aircraft Prodn.*, 1946, **8**, (87), 42–51).—Procedure and equipment for proof-stress determination are discussed with special reference to the machines and apparatus used, and also to the observation of proof stresses without the necessity for plotting stress–strain diagrams.—H. S.

The Specification of Test Loads [Aircraft Structures]. A. G. Pugsley (*Aircraft Eng.*, 1945, **17**, (202), 352–353).—Loading conditions for strength tests on aeroplane structures are discussed in relation to the loads which occur in service. Observations on load fluctuations which occur in level flight indicate broadly the more or less continual occurrence of stress fluctuations of $\pm 5\%$ to $\pm 10\%$ about the average. P. indicates the loading conditions for fatigue tests, based on the specified ultimate strength, and suggests that collapse should not occur before 50 million fluctuations. To meet the severe loading condition that may or may not occur once or a few times in the life of the aeroplane during a severe manœuvre. P. suggests that the structure should remain airworthy during and after 5 repetitions of loading to the proof load, and should not break before 20 applications of that load. For information on the performance under loads occurring more frequently in manœuvres of a less severe character, P. suggests that the structure should remain airworthy during and after 100 repetitions of loading to half the specified ultimate stress, and should not collapse before 500 repetitions. The importance of studies of the performance of structures under fluctuating and repeated loads is emphasized, and attention is directed to the importance of scatter in such tests, on which at present there is little information available.—H. S.

Determination of Allowable Working Stresses. D. P. Barkley (*Commonwealth Eng.*, 1946, **33**, (11), 384–388).—The concept of "factor of safety" in engineering design is analysed and discussed.—H. J. A.

Strain Analysis by Photogrid Method. W. F. Brown, Jr., and M. H. Jones (*Iron Age*, 1946, **158**, (11), 50–55).—The data required for an evaluation of the characteristics of a metal for a certain forming operation can be determined by measuring the distance between a given pair of lines during or after the process of forming. A series of such lines constitutes a grid. The requirements of a grid are detailed, and the technique of applying the grid to a metal surface and the subsequent strain measurement are discussed.—J. H. W.

Use of Statistics in Writing Specifications. (Goffman and Manuele). See p. 451.

Laboratory Tests to Predict the Performance of Metals [Zinc, Aluminium] Under Service Conditions. D. W. Sawyer and R. B. Mears (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1945, **17**, (1), 1–5).—S. and M. review the conditions of relationship between laboratory and service tests and give examples. Measurement of the solution potentials of zinc and aluminium has been found to be a useful laboratory test for predicting the feasibility of using cathodic protection for aluminium chemical plant. A correlation between service results and potential measurements is given.—E. N.

Aluminium Alloy Forgings. Inspection Standards for High-Temperature Oxidation. —— (*Metal Ind.*, 1946, **68**, (22), 425–426).—A summary of the results of a recent investigation on high-temp. oxidation in aluminium forgings to establish a standard inspection procedure for the acceptance or rejection of these forgings. Macrography and tensile-test results should be supplemented by microscopic tests in order to obtain a definite classification of the forging. —J. H. W.

Identifying Aged Material. Temper Determination of Clad 24S. —— (*Metal Ind.*, 1946, **68**, (26), 518).—To test whether an unidentifiable part of clad aluminium alloy 24S (copper 4·6, manganese 0·6, magnesium 1·5%) has been aged or not, a small micro-specimen is mounted along with a known aged sample, polished, and etched in a solution of 1% nitric acid and 5% acetic

acid in water. The specimens are then examined at a high enough magnification to resolve the grain boundaries. If these can be seen, the material has been aged. A check test consists in repolishing the specimen and immersing it in a 2% aqueous solution of ferric chloride: aged material evolves gas bubbles from its surface after a few sec.—J. H. W.

***Soft-Solder Selection Aided by Simple Test.** (Schumacher, Bouton, and Phipps). See p. 440.

Materials Engineering at Home and Abroad. (Townsend). See p. 448.

Supersonics in Metallurgy. A Review of Recent French Work. N. Marinesco (*Metal Ind.*, 1946, **69**, (7), 136–138).—Condensation of a paper read to the Centre de Perfectionnement Technique. M. describes the progress made in the use of supersonics in both light and heavy engineering and the good results so far obtained. Applications include the decreasing of the solidification temp. of metals, the tinning of aluminium, modifying in magnetic properties, and increasing the chemical activity of metals.—J. H. W.

Supersonic Flaw Detector. —— (*Canad. Metals*, 1946, **9**, (9), 31, 42).—A brief outline of the principles and methods of supersonic flaw detection in metals.—W. G. A.

Electron Diffraction in Practice. Wayne T. Sproull (*Indust. Radiography Non-Destructive Test.*, 1946, **5**, (1), 40–44).—An introduction to the theory and technique of electron diffraction. The important differences between electron- and X-ray diffraction are reviewed. The applications mentioned include studies of electroplating, electrolytic polishing, mercury and its amalgams, and the electrical conductivity of thin surface films.—L. M.

Correlation of Inspection Methods in the Metal Industry.—I, II. James V. Rigbey (*Canad. Metals*, 1945, **8**, (11), 36–40; (12), 38–41, 48, 50, 52).—A review of the application of radiography, magnetic crack detection, fluorescent crack detection, microscopic metallography, and supersonic crack detection. —H. J. A.

***Fluoroscopy. Application to the Examination of Metallic Objects.** B. Cassen and D. S. Clark (*Metal Ind.*, 1945, **67**, (23), 375–377; 1946, **69**, (2), 25–27; and *Aircraft Prodn.*, 1946, **8**, (93), 352–354).—Cf. *Met. Abs.*, this vol., pp. 99, 265. Describes investigations at California Institute of Technology on fluoroscopic examination of castings. The fluoroscope does not show large numbers of very small defects that are seen on radiographs. With the use of rotational scanning, the fluoroscope shows a surprisingly large number of medium and larger defects that are not detected radiographically.—H. S.

The History and Present Status of Emission Spectroscopy as Applied to Industry. (Convey). See p. 451.

RADIOLOGY

Accurate Interpretation of Radiographs. Henry R. Clauser (*Materials and Methods*, 1945, **22**, (5), 1418–1422).—The use of penetrameters is discussed, reference being made to the influence of contrast and definition on sensitivity. Some of the more common types of film blemishes are described and the importance of good viewing facilities is emphasized.—J. C. C.

Acceptance Standards for Castings. Leslie W. Ball (*Aircraft Prodn.*, 1946, **8**, (87), 3–6).—Cf. *Met. Abs.*, this vol., p. 59. B. discusses the use of radiography and X-ray micrography in assessing quality, with special reference to light-alloy castings for aircraft applications.—H. S.

Quality Control. IV.—Radiography. J. K. E. Cox (*Canad. Metals*, 1945, **8**, (9), 20–24).—The technique of radiography is reviewed, and the interpretation of radiographic results is discussed.—H. J. A.

Continuous X-Ray Inspection—Results Achieved with 2,000,000-Volt Unit at Large U.S. Ordnance Plant. David Goodman (*Canad. Metals*, 1945, **8**, (11), 32–35, 52).—The apparatus is described and an account is given of the

routine employed at an American ordnance factory where heavy bombs are radiographed. Details are given of safety measures and of the economics of the testing process.—H. J. A.

***Preliminary Investigation of Metal Pouring by Ciné Radiography.** S. L. Fry (*Proc. Inst. Brit. Found.*, 1944–45, **38**, A45–A53; discussion, A53–A54).—See *Met. Abs.*, 1945, **12**, 337.

XV.—FOUNDRY PRACTICE AND APPLIANCES

Aluminium Foundry Alloys. Their Selection and Preparation. E. Carrington (*Metal Ind.*, 1946, **69**, (3), 45–47; (4), 69–72).—C. discusses the problem of the selection of aluminium alloys and reviews their commercial requirements for various applications. The specifications for high-, medium-, and low-strength alloys are tabulated. Dealing with the foundryman's requirements in these alloys, C. surveys their expansion and contraction, their preparation, the use of scrap, effects of gas, degassing, and the use of fluxes in melting.
—J. H. W.

Better-Quality Aluminium and Magnesium Castings for Aircraft. Robert E. Ward (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (1/3), 13–14, 16).—Reprinted from *Trans. Amer. Found. Assoc.*, 1944, **52**, 475; *Met. Abs.*, 1945, **12**, 60.—N. B. V.

Melting Light Alloys. Developments in Open-Hearth Furnaces. H. Hocking (*Metal Ind.*, 1946, **68**, (22), 430).—Briefly describes suitable modifications to open-hearth furnaces for increasing the efficiency of melting for bulk outputs of light alloys.—J. H. W.

Fluxing Molten Aluminium with Dry Nitrogen. P. M. Hulme (*Materials and Methods*, 1945, **22**, (5), 1435–1438).—Nitrogen scavenging is now used successfully for producing sound castings of aluminium and aluminium alloys and is as effective as the use of chlorine, provided that too rapid a stream of nitrogen is not employed. The effect is to bring finely dispersed inclusions to the surface, and remove entrapped gases and dissolved hydrogen. Methods of introducing nitrogen into the melt in both crucible and reverberatory furnaces are described.—J. C. C.

Aluminium Casting Processes and Applications. Hiram Brown (*Modern Metals*, 1946, **2**, (4), 8–12).—Sand casting, gravity and pressure die-casting, plaster- and centrifugal-casting methods are described, and mention is made of new alloy developments and typical applications.—N. B. V.

Some High-Tensile Aluminium Casting Alloys. J. Morgan (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B134–B137; discussion, B137–B139).—See *Met. Abs.*, 1945, **12**, 144.

Sodium Silicate Sealing for Aluminium Castings. —— (*Iron Age*, 1946, **157**, (2), 63).—The sodium silicate system of sealing aluminium castings is not always completely effective. Tests were made to secure protection against leaking by baking at 220° F. (105° C.) for 2 hr. after treatment. No measurable effect resulted from the baking.—J. H. W.

The Future of the Light-Alloy Foundry Industry. W. C. Devereux (*Proc. Inst. Brit. Found.*, 1944–45, **38**, A14–A22).—See *Met. Abs.*, 1945, **12**, 338.

The Electric-Furnace Melting of Copper. R. H. Waddington and J. C. Bischoff (*Canad. Min. Met. Bull.*, **1946**, (409), 199–226).—Complete operational details are given for a method of continuous melting of copper in a three-phase direct-arc electric furnace. The economic benefits obtained from the electric-arc melting process are summarized.—H. J. A.

