Vol. 3 Part 10

The Monthly Journal of the INSTITUTE OF METALS

MEETING IN MANCHESTER ON NOVEMBER 4, 1936.

At the Joint Meeting of the Institute and the Manchester Metallurgical Society referred to on p. 509, Mr. D. G. Sopwith will read the Paper by Dr. H. J. Gough, M.B.E., F.R.S., and himself on "The Resistance of Bronzes to Fatigue and Corrosion-Fatigue," which is printed in this issue.

All members of the Institute are invited to attend the Joint Meeting.

G. Shaw Scott,
Secretary and Editor.

Oct. 15, 1936.

OCTOBER 1936

 Entered at Stationers' Hall

loose copies of Institute papers

Members who find it inconvenient to bring to the General Meetings copies of the Monthly Journal containing the papers to be discussed, may now purchase one loose copy of each paper. Orders, which must be for one whole year in advance, should be sent to the Secretary without delay. The service commenced with the Paris Autumn Meeting 1936 papers.

Annual charge 5s., post free.

INDEX TO ADVERTISERS

OCTOBER, 1936

HEAT-TREATMENT'S PLACE IN MASS PRODUCTION

Continuous Gas-Fired Furnaces at the Ford Works.

(From "The Heat-Treatment of Steel.")

It has not been so easy to apply continuous automatic processes to the heat-treatment of steel parts as it has to most other operations in the modern mass-production factory. But it has been done. With the help of an easily and accurately controlled source of heat and a little ingenuity a number of continuous heat-treatment furnaces have been produced, and are now in operation in this country.

As is to be expected, the Ford Motor Co. would make the utmost use of such furnaces, and their works at Dagenham have an interesting system of conveyor-belt furnaces for the hardening and tempering of forgings.

There is a hardening furnace of approximately 24 feet long, which is divided into three zones, in the second and third of which the temperature is automatically controlled. The forgings pass through the furnace on a conveyor belt of heat-resisting steel and are delivered by means of a shute into the quenching tank. They are then picked up by means of a slat conveyor and delivered to the operator at the tempering furnace.

The corresponding tempering furnace is also 24 feet long and, like the hardening furnace, is divided into three zones, but the temperature is automatically controlled in all of them. The forgings are carried through the furnace on a similar conveyor belt and delivered by means of a shute on to the main floor of the heat-treatment shop.

The capacity of this installation is approximately one ton of miscellaneous forgings per hour, but the rate of travel through the furnace can be altered by means of a variable-speed motor in order to give the required soaking time for the particular type of steel being treated.

For normalizing, a walking-beam furnace of similar size and throughput is used. This, too, is divided into three 8-ft. zones separately controlled.

Advantages of Gas Firing.

So the whole process of heat-treatment is practically continuous and automatic. How has this been made possible? The first essential, of course, was a form of heat that could be easily and accurately controlled and that could automatically be kept constant. It also had to allow of the obtaining and maintaining of the desired furnace atmosphere.

Without critical control of temperature, atmosphere, and speed of transit at each stage of the operation, these furnaces would not have been practicable. The desired results could not have been assured and the number of rejects would have been excessive.

The ideal form of heat for this type of furnace has been found in coal-gas. Town gas is of known and constant calorific value, and is available in a ready-to-burn form in almost unlimited quantities. It can be burnt in the widest variety of different burners, which can be accurately controlled singly or in a set, to give a constant heat input, distributed in any required way. By means of thermostats it is easily possible to provide automatic maintenance of any desired temperature.

All this is additional to the many other advantages of town gas, such as the saving in space and labour, the greatly increased life of the furnace due to its use—refractories last longer, and its greater reliability and cleanliness. Comparing its cost on the true basis of the quality and cost of the finished article, town gas is quite the cheapest fuel that can be used.

There is a treatise—entitled "The Heat-Treatment of Steel" issued free by the British Commercial Gas Association, which contains a fund of valuable information on the subject and is well worth sending for. It can be obtained from most local gas undertakings or from the Association's address, Gas Industries House, 1 Grosvenor Place, London, S.W.1.

All needing expert advice on gas equipment should write to the Association, who will place the inquirer into touch with the body best equipped to assist him.

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CONTENTS

METALLURGICAL ABSTRACTS

The monthly issue of *Metallurgical Abstracts* may be cut up for card indexes, as members will receive early in 1937 the year's abstracts in bound form.

INSTITUTE NEWS AND ANNOUNCEMENTS

Paris Meeting.