Porosity in Copper Alloy Castings. Causes and Prevention in Materials with High Copper Contents. K. Strauss (*Canad. Metals*, 1945, **8**, (1), 27–28).—A review of gas porosity as encountered in tin-bronzes, phosphor bronzes, gun-metals, &c.—H. J. A.

***Precision Casting Heat-Treatable Copper-Base Alloys.** H. Rosenthal, S. Lipson, and H. Markus (*Iron Age*, 1946, **158**, (12), 48–54).—Describes an investigation of the properties of cast "aluminium bronze" and beryllium–copper resulting from the heat-treatment of precision investment-cast specimens. An essential feature of the research was the adaptation of the insulating properties of the investment by quenching while the alloy was still in the solid-solution-temp. range. By quenching the castings immediately after solidification and then giving them a low-temp. reheating, their hardness and tensile properties become equivalent to those of specimens given the conventional heat-treatment. The properties attainable by the use of this special quenching technique meet the A.S.T.M. requirements for cast material.

—J. H. W.

***Mould Dressings. Effect on the Surface Quality of Bronze Ingots.** W. T. Pell-Walpole (*Metal Ind.*, 1946, **69**, (7), 129–134).—Describes work on the development of a mould dressing that can be used thinly, but which is strong, as is required for securing max. internal soundness of bronze ingots cast in chill moulds. "Blowing" in such ingots can be eliminated, even under unfavourable conditions, by using a thin coating of resinous aluminium paint (Otopose), or some similar suspension of aluminium powder or oxide. Stockholm tar and a commercial refractory dressing, "B," also tend to reduce blowing, though to a less extent than the aluminium paint.—J. H. W.

Chill-Cast Bronzes. W. T. Pell-Walpole (*Metal Ind.*, 1946, **68**, (16), 303–305; (17), 323–324; (18), 346–348).—A comprehensive review of the relation between porosity and tensile strength in chill-cast bronzes. P.-W. discusses the various types of porosity commonly met in the foundry; the cause, nature, and appearance of entrapped-gas-, shrinkage-, and soluble-gas porosity; and the graphical representation of the percentage porosity and corresponding tensile properties of two series of chill-cast phosphor bronzes. Shrinkage porosity has the most detrimental effects on tensile properties, while entrapped-gas porosity has the least harmful effects.—J. H. W.

The Technology of Producing Propeller Screws in the United States. V. A. Leonov (*Sudostroenie*, **1946**, (3), 23–26).—[In Russian]. L. gives a detailed description of American practice, in particular of the methods used by the Iron Works Corporation in producing propellers for "Liberty" ships. The propellers are cast almost to size in cement moulds and are then finished by means of pneumatic grinding tools.—N. B. V.

***The Continuous Casting of Ingots of LT96 and Other Copper–Zinc Alloys.** A. A. Budaev (*Tsvet. Metally*, **1945**, (6), 52–56).—[In Russian]. A machine for the continuous casting of ingots of 30–100 mm. dia. has been devised and tested, and the conditions have been established for producing copper–zinc alloy ingots of 50 and 60 mm. dia. The effect of the casting conditions on the macrostructure of the ingots has been studied.—N. A.

Casting and Handling Ten-Ton Lead Bullion Blocks. K. Harms and T. D. Jones (*Min. and Met.*, 1946, **27**, (475), 391–392).—To facilitate transport, one American smelter now casts lead in 10-ton blocks instead of 100-lb. bars. The lead is cast in a rectangular cast-steel mould, from which the solid block is subsequently lifted by two steel screws that have been cast in. The screws are then removed and the holes left by them are plugged with more lead.

—N. B. V.

Lead Products—Manufacture Involves Melting, Casting, Extrusion, Rolling, and Burning. —— (*Canad. Metals*, 1945, **8**, (10), 30–32).—The operations of the lead division of the Canada Metal Company, Ltd., are reviewed.

—H. J. A.

Magnesium-Melting-Pot Life Increased by Sprayed Special Alloy Coating. A. V. Keller (*Indust. Heating*, 1945, **12**, (12), 2074, 2076, 2078, 2080; and *Metal Ind.*, 1946, **68**, (16), 306).—Cast-steel pots of 600 lb. capacity, used in

casting Dow Metal C, are subject to severe scaling in areas in contact with the flame from gas burners. The life of the pots has been more than quadrupled by Metcolizing. The cleaned pot is sprayed (*a*) with a chromium–nickel alloy, (*b*) with pure aluminium, and (*c*) with a proprietary sealing compound. Service data for treated and untreated pots are compared.—P. R.

***The Cause and Control of Microporosity in Magnesium Alloys.** E. A. G. Liddiard and W. A. Baker (*Proc. Inst. Brit. Found.*, 1944–45, **38**, A63–A75; discussion, A75–A77).—See *Met. Abs.*, 1945, **12**, 339, 412.

Bearings and Bearing Metals. (Brouk). See p. 447.

Non-Ferrous [Zinc Alloy] Dies and Moulds. L. Sanderson (*Indian and Eastern Eng.*, 1946, **48**, (2), 253–256).—S. discusses the use of zinc alloy dies and moulds for the blanking of aluminium sheet or the moulding of plastics. A typical composition of the alloy used is: aluminium 3·9–4·1, magnesium 0·03–0·04, copper 1·0, lead, cadmium, and tin <0·003%.—H. J. A.

***The Study of Casting Systems by Means of Models.** A. A. Bochvar, E. M. Notkin, S. I. Spektorova, and N. M. Sadchikova (*Izvest. Akad. Nauk S.S.S.R.*, **1946**, [Tekhn.], (6), 875–882).—[In Russian]. A new method of making models of complicated castings has been introduced, using transparent organic material for the mould. A study of the effect of the cross-sections of the principal parts of the casting (run from below and also by means of a vertical gate) has shown that the rate of filling the mould depends chiefly on the cross-section of the gate. The separation of oxides and slag depends on the cross-section of the gate and on the shape and size of the arrangement for entrapping them. With increase in the dia. of the gate, the time of filling the mould is reduced, but turbulence and the quantity of oxides and slag carried over increase markedly. With gates and risers of small dimensions, the vertical-gate system ensures filling of the mould layer upon layer, which is an important advantage over the method of casting from below from the point of view of directionality of crystallization. Further study must be directed to the evolution of casting systems in which improved separation of oxides and slags would be achieved without reduction of the rate of filling the mould.—N. A.

Precision Casting by the Lost-Wax Process. Adam Dunlop (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B1–B7; discussion, B7–B10).—See *Met. Abs.*, 1945, **12**, 125.

Acceptance Standards for Castings. (Ball). See p. 431.

Uses of Gases in the Foundry. Harold Haynes (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B68–B71; discussion, B71–B74).—See *Met. Abs.*, 1945, **12**, 198.

A Study of Moulding Methods for Sound Castings. Frederick G. Sefing (*Proc. Inst. Brit. Found.*, 1944–45, **38**, A142–A150; discussion, A150–A154).—See *Met. Abs.*, 1945. **12**, 262, 339, 413.

The Development and Application of Pattern Equipment for the Production of a Light-Alloy Casting. F. H. Hoult (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B104–B111; discussion, B111–B113).—See *Met. Abs.*, 1945, **12**, 261, 415.

Plaster, Plastics, and Low-Melting-Point Metals in Pattern-Making. H. Plucknett (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B64–B67).—See *Met. Abs.*, 1945, **12**, 262.

***Synthetic Foundry Sands with Cement as a Binder.** K. Endell and W. Strasmann (*Giesserei*, 1942, **29**, (21), 349–356).—E. and S. review the literature on synthetic foundry sands with cement binders; and describe experiments on three German types of cement, in which the effect of water content on shear strength and permeability was investigated. Ordinary Portland cement was found to be less suitable than either Novo (a high-quality Portland cement) or fused aluminous cement. Higher initial strengths were obtained with low water content with Novo than with fused aluminous cement. Novo further had the advantage of sintering less markedly at 1400° C.—M. A. V.

Resin Binders Improve Sand Cores. F. G. Felske (*Modern Plastics*, 1945, **23**, (2), 118–120; *C. Abs.*, 1946, **40**, 1690).—Urea–resin binder cures in 30–90 min. at 325° F. (163° C.). It is especially useful in casting aluminium and magnesium owing to its low temp. of breakdown.

Foundry Practice at Consolidated—Production of Wide Range of Castings for Maintenance and Repair. T. R. Stanley (*Canad. Metals*, 1945, **8**, (12), 24–26).—Describes the operating techniques employed at the foundry of the Consolidated Mining and Smelting Company of Canada.—H. J. A.

Gravity Die-Casting. Theoretical and Production Aspects Applied to Aluminium Alloys. R. Hinchcliffe (*Metal Ind.*, 1946, **69**, (8). 151–153; (9) 174–176; (10), 193–195).—H. describes (*a*) the characteristic properties of aluminium and its alloys as they affect the process of gravity die-casting, (*b*) the problem of solidification, (*c*) the proper gating, (*d*) the feeding methods required, and (*e*) the mechanical design of gravity dies. Details of some difficult die-castings are given.—J. H. W.

Aluminium Die-Castings. S. K. Ghaswala (*Indian and Eastern Eng.*, 1946, **99**, (1), 66–68).—A review of American practice for the die-casting of aluminium–copper, aluminium–zinc, aluminium–silicon, and aluminium–manganese alloys. Pressure die-casting machines are described, and the relative advantages compared of steel, cast iron, and aluminium alloy for the manufacture of dies.—W. G. A.

Permanent-Mould Fundamentals. [Aluminium Alloys]. J. W. Wheeler (*Modern Metals*, 1946, **2**, (2), 11–16).—A review of the gravity die-casting of aluminium alloys.—N. B. V.

New Magnesium Die-Casting Alloy [Eclipsaloy]. (Hauser). See p. 412.

Die-Casting [Machines and Alloys]. Herbert Chase (*Materials and Methods*, 1945, **22**, (5), 1441–1452).—A "*Materials and Methods* manual" describing concisely die-casting machines and alloys and discussing the advantages and limitations of die-castings, design principles, and present and future applications.—J. C. C.

Gravity Die-Casting. A. R. Palmer (*Proc. Inst. Brit. Found.*, 1944–45, **38**, B94–B101); discussion, B101–B103.—See *Met. Abs.*, 1945, **12**, 374.

Some Aspects of Good Foundry Management. A. C. Boak (*Canad. Metals*, 1945, **8**, (10), 33–36).—Samples of report and record cards which may be of use in foundry management are illustrated.—H. J. A.

The Foundry Data Sheet. —— (*Foundry*, 1945, **73**, (12), 145–146; 1946, **74**, (1), 157–158; (2), 151–152; (3), 161–162; (4), 167–168; (5) 203–204; (6) 187–188; (7), 169).—A glossary of terms used in the foundry.—J. E. G.

XVII.—FURNACES, FUELS, AND REFRACTORY MATERIALS

New Conveyor Design Increases Output of Aluminium Billet-Heating Furnace. John H. Loux (*Indust. Heating*, 1946, **13**, (1), 90; and *Metal Ind.*, 1946, **68**, (19), 364).—A conveyor device for moving aluminium billets through a heating furnace consists of a motor-activated drive tube, extending through the furnace; the billet rests partly on this and partly on a series of obliquely set idler rollers. The revolution of the tube causes the billet to rotate, and to bring the rollers into operation, the billet being moved forward.—P. R.

Melting Light Alloys. Developments in Open-Hearth Furnaces. (Hocking). See p. 432.

The Electric-Furnace Melting of Copper. (Waddington and Bischoff). See p. 432.

Brazing and Heat-Treating Assemblies for Magnilastic Expansion Joints. (——). See p. 441.

Heating-up of Electric Resistor Furnaces. Victor Paschkis (*Indust. Heating*, 1946, **13**, (2), 250, 252, 254, 256, 258, 260; (3), 434, 436, 438, 460).—The initial rate of energy output and the design of furnace walls are considered in relation to the heating-up time and the power consumption of electric-resistor furnaces. The process of heating-up falls into two phases: in the first, the rate of energy input is const. and equal to the connected load. When the operating temp. is reached, the second phase is entered, when the furnace temp. is held practically const. and the rate of heating decreases until steady conditions are reached. Graphs show the effects of individual variables such as "excess ratio," rate of energy input, and thickness and thermal conductivity of walls.—P. R.

Induction Heating. Practical Hints on the Design of Coils. W. S. Williams (*Metal Ind.*, 1946, **68**, (25), 500).—All induction-heating coils are based on four types: the internal helix, the external helix, the pancake, and the hair-pin. W. discusses the use of each of these singly and in combination, and gives practical hints on induction heating generally.—J. H. W.

High-Frequency Heating. L. G. Thomas (*Elect. Eng. and Merchandiser*, 1946, **23**, (3), 73–78).—A general review of induction and dielectric heating.
—H. J. A.

Electronic "Blow Torch" may Revolutionize High-Frequency Heating. —— (*Indust. Heating*, 1945, **12**, (11), 1902, 1904).—The electronic "blow torch" is a dielectric heating device which projects ultra-short radar waves towards an object to be polymerized, cured, or bonded. The torch can be used in restricted areas and on pieces of irregular shape.—P. R.

Some Statistical Methods in Refractory Testing. E. H. M. Badger (*Trans. Brit. Ceram. Soc.*, 1946, **45**, (1), 33–43; discussion, 43–44).—In testing samples taken from a consignment of refractory materials there is bound to be variation between individual pieces. An attempt is made to apply the Gaussian theory of frequency distribution to the problem of assessing the results of tests.
—M. A. V.

XVIII.—HEAT-TREATMENT

Annealing Welded Joints in Pipelines. A. W. Isermann (*Elektroschweissung*, 1940, **11**, (6), 99–102).—Description of a portable electric-resistance heater, which can be clamped round welded joints in pipelines for annealing *in situ*.—M. A. V.

Salt Baths. A Novel Device for Handling Molten Chromate. F. P. Golby (*Metal Ind.*, 1946, **69**, (6), 113–115).—A method of avoiding the risk of dermatitis in the use of fused chromate compounds in the heat-treatment of magnesium alloys.—J. H. W.

A Critical Survey of Controlled Atmospheres. Edward J. Funk, Jr., and David Lee von Ludwig (*Iron Age*, 1946, **158**, (12), 42–47).—Controlled atmospheres for various heat-treatments of ferrous and non-ferrous metals and alloys are evaluated from the point of view of economics and metallurgical suitability. A code system is suggested whereby the base atmospheres and their modifications can be readily and systematically identified.—J. H. W.

XIX.—WORKING

***On Some Rolling Problems and Rolling Effects in Aluminium–Copper–Magnesium Alloys.** H. Bohner (*Metallwirtschaft*, 1944, **23**, (44/47), 407–415).—In rolling Duralumin alloys, anomalous mechanical properties and a coarse grain structure frequently develop in sheets of varying thickness. A study was made of the effects of (*a*) ingot pouring rate for both chill- and continuously

cast ingots, (*b*) hot-rolling temp., (*c*) rolling of previously forged billets, (*d*) progressively increasing rolling reductions, and (*e*) temp. and time of solution- and ageing treatment, on the properties of the final sheets. Samples taken longitudinally and transversely to the direction of rolling, from the surface and middle of the sheets, were examined for proof strength, tensile strength, and elongation, while their structure was examined by microscopic and X-ray methods. Little difference was found between chill- and continuously cast billets provided the pouring rates were correct, and initial forging of the billet had only a negligible effect on the final properties of the sheet. The mechanical properties were found to increase with increase of rolling reduction until a critical value was reached, after which the proof stress and tensile strength diminished while the elongation continued to increase. Similarly, it was not until a critical rolling reduction was reached that the centre had mechanical properties superior to those of the outside. Low mechanical properties could be improved by increasing the solution temp. provided that the rolling reduction had not exceeded 70%. The anomalous mechanical properties and crystal structures are almost entirely determined by the conditions of the penultimate and final heat-treatments and by the magnitude of the rolling reduction between them.—E. N.

Lead Products—Manufacture Involves Melting, Casting, Extrusion, Rolling, and Burning. (——). See p. 433.

***The Influence of Rate on the Resistance of Metals to Plastic Deformation.** (Sokolov). See p. 409.

Zinc Extrusions Attain Commercial Status. Herbert Chase (*Materials and Methods*, 1945, **22**, (6), 1724–1727).—Rods, bars, and special shapes in zinc and zinc alloys are now produced by extrusion, using a vertical press taking billets 18 in. long and 5 in. in dia.—J. C. C.

Extrusion. A Comparison of Direct and Indirect Methods. A. Ahearne Heron (*Metal Ind.*, 1946, **68**, (20), 389–391).—The chief disadvantages of direct extrusion, the only method at present adopted in practice, are slow speed, inconsistency of product, and the production of a bar with marked flow characteristics. Indirect, or inverted, extrusion, in which the die is moved on to a stationary billet, would overcome these difficulties, and have these advantages: less generation of heat, better flow conditions, and hence faster extrusion; use of larger containers for the same size of press; an improved forging bar with no pronounced flow lines; smaller discard; and the possibility of extruding aluminium-coated bars.—J. H. W.

Recent Improvements in the Design of Extruding Presses for Welding-Electrode Coatings. R. Müller-Börner (*Elektroschweissung*, 1940, **11**, (6), 97–99).—Older processes for extruding coatings for welding electrodes suffer from the disadvantage of a change in the direction of flow of the coating material. Apart from the question of increased power requirements, the high pressure necessary is apt to lead to the moisture being forced out of the binder. The type of extrusion press here described avoids these difficulties by maintaining the flow of material as nearly as possible in one direction.—M. A. V.

***Investigation of the Character of the Flow of Non-Ferrous Metals in Hot Extrusion.** V. V. Zholobov (*Tsvet. Metally*, 1945, (4), 53–57).—[In Russian]. Z. describes some tests, using a co-ordinate lattice, on brass in a 1000-ton horizontal press using an unheated container and no lubrication, and in a 600-ton vertical press using a graphite lubricant.—N. A.

***The Behaviour Under Tensile Stress of Metals Deformed by Compression.** (Körber, Eichinger, and Möller). See p. 414.

Processing with Magnesium [Alloys]. Avoiding the Breakdown of Corrosion-Resistance. N. H. Simpson (*Metal Ind.*, 1946, **69**, (4), 67–68).—An outline of the common methods of fabrication and processing with magnesium alloys.—J. H. W.

***Magnesium [Alloy] Forgings. An Investigation into Their Production and Properties.** —— (*Metal Ind.*, 1946, **69**, (1), 8–11; (2), 30–32).—A summary of the main conclusions of the four reports on "The Production and Properties of Magnesium Press and Hammer Forgings," issued by the U.S. War Production Board. The reports describe the manufacture of complicated forgings in standard magnesium forging alloys, the production of a large number of magnesium forgings made in dies originally designed for aluminium alloys, and the static mechanical properties developed in certain of the forgings. The production and testing of a large structural member in both magnesium and aluminium alloys are discussed, and a comparison is given of the mechanical characteristics of both alloys. The effects are studied of variations in the handling of the high-strength alloy (aluminium 8·5, zinc 0·5%, magnesium remainder) on its forgeability and properties.—J. H. W.

Kirksite A for Tooling [for Forming Light Alloys]. W. W. Richmond (*Modern Metals*, 1946, **2**, (5), 21–22, 24).—The properties of Kirksite A and its use for dies for forming light alloys are briefly dealt with.—N. B. V.

Forming Magnesium [Alloy]. —— (*Modern Metals*, 1946, **2**, (3), 14–18).—An account of the bending and forming of magnesium alloy sheet, extrusions, and tubes, reproduced from a booklet "Designing with Magnesium," published by the American Magnesium Corp. The properties and forming characteristics of the wrought alloys used in structural design are tabulated. In general the same methods of working may be used as for aluminium, but with some modifications necessitated by the elevated working temp. that has to be used (400°–700° F. (204°–371° C.)).—N. B. V.

Hot Dimpling. Modern Techniques for High-Strength Aluminium Alloys. —— (*Metal Ind.*, 1946, **69**, (11), 213–216; (12), 238–239).—Gives results of an investigation, carried out in the U.S.A., on the general subject of dimpling. In particular, new techniques in hot dimpling are described. The heated-die method of hot dimpling is considered; the direct resistance-heating method is preferred.—J. H. W.

Riveting, Countersinking, and Dimpling Magnesium. L. B. Harkins (*Modern Metals*, 1946, **2**, (4), 20–23).—Practical hints.—N. B. V.

Aircraft Components. Shop Layout for Their Production from Light Alloys. C. Monday (*Metal Ind.*, 1946, **69**, (1), 3–6).—M. describes the lithographic-reproduction process for the preparation of detail parts, and the drilling, routing, and pressing operations that follow. Notes on shop layout for efficient production are given. Many of the processes and machines can be used for practically any free-milling non-ferrous metal.—J. H. W.

Carbide Mills Aluminium Alloys. G. R. Gwynne (*Machinist* (*Eur. Edn.*), 1946, **90**, (25), 1008–1009).—Only cemented-carbide tools can be used for milling 14S-T and 75S-T alloys at high speed. The methods of using these cutters, and precautions required to protect the cutting edges, are described.—J. H. W.

Temperature in the Cutting of Metals. M. P. Levitsky (*Zhur. Tekhn. Fiziki*, 1946, **16**, (4), 455–462).—[In Russian]. L. corrects an error in the integration of an equation given in an earlier paper (*ibid.*, 1940, **10**, (13)).—N. A.

Forty Years' Progress in Cutting Tools. J. H. Barber (*Proc. Inst. Mech. Eng.*, 1946, **154**, (1), 18–21).—A review of the subject from 1900 to 1946.
—H. J. A.

Fusion Cutting by High-Speed Band Saw. R. W. Hancock (*Sheet Metal Ind.*, 1945, **22**, (219), 1205–1210).—A band saw is operated at a speed of 12,000 ft./min. and, owing to the intense heat generated by friction when work is fed into the machine, the work is cut partly by the normal action of the saw, and partly by the saw brushing away the semi-molten material. Fast cutting of pressings, armour plate, and non-ferrous ingots is possible with no appreciable work drag or distortion.—R. Gr.

XX.—CLEANING AND FINISHING

Surface Finishes for Aluminium [and Its Alloys]. J. F. Mason (*Iron Age*, 1946, **158**, (9), 40–43; (10), 50–53; (11), 66–69).—M. describes the formation of electrolytic oxide coatings for the protection of aluminium against corrosion and abrasion, and discusses the use of various acids and several patented processes. Information is given on electropolishing, colouring and sealing anodic films, methods of applying a wide variety of metals to aluminium and its alloys by electroplating, composition of plating baths, times and temp. of plating, cleaning, pre-treatment, and after-treatment.—J. H. W.

Spray-Finishing and Drying Aluminium Fabrications at Woodall Industries. —— (*Indust. Heating*, 1946, **13**, (2), 301–308).—Illustrated accounts are given of the spraying booth and the dipping and drying equipment used in applying sprayed coatings of zinc-chromate primer and aluminium paint to light-alloy aircraft parts.—P. R.

Hard-Surfacing Light Metals. [Metal Spraying]. W. C. Reid (*Modern Metals*, 1946, **2**, (3), 6–7).—Aluminium and magnesium alloys can be hard-surfaced to any required depth with any other metal or alloy by means of a metallizing gun. The bond is purely mechanical and is secured by roughening the light-metal surface by blasting or by means of a special tool. All metals except brasses and bronzes can be applied directly to the prepared surfaces; brasses and bronzes should be applied over a thin coating (0·002–0·004 in.) of stainless steel. Slight surface preheating ensures even stronger bonds. Finishing by any of the customary methods can proceed immediately after spraying. The process has numerous applications in cases where a high wear-resistance is required in light alloys.—N. B. V.

***The Surface Preparation of Aluminium Alloy Sheet for Spot Welding.** (Wyant, Ashcraft, Cameron, and Moore). See p. 442.

"Dyed Metal" (Metal Finishes). —— (*Standards Rev.*, 1946, (6), 15–19). —Brief review of electroplating, phosphating, and anodizing; several examples of the latter are illustrated in colour. Standard specifications covering thickness of film, resistance to abrasion, reflectivity, and tests for fastness of colour, are in preparation by the British Standards Institution.—P. R.

Aspects of Finishing Processes Applicable to Automobile Engines and Chassis. H. H. Jackson (*J. Inst. Automobile Eng.*, 1946, **14**, (8), ix–xii; **Body Corrosion.** J. R. Stanfield (*ibid.*, xii–xiii); **A Motor-Cycle Manufacturer's Views on Finish and Protective Coatings.** V. Page (*ibid.*, xiii–xiv); **Discussion** (*ibid.*, xiv–xxii).—A report of a joint meeting of the Birmingham Centre of the Institution of Automobile Engineers and the Electrodepositors' Technical Society. Topics discussed include, besides plating for decorative purposes, plating of bearings, cylinder bores, and gears.—N. B. V.

Glycerine in Metal Treatment. Georgia Leffingwell and Milton A. Lesser (*Materials and Methods*, 1945, **22**, (5), 1432–1434).—A brief review, with 24 references, of the uses of glycerine in solutions for quenching, plating, cleaning, and electropolishing.—J. C. C.

Selection of Metal-Cleaning Methods. Charles Delmar Townsend (*Material and Methods*, 1945, **22**, (5), 1411–1417).—Discusses methods of cleaning various metals and alloys by sand blasting, tumbling, alkalis, electrolytic treatments, solvents, or vapour degreasing plant. Recommendations are summarized in tabular form.—J. C. C.

Selecting a Liquid Metal Cleaner. Gilbert C. Close (*Finish*, 1945, **2**, (10), 17–19; *C. Abs.*, 1946, **40**, 1128).—C. discusses cleaning requirements, difficulties caused by drawing compounds in metal-forming operations, the mechanics of cleaning, and types of cleaner and their characteristics.

***Recovery of Copper from Waste Waters [Used After Pickling Copper or Brass].** (Southgate and Grindley). See p. 451.

XXI.—JOINING

†**Glass-to-Metal Seal Design.** W. J. Scott (*J. Sci. Instruments*, 1946, 23, (9), 193–202).—A general account of the different types of glass-to-metal seals, and of the factors which produce a satisfactory result. Joints may be either directly metal-to-glass, or through an intermediate layer of oxide. The latter type gives the stronger bond, but a thick, porous, oxide layer is harmful. The coeff. of expansion of metals and alloys suitable for sealing into glass are discussed, and the way in which strains are built up described. Solid glass does not fail under pure compression; it fails on account of the tension component of stress, and joints should be designed to avoid harmful tension. Joints of different types are illustrated and discussed.—W. H.-R.

***Soft Soldering.** Morris E. Fine and Ralph L. Dowdell (*Trans. Amer. Soc. Metals*, 1946, 37, 245–272; discussion, 273–277).—The soldering characteristics of a number of soft solders and fluxes, when used on sheet steel, were studied by means of spread-of-drop tests and capillary-rise tests between steel strips (clamped together and suspended vertically with their lower ends immersed in molten solder for 15 min. or 1 min.). All the tests indicate that greatest spreading is obtained with the 50 : 50 tin–lead alloy, and that the presence of lead chloride in the flux is advantageous. Preferred fluxes are mixtures of: stannous chloride 20, zinc chloride 40, and ammonium chloride 40%; lead chloride 50, zinc chloride 50%; and zinc chloride 15, lead chloride 5 g., petrolatum 25, and water 2 c.c. The action of fluxes is considered to be to clean the solder and metal surfaces, to protect them from further oxidation, and to change the character of the surfaces (by "plating out" lead or tin) so as to cause the solder to spread more freely. The alloying action between various solders and Armco iron after heating in contact for 1–20 hr. at 650° and 825° F. (343° and 441° C.) was studied microscopically. Tensile tests are described on lap joints between steel strips, made with 50 : 50 tin–lead and 87·5 : 12 : 0·5 lead–antimony–arsenic solders, and it is concluded that, in sound joints, the strength is independent of the solder thickness, but that the effects of soldering temp. and time depend on the solder composition. Joints made with 50 : 50 tin–lead solder become weaker on ageing or reheating to 50°–120° C., probably as a result of recrystallization. Joints made with the lead–antimony–arsenic alloy, however, are not subject to age-softening.

—J. C. C.

***Soft-Solder Selection Aided by Simple Test.** E. E. Schumacher, G. M. Bouton, and G. S. Phipps (*Materials and Methods*, 1945, 22, (5), 1407–1410).—A pair of 0·040-in. wires, twisted so that adjacent turns are 1 in. apart, are fluxed and their lower ends immersed vertically for 15 sec. in a bath of molten solder. The capillary rise is observed and interpreted as a measure of the wetting ability of the solder under the conditions used. Results of tests on copper, brass, and iron wires fluxed with zinc chloride–ammonium chloride or rosin indicate that the max. rise is obtained with solders containing 40–50% tin. Photomicrographs of sections at various distances from the solder level show that there is a progressive change in the composition of the solder, the alloy at the higher levels becoming richer in eutectic. The mechanism is similar to that of a fractionation process, and with low-tin solders the amount of solder at the higher levels is relatively small, even though penetration may be good.—J. C. C.

Low-Tin and Tin-Free Solders and Tinning Materials. E. S. Shpichinetsky and I. L. Rogel'berg (*Tsvet. Metally*, 1945, (2), 27–32).—[In Russian]. A review of the literature.—N. A.

***Metal Flow and Fillet Formation in Brazing Aluminium [and Its Alloys].** Mike A. Miller (*Weld J.* (*J. Amer. Weld. Soc.*), 1946, 25, (2), 102–114S, 122S).—M. has examined the size and shape of fillets formed in various capillary

environments and established a number of relationships by a trigonometric evaluation of data. Aluminium brazing alloys are inherent fillet-formers.
—P. H.

Copper Brazing of Incendiary Bombs. —— (*Indust. Heating*, 1945, **12**, (10), 1722, 1724, 1726, 1728, 1730, 1798).—The firing mechanism of an incendiary bomb developed in the U.S.A. consisted of five parts, which were assembled and placed in a steel casing before brazing. The brazing copper penetrated between the various parts and formed a tight, uniform seal round the casing, about 14 g. of copper brazing about 30 sq.in. of joints.—P. R.

Copper-Brazing of Steel Assemblies. J. D. Jevons (*Canad. Metals*, 1945, **8**, (1), 24–26).—A review of the advantages, techniques, and precautions to be observed in copper-brazing steel components. J. discusses the strength of the resulting joint, and possible applications of the method.—H. J. A.

Brazing and Heat-Treating Assemblies for Magnilastic Expansion Joints. —— (*Indust. Heating*, 1946, **13**, (1), 38, 40, 42, 44, 92, 94).—A proprietary expansion joint consists of a series of diaphragms, joined alternately at their inner and outer peripheries. Materials used include phosphor bronze, Inconel, Monel, beryllium–copper, copper, and brass. The assemblies may be soldered, welded, or brazed. An account is given of a large controlled-atmosphere electrically heated brazing furnace, with "flame curtains" at both charging and discharge ends, and a water-cooled cooling chamber.—P. R.

Joining Metals by Welding, Brazing, and Allied Processes. E. V. Beatson (*Coventry Eng. Soc. J.*, 1946, **27**, (2), 29–32; (3), 35–42; discussion, 42–43).—A review of methods of joining metals. The influence of composition on the properties and applications of tin–lead solders is illustrated by a phase diagram. B. summarizes the essential features of soldering with the iron and of dip, flame, carbon-resistance, direct-resistance, and high-frequency induction soldering. Alloys and fluxes for brazing are briefly reviewed, as are the procedures in torch, resistance, furnace, and copper brazing. Short descriptions are given of the different welding processes.—P. R.

Fabrication by Electric-Furnace Brazing. H. M. Webber (*Gen. Elect. Rev.*, 1946, **49**, (5), 22–29).—Describes several applications of electric-furnace brazing in the production of military equipment.—E. V. W.

Welding Aluminium and Aluminium Alloys. —— (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (7/9), 46, 48–50).—Reprinted from "The Oxy-Acetylene Handbook," published by The Linde Air Products Co.—N. B. V.

Development of the Weibel Welding Process for Aircraft Construction [Aluminium]. F. Heibling (*Junkers Nach.*, 1943, **14**, (7/8), 53–59).—The turned-up edges of aluminium and suitable aluminium alloy sheets are laid together and are welded between carbon electrodes applied directly to the sides of the joint, resulting in a butt weld. The current-control gear provides for 3·5–8 V. and 80–260 amp. The electrodes are of hard carbon, copper-coated to a distance of 20 mm. from the arc, and the coating wears off as the carbon is used up. The electrode tips have to be of proper shape. The tongs holding the electrodes are of special design with spring mechanism, the gap being controlled by hand. They are water-cooled to permit lightness of the metal sections. Joints can be made between sheets of thickness 0·3–0·6 mm., and in long runs. Pickled surfaces are preferred. Flux is applied only to the under-side and not to the side to which the electrodes are applied. As the turned-up edges of the parts to be welded should register closely at a uniform height and should fit exactly, precision forming is advised. Data are given for height of turn-up and radius for sheets of 0·3–1·5 mm. thickness in aluminium, Al–Mg 5, Al–Mg 7, and Al–Mg–Si materials.—H. S.

Carbon-Arc Welding of Aluminium Speeds Fabrication. W. J. Conley (*Materials and Methods*, 1945, **22**, (5), 1423–1425).—Describes equipment and

methods used for constructing the hollow deck balk of a military floating bridge.—J. C. C.

***The Surface Preparation of Aluminium Alloy Sheet for Spot Welding.** R. A. Wyant, D. J. Ashcraft, T. B. Cameron, and K. H. Moore (*Weld. J.* (*J. Amer. Weld. Soc.*), 1946, **25**, (2), 65–76S).—Contact-resistance measurements and electron-diffraction studies are used to determine the effect of various surface-preparation techniques. Foreign material must be removed from Alclad sheet before solution-treatment. The metal should not be allowed to dry before rinsing after cleaning in alkaline solutions containing inhibitors. Immersion of Alclad sheet in hot water causes the formation of a surface film of Boehmite which may make ineffective the subsequent chemical preparation for welding. Hot-water immersion after alkaline cleaning produces no ill effects. Surface treatment in hydrofluosilicic acid solutions produces a condition suitable for welding, and stable for many weeks, even after oiling and degreasing.—P. H.

***An Investigation of the Spot Welding of Aluminium Alloys Using Magnetic-Energy Storage Equipment Provided by the Sciaky Brothers.** W. F. Hess, R. A. Wyant, and B. L. Averbach (*Weld. J.* (*J. Amer. Weld. Soc.*), 1945, **24**, (12), 629–643S).—The performance of the apparatus is critically examined and the results of employing various techniques compared. In particular, the relation between pressure cycle and weld quality is discussed. Crack- and porosity-free welds of equal quality may be obtained by the use of either a forge cycle or const. high electrode pressure. Forging pressure must be applied rapidly and without delay to secure optimum properties. The consistency of welds is comparable with that obtained with condenser-discharge and A.-C. equipment. Correct operation of the primary contactors is essential for consistent operation.—P. H.

Spot Welding of Heavier Gauges of Aluminium Alloy. II.—New Portable Instruments for Rapid Measurement of Current and Tip Force in Spot-Welding Machines. R. C. McMaster and N. A. Begovich (*Weld. J.* (*J. Amer. Weld. Soc.*), 1945, **24**, (12), 644–667).—Cf. *Met. Abs.*, 1946, **13**, 108. Current and tip force are measured by means of a small unit, comprising a toroid and a strain-gauge bridge. The unit may be slipped over the electrode holder of any spot welder and clamped ready for use in a few min. The simultaneous records of welding current and tip force obtained by this unit may be applied to either a magnetic or a cathode-ray oscillograph. By using a long-persistence tube in the cathode-ray oscillograph, visual checking of welder performance may be carried out. Otherwise, permanent records may be obtained by employing a 35-mm. camera in conjunction with the tube.—P. H.

***The Spot Welding of Dissimilar Thicknesses of Alclad 24S-T.** W. F. Hess, R. A. Wyant, and B. L. Averbach (*Weld. J.* (*J. Amer. Weld. Soc.*), 1945, **24**, (12), 667–672S).—Welding of dissimilar thicknesses of 24S-T alloy requires special attention to electrode contour and surface resistance. To keep the surface of the thin sheet smooth it is necessary to use a flat tip against the thin sheet and a domed tip or smaller flat against the thick sheet. The resultant tendency for concentration of the fusion zone in the thicker sheet cannot be corrected by using a low-conductivity electrode against the thin sheet. Medium or high surface resistance is necessary when the dissimilar-thickness ratio becomes of the order of 3 : 1. It is inadvisable to weld a dissimilar-thickness ratio of 6 . 1 because of the erratic nature of the fusion zone and high sheet separation.—P. H.

***An Investigation of Current Wave-Form for Spot Welding Alclad 24S-T in 0·020-in. Thickness.** W. F. Hess, R. A. Wyant, and B. L. Averbach (*Weld. J.* (*J. Amer. Weld. Soc.*), 1946, **25**, (1), 20–29S).—The effect of using two different current wave-forms in conjunction with other variables was studied. Weld strength, particularly in chemically treated stock, is less affected by changes

in current when a rapidly rising-current wave-form is employed. Current wave-form affects the distribution of current over the contact area, the rapidly rising wave-form tending to produce toroidal-shaped welds.—P. H.

***Tension Tests of Single-Row Spot-Welded Joints in 24S-T Alclad Aluminium Alloy Sheet.** R. Della-Vedowa (*Weld. J.* (*J. Amer. Weld. Soc.*), 1946, **25**, (2), 115–122S).—The strength of spot-welded joints in tension increases with decrease in weld spacing until the weld nuggets touch. A still further decrease in spacing causes a corresponding reduction of strength in tension. Differences in nugget penetration have no effect on the tension strength of spot welds of the same dia. Small, closely spaced welds have a higher tension strength than large, closely spaced welds.—P. H.

The Spot Welding of Heavy-Gauge Aluminium-Coated Duralumin. H. E. Dixon (*Welding*, 1945, **13**, (11), 486–498).—D. gives data relating to weld quality as affected by various factors, and makes recommendations for suitable welding technique. Machines of the stored-energy type are preferred, and some method of securing a consistent current cycle is necessary when making a rapid succession of unidirectional discharges. Electrode working conditions are more severe than when welding thin sheets, since local deformation and "point" contact are reduced. Chemical pre-cleaning is recommended, and the importance emphasized of adequate production tests prior to selecting the machine setting.—P. H.

Aluminium Spot Welding and Carriage Construction on the S.B.B. [Swiss Federal Railway]. F. Halm (*Schweiz. Arch. angew. Wiss. Techn.*, 1946, **12**, (8), 257–264).—[In German]. A general account of the introduction of aluminium into the construction of carriages for a Swiss narrow-gauge line. No technical details of construction are given, but several small-scale diagrams are included.—N. B. V.

***The Structure of Aluminium [and Aluminium Alloy] Spot Welds.** (Hug). See p. 415.

***The Flash Welding of Alclad 24S-T Alloy in the 0·064-in. Thickness.** W. F. Hess and F. J. Winsor (*Weld. J.* (*J. Amer. Weld. Soc.*), 1946, **25**, (1), 9–20S).—An account of an exploratory investigation. The most important and critical variable is the timing of current cut-off with respect to upset. Highest weld strengths are obtained when current cut-off and upset are simultaneous. The amount of upset is also important, though less critical than the timing. The upset should be enough to squeeze out oxidized material, but not enough to deform the metal severely in its hot-short condition. The magnitude of the power level during flashing has little effect upon results if it is high enough to prevent initial butting.—P. H.

Aluminium Bonded to Steel or Cast Iron. M. G. Whitfield and V. Sheshunoff (*Materials and Methods*, 1945, **22**, (4), 1090–1096; and *Metal Treatment*, 1946, **13**, (45), 70–76).—The Al-Fin process was originally developed for manufacturing aluminium-finned cylinder barrels, and consists in casting the light metal on a specially prepared steel surface. Aluminium and such aluminium alloys as No. 43, 355, 122, or 142 may be bonded to plain, alloy, or stainless steels or cast iron. The authors discuss the properties of the composite materials, and refer to the application of the process for cylinder barrels, steel-backed aluminium bearings, electronic-tube assemblies, and service at high temp. where resistance to oxidation and sulphur attack is required.—J. C. C.

Welded Aluminium Alloy Tank Cars. A. H. Woollen (*Weld. J.* (*J. Amer. Weld. Soc.*), 1946, **25**, (2), 129–130).—A brief account of the uses and development of aluminium alloy tank cars of welded construction.—P. H.

***Pressure Welding (Production of Light Alloy Charge-Cooler Elements).** H. Herrmann (*Welding*, 1946, **14**, (3), 120–126; *Metal Ind.*, 1946, **68**, (8), 143–147; *Aircraft Prodn.*, 1946, **8**, (91), 207—210).—Translation by the Ministry of Aircraft Production of a paper not previously published in Germany.

Cf. *Iron Age*, 1946, **158**, (6), 56–60. A process developed in Germany for the welding of light-alloy components without fusion. Two thin sheets are laid cold, one on the other, between hot-welding dies. Pressure sufficient to cause a definite reduction in thickness is then applied, and welding takes place. Working temp. and pressures average 450° C. and 2–5 tons/sq.in., respectively, for light alloys. Pre-cleaning of the sheet is critical.—P. H.

Plastic Bonding of Light Metals. E. Preiswerk and A. von Zeerleder (*Plastics*, 1946, **10**, (110), 357–360; *Light Metals*, 1946, **9**, (102), 356–360).—See *Met. Abs.*, this vol., p. 341.

Aircraft Welding: New Applications Speed Production Rate. H. O. Klinke (*Canad. Metals*, 1945, **8**, (4), 41).—An address to the Canadian Welding Society.—H. J. A.

Welding Precious Metals [Gold, Silver, Platinum]. F. W. Meyers, Jr. (*Iron Age*, 1946, **158**, (8), 59–62).—Describes practical methods of welding gold, silver, and platinum by the torch and by the hammer methods. Both pure and clad metals are included.—J. H. W.

The Spot Welding of Magnesium (a Review of Available Literature). R. F. Tylecote (*Welding*, 1946, **14**, (2), 74–79).—Methods of surface preparation are discussed and various chemical reagents compared on the basis of contact-resistance. Increase in weld strength with increase of c.d. is limited by splashing or spitting, which necessitates a compromise. The electrodes now preferred are radius domed, and of the usual construction. A great improvement in strength results on annealing welds, and it is suggested that suitable modifications may allow this to be done in the machine. An after-weld protective treatment, such as chromating, is preferred to the use of a sealing compound.—P. H.

Heliarc Welding of Magnesium. —— (*Modern Metals*, 1946, **2**, (2), 17–18).—A general account of the process.—N. B. V.

Helium-Shielded Arc Welding of Magnesium Alloys. F. A. Wassall (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (1/3), 10, 12; (4/6), 26).—Reprinted from *Weld. J.* (*J. Amer. Weld. Soc.*), 1944, **23**, 148; *Met. Abs.*, 1944, **11**, 202.—N. B. V.

Magnesium Alloy Sheet and Tube, and Its Fabrication by Oxy-Acetylene Welding. E. Ryalls (*Welding*, 1945, **13**, (11), 499–508).—R. discusses, in a practical way, the weldability of magnesium alloys, the design and preparation of welds, and the welding technique, and gives examples of fabrication with suggestions for forming. He stresses the importance of design in relation to flux removal, and the difficulty of joining AM503 and AZM alloys. Working after welding, to rectify distortion, should only be carried out in the hot state. —P. H.

Resistance Welding of Heat-Resisting Materials: Application to Stainless Steel, Inconel, and Nickel–Chromium Alloy. H. E. Lardge (*Aircraft Prodn.*, 1946, **2**, (89), 107–113).—L. discusses spot welding, seam welding, and stitch welding of annealed sheet materials in thickness varying from 16 to 26 S.W.G. Distortion during welding is reduced by welding under water or by a flow of water over the electrodes and the work. Pickling after welding is not advised on account of the difficulty of removing residues from joints. Electrode pressures used are higher than those for welding mild steel, and spot welds may be made at closer pitch than in mild steel, without adverse effect on the static strength of each weld, the higher electrical resistivities of the materials causing less "shunt" effect in welding.—H. S.

Controlling Distortion in the Gas Welding of Sheet Metals. C. G. Bainbridge (*Sheet Metal Ind.*, 1946, **23**, (226), 356–362).—B. considers the causes of distortion and makes suggestions on the best method of designing and locating joints. He also deals with welding procedure, blow-pipe manipulation, and the use of jigs.—R. Gr.

Electronic Control in Resistance Welding. B. G. Higgins (*Aircraft Prodn.*, 1946, **8**, (90), 155–159).—The control of welding time by electronic control of the welding-transformer primary current is described with special reference to spot welding and seam welding. Details are given of timing circuits in which ignition control is used.—H. S.

Atomic-Hydrogen Welding. I. H. Hogg (*Metro-Vick. Gaz.*, 1945, **21**, (350), 117–125).—Reviews the history, apparatus, techniques, and applications of the atomic-hydrogen method of welding.—H. J. A.

Recent Improvements in the Design of Extruding Presses for Welding-Electrode Coatings. (Müller-Börner). See p. 437.

How Metal Bellows are Fabricated. (Geschelin). See p. 448.

Annealing Welded Joints in Pipelines. (Isermann). See p. 436.

Welding and Brazing Combined Form New Uses for Steel Stampings. —— (*Steel Processing*, 1945, **31**, (11), 699–702).—Resistance or spot welding may be used in place of jigs to hold parts in position during copper or silver-solder brazing. Examples of complex assemblies are illustrated. Strip or wire spirals may sometimes be used to form threads where close accuracy is not required.—J. C. C.

Practical Tests in Welding Instruction. J. Krakat (*Elektroschweissung*, 1940, **11**, (5), 86–90).—Details of 18 suggested welding tests which a competent craftsman should be able to carry out successfully. These are intended for electric-arc welders, but are based on recommendations previously made for gas-welders.—M. A. V.

Overhead Charges in the Electric-Welding Shop. A. Schmid (*Elektroschweissung*, 1940, **11**, (10), 157–162).—The allocation of overhead charges to costs of electric welding presents some difficulties, and an examination was made of the costs of carrying out simple butt-welds on plates of different thicknesses. The overheads depended largely on the consumption of current and electrode material, and therefore on the plate thickness, and a table is given, analysing the total cost of welding plates of different thicknesses.

—M. A. V.

Riveting, Countersinking, and Dimpling Magnesium. (Harkins). See p. 438.

New Aspects of the Bonding of Rubber to Metals. H. E. Zentler-Gordon and K. W. Hillier (*Sci. J. Roy. Coll. Sci.*, 1944, **14**, 140–160; *C. Abs.*, 1946, **40**, 1687).—Critical discussion and review of alloy-plating on α-brass, the behaviour of various types of rubber, and the design and application of rubber–metal units. 17 references are given.

Bonding Rubber to Metals. John H. Gerstenmaier (*Modern Metals*, 1946, **2**, (4), 13).—G. deals briefly with several recent applications of rubber-bonded metal parts.—N. B. V.

XXII.—INDUSTRIAL USES AND APPLICATIONS

Post-War Horizons for Aluminium [Alloys]. F. Keller (*Min. and Met.*, 1946, **27**, (476), 431–433).—War-time improvements in aluminium alloys and in techniques for their fabrication are indicated, and future applications of the alloys are surveyed.—N. B. V.

Aluminium [Alloys] and the Automobile Engineer. E. G. West (*J. Inst. Automobile Eng.*, 1946, **14**, (4), 109–146).—W. reviews the properties, fabrication, and finishing of the principal cast and wrought aluminium alloys, and indicates briefly the uses to which they have been put in power units, motor cars and motor cycles, and commercial vehicles.—N. B. V.

Light Alloys in Cars. Improved Performance by Weight Reduction. G. Geoffrey Smith (*Metal Ind.*, 1946, **69**, (14), 288).—Read before the Vauxhall Supervising Group. By the application of present-day metallurgical know-

ledge, it should be possible to effect a saving of about 15% in the weight of a motor car. Since cars have nowadays to last longer, more efficient protection against rusting is required.—J. H. W.

Light-Alloy Cylinder Heads from German Aircraft Engines. C. Wilson (*Automotive Ind.*, 1945, **92**, (3), 54, 58).—A report, prepared for the Ministry of Aircraft Production, describing the composition, design, and properties of three types of light-alloy cylinder head recovered from German aircraft engines. —P. R.

Important Engineering Data on Aluminium Alloy Bearings for Engines. D. B. Wood (*Automotive Ind.*, 1946, **94**, (11), 27–30, 74–78).—W. studies three aluminium-base bearing alloys, 750-T533, XA750-T7, and XA80-S, and tabulates physical and mechanical properties. It is claimed that the general durability and resistance to severe loading of these alloys are superior to those of most bearing materials.—P. R.

How and When to Use Aluminium Alloys. R. L. Moore (*Engineering News-Record*, 1945, **135**, 518–524; *C. Abs.*, 1946, **40**, 1436).—M. discusses the mechanical properties of commonly used aluminium alloys in relation to their structural applications.

Aluminium and Its Alloys. E. G. West (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (10/12), 59–60, 62, 64–66).—A paper presented to the Design and Industries Association. Properties, methods of fabrication and finishing, and uses are reviewed.—N. B. V.

Aluminium [in Display, Exhibition, and Store-Planning Applications]. E. G. West (*Display*, 1946, **27**, (11), 16–18, 20).—N. B. V.

The Use of Aluminium Alloys as Constructional Material for Domestic Washing Machines. —— (*Aluminium and Non-Ferrous Rev.*, 1945, **10**, (4/6), 18, 20, 22).—Tests have shown that pure aluminium and corrosion-resistant aluminium casting alloys are quite suitable for the construction of washing machines, provided that the washing lyes used have known characteristics. Excess soda must be avoided unless water glass is added to the washing media. Some of the tests are described.—N. B. V.

Aluminium Portable Washing Machine. —— (*Modern Metals*, 1946, **2**, (3), 19).—N. B. V.

Palletize for Handling [Aluminium]. T. Palmer (*Modern Metals*, 1946, **2**, (5), 14–16).—Aluminium pallets, though initially much dearer than wooden ones, should in the long run effect considerable saving in the bulk transportation of all types of package. Economics are examined, and the construction of pallets in 52S alloy is described.—N. B. V.

The Aluminium [Alloy] Blitz Can. A. B. Carlson (*Modern Metals*, 1946, **2**, (2), 6–7).—Towards the end of the war, aluminium (52S alloy) was substituted for steel in the 5-gall. containers extensively used by the U.S. Forces. C. describes the construction of them by seam welding and the external finishing of them by means of a zinc chromate primer and paint. No protection was required internally.—N. B. V.

[Aluminium] Lawn Sprinkler. L. A. Weil (*Modern Metals*, 1946, **2**, (4), 24).—N. B. V.

Aluminium Foil and Its Application in Modern Packaging Technique. J. C. Bailey (*Brit. Packer*, 1946, **7**, (9), 4–8).—The uses of plain and paper- or plastic-backed foils are described.—N. B. V.

Boron Carbide—Hardest Man-Made Material. Edwin Laird Cady (*Materials and Methods*, 1945, **22**, (4), 1058–1063).—Boron-carbide powder is used, as a substitute for diamond dust, for lapping such parts as tungsten-carbide dies; sintered pressings are used for lining pestles and mortars, for abrasive-blast nozzles, and other similar applications.—J. C. C.

New Uses for Cerium. G. Ahrens (*Metals and Alloys*, 1945, **22**, (3), 748–750).—Cf. *Modern Metals*, 1945, **1**, (8), 20–21; *Met. Abs.*, this vol., p. 274.

Reviews briefly the uses of cerium standard alloy (cerium 45–50, iron 0–5, silicon 0·1–0·3%, balance other rare earths) as an addition to aluminium and magnesium alloys. A *bibliography* of 37 references is appended.—J. C. C.

Brasses A.S.T.M. B36–43T, Alloys 1 to 8; B134–42T, Alloys 1 to 8; B135–43T, Alloys 1 to 5. —— (*Machine Design*, 1944, **16**, (8), 149–153).—Discusses hot- and cold-working properties, corrosion-resistance, and suitability for welding and brazing; and gives recommendations regarding fabrication.
—P. R.

Bearings and Bearing Metals. Bernard O. Brouk (*J. Amer. Soc. Naval Eng.*, 1946, **58**, (3), 418–440).—B. discusses types of sleeve bearings and bearing metals used in Diesel engines and other types of propulsion equipment. Bearings referred to include tin and lead-base white metals, lead-bronze bearings, aluminium alloy bearings, tin-substitute bearing metal, and specially treated, graphitized, tin-base white metals. Special consideration is given to bonding problems, pressure die-cast bearings, the centrifugal casting of bearings and linings, grid bearings, and the supersonic method of testing bearings. B. reviews types and causes of failure in bearings and suggests methods for their elimination. Tests were made to determine the bond strength and resistance to shear of tin-base bearings on steel shells. Other tests were carried out on the corrosion of bearings, and on the use of a dimethyl-silicone polymer fluid as a lubricant with seven different types of bearing metal. Reference is made to running-surface conditions and to the maintenance and safeguarding of bearings while in operation.—J. W. D.

Standard [Bi-Metallic] Bushes. —— (*Automobile Eng.*, 1946, **36**, (476), 253–254).—Cf. *Machinery* (*Lond.*), 1946, **68**, (1756), 713–718; *Met. Abs.*, this vol., p. 339. The development of standard wrapped bushes, made from bi-metallic material, consisting of steel strip lined with a lead-bronze alloy, which is bonded to the steel by a sintering process, is described. The advantages of such bushes over cast bushes as regards cost, lightness, strength, and life are summarized, and their suitability for various applications discussed.
—J. W. D.

Magnesium [Alloy] Appliance Mover. L. M. Oldt (*Modern Metals*, 1946, **2**, (5), 10–13).—Describes the design and fabrication of a truck intended for moving household appliances such as stoves and refrigerators. It is built up mainly of arc-welded magnesium alloy extrusions and sheet.—N. B. V.

Bell Telephone—A Magnesium Consumer. J. P. Guerard (*Modern Metals*, 1946, **2**, (4), 6–7).—After a brief account of the properties of magnesium, G. mentions its use in aircraft instruments.—N. B. V.

Titanium—a Growing Industry. Otto Herres (*Min. and Met.*, 1946, **27**, (472), 210–212).—Sources and uses of titanium and its compounds are reviewed.—N. B. V.

Roll-Cap Roofing [Zinc Sheet]. —— (*Zinc Bull.*, 1946, N.S. (1), 2–3).—An information sheet on the roll-cap system of roofing with zinc sheet.
—W. G. A.

Zinc-Base Die-Casting Alloys A.S.T.M. No. B86–43; Alloys Nos. XXI, XXIII, and XXV. —— (*Machine Design*, 1944, **16**, (9), 149–150, 152).—The principal physical properties, chemical compositions, and important mechanical properties of three zinc-base die-casting alloys are tabulated. Other information includes strength and hardness at low and at elevated temp., recommendations for drilling, reaming, tapping, bending, and forming, notes on electrodeposited, lacquer, and enamel finishes, and an account of the corrodibility of the alloys by hydrocarbon fuels and lubricants, ink, alcohol, glycerine, soaps, and creams.—P. R.

Zirconium in Industry. M. Schofield (*Indust. Chemist*, 1945, **21**, (251), 641–643).—S. describes the occurrence, extraction, and uses of zirconium. The metal is used as a photo-flash starter and as a primer for ammunition

because of its low ignition point and great heat of combustion. The sintered or drawn metal is used for electrodes; other uses include the deoxidation of brasses and bronzes. Zirconium–copper has properties resembling those of beryllium–copper.—P. R.

Production and Uses of Rare Metals. W. J. Kroll (*Min. and Met.*, 1946, **27**, (473), 262–266).—A review. K. urges the need for intensive investigation into the properties and possible applications of some of the rare metals.
—N. B. V.

Non-Ferrous Alloys Used in War-Time Germany. A. A. Bochvar (*Tsvet. Metally*, **1946**, (3), 40–54).—[In Russian]. A review of copper, aluminium, and zinc alloys.—N. A.

Substitute Materials for Fittings. F. Petrak (*Chem. Techn.*, 1943, **16**, (5), 39–43).—P. discusses the re-design and use of substitute materials for various types of fittings, such as sluice valves, central-heating- and cold-water fittings, chemical-engineering plant, and gauges. By the use of plain carbon steels with and without chromium plating, cast iron, zinc alloys, non-metallic linings, and weld-on corrosion-resistant faces, in place of alloy steels, bronzes, brasses, and corrosion-resistant alloys, substantial savings were made in the use of strategic materials, thus satisfying the needs of German war economy. The results have a peace-time application.—E. N.

Materials Engineering at Home and Abroad. J. R. Townsend (*Bull. Amer. Soc. Test. Mat.*, 1946, (140), 19–22).—An appeal is made for co-operation between buyer and supplier in the acceptance-testing of mass-production components.—H. J. A.

Some Vibration Problems in Gas-Turbine Engines. R. G. Voysey (*Proc. Inst. Mech. Eng.*, 1945, **153**, (12), 483–495).—Describes the history and investigation of vibration troubles with the centrifugal impeller of the early jet-propulsion units. V. sketches the evolution of a method of estimating fundamental frequencies in the components, and gives details of vibration problems in turbine blades. Also discussed are the failure of plastic compressor blades and the importance of internal damping capacity in the field of vibration problems.—H. J. A.

†**Recent Developments in Materials for Gas Turbines.** T. A. Taylor (*Proc. Inst. Mech. Eng.*, 1945, **153**, (12), 505–512; and (condensed) *Metallurgia*, 1946, **34**, (204), 316–320).—The metallurgical requirements, and possible modes of failure, of various components in a gas turbine are discussed. Nominal compositions and test data for some of the materials are given, including Brown-Firth's Stayblade and Rex 78. The nickel-base alloy, Nimonic 75, has found use in the construction of flame tubes, while high-strength, cast aluminium alloy components have also been employed.—H. J. A.

The Cleaning and Repair of Stills and Tanks: Revision of Factory Form 814. [Use of Non-Ferrous Dip Rods]. —— (*Indust. Chemist*, 1944, **20**, (236), 481–488).—Attention is directed to several of the less obvious risks in the cleaning, examination, or repair of stills, drums, &c., which have contained materials giving rise to poisonous or inflammable gases or vapours. Causes of explosions and of the actual ignition are reviewed, and the revised safety recommendations include the use of nickel, copper, aluminium, gun-metal, or Monel-metal dip rods instead of iron or steel.—P. R.

How Metal Bellows are Fabricated. Joseph Geschelin (*Automotive Ind.*, 1945, **92**, (4), 36–38, 64).—Metal bellows are produced from a variety of alloys, including phosphor bronze, brass, copper, beryllium–copper, Monel metal, Inconel, and nickel-silver. Joining methods include welding and brazing. Gas-flux torches, induction heaters, and controlled-atmosphere electric furnaces are used for brazing; a large unit of the last-named type is described.
—P. R.

The Forming of Metal Bellows. R. A. Collacott (*Canad. Metals*, 1945, **8**, (1), 30).—C. discusses the choice of materials for the construction of metal bellows, and the mechanism of failure of these articles.—H. J. A.

The Repair of Oil-Engine Components [by Metal Spraying]. O. S. M. Raw (*Indian and Eastern Eng.*, 1946, **99**, (1), 111–114).—R. reviews the metal-spray process for the repair and building up of worn bearing surfaces and fractured shafts. The sprayed surface has the advantage of being able to absorb lubricating oil, and it is feasible that certain wearing parts may, in the future, be produced originally by the metal-spray process.—W. G. A.

Worn Shafts [Building Up by Metal Spraying]. S. Staton (*Iron and Steel*, 1946, **19**, (10), 511–512).—S. discusses the building up of worn shafts by metal spraying. He deals briefly with metal-spraying equipment, the suitability of the process, the preparation of the surface, either by shot-blasting or rough machining, and the application of the metal spray.—J. W. D.

***The Load in a Bolt Due to Tightening the Nut. [Effect of Metallic Coatings].** John L. M. Morrison (*Engineering*, 1946, **161**, (4190), 409–412).—A method is described involving the measurement of the torque in a bolt to determine the effective coeff. of friction during the tightening of nuts. The effects of coating bolts and nuts with zinc and cadmium, and of Coslettizing, were studied. If cadmium-plating finish is added or substituted for another, the initial load with oil as lubricant is much increased. The use of graphite as a lubricant seems to minimize or eliminate the variations otherwise caused in the coeff. of friction by different rubbing surfaces.—R. Gr.

†**The Industry of the Non-Ferrous Metals and Particularly of the Light Metals.** André Dumas (*Mém. Soc. Ing. Civils France*, 1945, **98**, (6/8), 292–317; discussion, 318–322).—The evolution of the principal non-ferrous metals: copper, zinc, lead, tin, and, particularly, aluminium and magnesium, during the last six years is reviewed as regards production and consumption, secondary material, primary mineral sources, methods of manufacture, forging, metallurgical progress, applications, and economies. *Léon Guillet*, in the discussion, dealt with the metallurgical developments that have resulted in the production of aluminium of 99·99% purity, and cited special recently devised alloys. He directed attention to the principal physical properties and the special applications of the relatively rare metals, niobium, tantalum, boron, titanium, zirconium, beryllium, gallium, indium, rhenium, and uranium.

—J. H. W.

XXIII.—MISCELLANEOUS

The British Non-Ferrous Metals Research Association. A Year's Progress. W. L. Hall (*Metallurgia*, 1946, **34**, (203), 257–260).—A review of the activities of the Association and of the researches in progress.—J. W. D.

Metallurgical Research at the National Physical Laboratory. N. P. Allen (*Metallurgia*, 1946, **34**, (203), 252–254).—A brief review of the researches being carried out on metals and alloys.—J. W. D.

Research and the Smaller Firm. (Sir) Edward Appleton (*Mech. World*, 1946, **120**, (3121), 462–464).—An address to the Manchester Joint Research Council's conference on "Research and the Smaller Firm." Deals briefly with the relationship between the D.S.I.R., the Research Associations, and industry.—W. G. A.

Trends in Metallurgy. Gustav W. Pirk (*Wire and Wire Products*, 1945, **20**, (10), 758–761, 764–765, 768–770, 797).—An elementary account of the crystal structure of metals, and the effects of cold working and alloying.

—J. C. C.

Research on Metallic Surfaces Organized in France. Albert M. Portevin (*Metal Progress*, 1946, **49**, (3), 560–561).—A short account is given of the

formation in France, in 1942, of a Technical Committee on the Conditions and Properties of Metallic Surfaces for the study of the problems presented in the industrial applications of metals, for the planning and carrying out of research, and the co-ordination and dissemination of the results obtained. The sub-committees deal respectively with mechanical surface studies, thermal processes, paints and other non-metallic coatings, metallic coatings, chemical treatments and tests, and corrosion studies.—P. R.

A Metallurgical Inventory: Some of the Things That Have Happened in the Last Fifteen Years. H. W. Gillett (*Min. and Met.*, 1945, **26**, (465), 419–423).—G. surveys broadly some of the chief advances in both ferrous and non-ferrous metallurgy that have occurred during the life of the Battelle Memorial Institute, of which he is Chief Technical Advisor.—N. B. V.

Non-Ferrous Physical Metallurgy [in 1944]: Notable Advances in Processing, Fabrication, and Surface Treatment. Michael B. Bever and Carl F. Floe (*Min. and Met.*, 1945, **26**, (458), 90–96).—A review of progress during 1944, principally as recorded in the American literature.—N. B. V.

Non-Ferrous Physical Metallurgy [in 1945]. Ralph Hultgren and Earl R. Parker (*Min. and Met.*, 1946, **27**, (470), 93–100; and (condensed) *Metal Ind.*, 1946, **68**, (19), 371–374).—A survey of the principal research papers published in America in 1945.—N. B. V.

Recent Developments in the Field of Materials and Processes. Paul E. Lamoureux (*Eng. J.*, 1945, (12), 38–46; discussion, 46–48).—Read before the Engineering Institute of Canada. L. reviews a wide field of materials and processes which are of interest in aircraft construction, and mentions an aluminium–zinc–magnesium alloy (Alcoa 75S) which has superior properties over Alclad 24S-T. The composition and properties are given of a naturally ageing aluminium–5·25% zinc alloy. Other subjects dealt with include brazing, electroplating, heat-treatment, and the application of plastics as bonding agents for metal components.—H. J. A.

War-Time Materials Developments and the Post-War World. J. C. De Haven (*Bull. Amer. Soc. Test. Mat.*, 1946, (**138**), 17–24).—DeH. reviews such topics as the war-time development of the "lost-wax" casting process, forming processes for aluminium sheet, and some applications of magnesium alloys.—H. J. A.

German War-Time Technical Development. —— (*Iron Age*, 1946, **158**, (9), 39).—Summary of reports of German practice in various technical fields, issued by the Office of the Publication Board, Washington. Subjects include supersonic testing, the use of titanium, protective coatings, nickel substitute, fluorescent screens, and a copper-contact rectifier.—J. H. W.

†**Aeronautics and the Metallurgist.** Leslie Aitchison (*J. Roy. Aeronaut. Soc.*, 1946, **50**, (429), 677–693; discussion, 693–709; (condensed) *Aircraft Prodn.*, 1946, **8**, (92), 276–280; and *Aeroplane*, 1946, **70**, (1823), 511–512).—The general position of metallic materials for aircraft construction is discussed in relation to advances made during the last 30 years. Special reference is made to advances in the light-alloy field. The general requirements as to ductility are indicated, and the significance of ductility is considered from its various aspects. While the prospects of further advances may appear slight in particular fields, A. stresses the importance of improvements in manufacturing technique, and of progress along new lines indicated by fundamental research in the various fields of long-range study.—H. S.

Standard Specifications. Principles of Preparation for Aluminium Alloys. G. M. Hutt (*Metal Ind.*, 1946, **69**, (13), 255–258; (14), 281–282).—Since few British Standards exist for aluminium alloys in the general engineering series, D.T.D. specifications serve the function of standard specifications. The principles to be observed in drawing up such specifications are described.

—J. H. W.

A Chronology of Wire and Wire Products. F. A. Morral (*Wire and Wire Products*, 1945, **20**, (11), 862–866, 885–887).—See *Met. Abs.*, this vol., p. 65. A revised compilation.—J. C. C.

The History and Present Status of Emission Spectroscopy as Applied to Industry. John Convey (*Metallurgia*, 1946, **34**, (204), 331–335).—C. discusses the historical foundations of spectroscopy, and considers the recognition of characteristic spectra and the development of quantitative spectrochemistry. Special reference is made to the improvements of spectrographs, the control of spectral excitation, and the photometric precision of spectral-line densitometry. —J. W. D.

Electronics—and the Chemical Industry. J. A. Hutcheson (*New Zealand Eng.*, 1946, **1**, (4), 292–295).—A short review of the mass spectrograph, electron diffraction, induction heating, and dielectric heating.—H. J. A.

Use of Statistics in Writing Specifications. Casper Goffman and Joseph Manuele (*Bull. Amer. Soc. Test. Mat.*, 1946, **139**, 13–17).—The nomenclature and elementary theory of statistical quality control are indicated. The application of such methods to acceptance-testing specifications is discussed. —H. J. A.

Systematic Designation of Metallic Materials. E. Siebel and G. Fick (*Aluminium*, 1944, **26**, (4), 52–53).—Describes a systematic nomenclature for aluminium alloys, taking into account their composition, properties, and applications. (See also abstract below).—E. N.

***Systematic Nomenclature for Metallic Materials.** Erich Siebel and Franz Fischer (*Metall u. Erz*, 1944, **41**, (13/14), 155–157).—A system of nomenclature for ferrous and non-ferrous alloys has been devised which takes into account their composition, purpose, and mechanical properties. Thus: (1) D.Zn.AlCu43 is a pressure-casting zinc alloy with 4% aluminium and 3% copper; (2) Mg.Al9(Ah26) is a forging alloy of magnesium containing 9% aluminium which in the age-hardened condition has a minimum tensile strength of $\nless$26 kg./sq.mm.—E. N.

***Recovery of Copper from Waste Waters [Used After Pickling Copper or Brass].** B. A. Southgate and J. Grindley (*Indust. Chemist*, 1945, **21**, (242), 144–152).—Describes a method developed by the Water Pollution Research Board at the request of the Ministry of Supply. It applies particularly to the treatment of waste washing waters used after the pickling of copper or brass, but spent pickle liquor can also be treated. Washing waters may be electrolysed, the copper being recovered as metal and the sulphuric acid regenerated, or treated with lime or scrap steel. The use of steel is preferable, as the copper is precipitated as metal rather than as an impure copper-hydroxide sludge. Descriptions are given of preliminary experiments on the most effective method of treating with steel, and of the operation of a full-scale recovery plant in the North of England. The copper recovered represented 0·05–0·06% of the wt. of copper pickled, and 95·6–97·4% of the copper present in the waste water. The value of the recovered copper was, however, reduced by contamination by iron.—P. R.

Magnesium in Industry. Magnesium Burns. Frank J. Jarzynka (*Indust. Med.*, 1943, **12**, 427–431).

The Planning and Equipment of Libraries in Research Organizations and Industrial Concerns. B. Fullman (*J. Documentation*, 1946, **2**, (2), 68–75).—The author is the Information Officer of the British Non-Ferrous Metals Research Association.—S. G.

The Basic Principle of the Method of Indexing Equipment in Industry, with Reference to Non-Ferrous Metals. I. M. Razumov (*Sbornik Nauch. Trudov Moskov. Inst. Tsvet. Metallov Zolota*, **1940**, (9), 620–637).—[In Russian].—N. A.

Non-Ferrous Cost Accounting. —— (*Foundry*, 1946, **74**, (2), 82–85, 238, 240–242; (3), 100–102, 154, 156, 158; (4), 216–219).—A detailed account of

the accounting procedure and cost methods developed by the Non-Ferrous Founders' Society of America.—J. E. G.

The Patentability of Metallic Materials. Wilhelm Lidle (*Metall u. Erz*, 1942, **39**, 221–224, 241–243, 255–259).

Patent Policies for Sponsored Research. Ralph A. Morgen (*J. Eng. Education*, 1946, **36**, (10), 618–620).—M. describes the policy of the University of Florida with respect to the patenting of the results of sponsored research. This policy was formulated after an examination of the practice in other American University Institutions.—H. J. A.

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XXV.—BOOK REVIEWS

Saws and Sawing Machinery. By Eric N. Simons. 8vo. Pp. viii + 224, with 145 illustrations. 1946. London: Sir Isaac Pitman and Sons, Ltd. (15*s*. net.)

This book contains valuable information on all types of saws and sawing machinery, and should prove useful to users and purchasers alike. It contains not only descriptions and specifications of a wide range of the most modern sawing machines for various purposes, but also gives expert information on the proper use and running of each. Important innovations dealt with are hydraulic sawing, segmental saws, tungsten-carbide-tipped saws, and improvements in the form of teeth, methods of sharpening, and the quality of steel used for blades. No type of saw appears to be omitted, for detailed attention is given to hand, power, wood, metal, circular, hack, band, and contour saws. Two appendices are included, one dealing with methods of guarding most of the types of sawing machines discussed, and the other containing useful information and tables.—J. W. Donaldson.

Metal Statistics, 1946. Thirty-ninth annual edition. Post 8vo. Pp. 816. 1946. New York: American Metal Market, 18 Cliff Street. ($2.)

This annual volume of statistics has long been recognized as a very complete and reliable reference book. After some useful general information, appropriate statistics (the headings vary, of course, rather widely for the different materials) are given for iron and steel (and manganese ore and alloys; tinplate; and alloying elements—molybdenum, tungsten, and vanadium); fuels; aluminium; antimony; cadmium; cobalt; copper; copper, brass, and bronze products; gold; lead; magnesium; mercury; nickel; platinum metals; silver; tin; zinc; and miscellaneous statistics, which include beryllium.

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