THE first meeting of the Institute to be held in France took place from Monday, September 14, to Friday, September 18. About 200 members and their ladies assembled in Paris on September 14. One party, included in which was the President, travelled by air from London in a specially chartered aeroplane. The first gathering was to hear Professor P. A. J. Chevenard deliver the Fifteenth Autumn Lecture (in the Grande Salle of the Maison de la Chimie). An audience of over 400 persons, including many Frenchmen, listened to the lecture, which was delivered in French. Afterwards members and visitors had an opportunity for informal conversation and partook of light refreshments, later witnessing a display of cinematograph films of metallurgical interest entitled "La Magie du Fer Blanc" and "Quelques Pages sur l'Industrie française de l'Aluminium."

In the morning of Tuesday, September 15, members again assembled at the Maison de la Chimie, the admirable headquarters of the Institute during its stay in Paris, when an official welcome was extended by M. J. Dalmais, Chairman of the Local Reception Committee, and the President announced that an invitation had been received to hold the 1937 Autumn Meeting in Sheffield.

MONSIEUR DALMAIS WELCOMING MEMBERS AT OPENING SESSION OF PARIS MEETING, SEPTEMBER 15, 1936.

(Left to right: Dr. Richard Seligman, Past-President; Mr. G. Shaw Scott, Secretary; M. J. Dalmais, Chairman of Local Reception Committee; Mr. W. R. Barclay, President; Professor D. Hanson, Vice-President; Dr. H. Moore, Past-President.)

The Secretary read the following list of members nominated by the Council as Officers for the year 1937–1938. No other nominations were received.

President :
W. R. Barclay, O.B.E.

Vice-Presidents :
Engineer Vice-Admiral Sir Robert Dixon, K.C.B., D.Eng.
Lieutenant-Colonel The Hon. R. M. Preston, D.S.O.

Members of Council :
W. T. Griffiths, M.Sc.
Stanley Robson, M.Sc.
A. J. G. Smout.
D. Stockdale, M.A., Ph.D.

Biographical details of the abovementioned members who are newly nominated to the Council are given on pp. 506–507.

Papers Nos. 740, 742, 743, and 744 were then presented for discussion, and the proceedings were adjourned at 12.30 p.m.

In the afternoon several works were visited by members, and in the evening a banquet was given by the Bureau International des Applications de l'Aluminium at the Maison de la Chimie. The toast of "The Institute of Metals" was proposed by M. Dalmais and replied to by the President, Mr. W. R. Barclay, O.B.E., who was in the Chair. The toast of "The French Metallurgical Industries" was proposed in French by Dr. C. H. Desch, F.R.S. (Vice-President), the response being made by M. G. J. Painvin (Administrateur-Délégué, Société d'Électrochimie, d'Électro-métallurgie et des Aciéries Électriques d'Ugine).

On Wednesday, September 16, the General Meeting was continued at the Maison de la Chimie, when papers Nos. 733, 734, 737, 739, and 745 were presented for discussion, the meeting concluding at 12.30 p.m. with a vote of thanks to the Institute's hosts and the presentation, by the President on behalf of the Council, of a souvenir of the meeting to M. J. S. Douchement, who had acted as Honorary Secretary of the Local Reception Committee.

After a series of visits during the afternoon, there was, at 5.30 p.m., a Civic Reception at the Hôtel de Ville by the Municipal Council of Paris, the day being concluded with a dance at the Pavillon Dauphine, Bois de Boulogne.

Thursday, September 17, was devoted to an all-day excursion to Versailles. In the morning the Château was visited, and after lunch the gardens and Trianons were inspected, tea following at the Trianon Palace, the party returning to Paris about 6 p.m.

On Friday, September 18, there was an all-day excursion to Rouen and Havre. Before lunch members, accompanied by guides, visited places of historical interest in Rouen. In the afternoon the party divided—one going by motor coach to visit the Abbaye of Jumièges, Caudebec-en-Caux, and the Abbaye of St-Wandrille, returning to Rouen through Yvetôt and Barentin, and the other party proceeding to Havre to visit the works of the Tréfileries et Laminoirs du Havre. The parties rejoined at Rouen, and arrived in Paris at 7.35 p.m., thus concluding one of the most successful meetings ever held by the Institute.

President's Visit to Amercia.

The President (Mr. W. R. Barclay) sailed from this country in the *Queen Mary* on September 30 for a visit to the United States and Canada. He will be paying a number of visits to works in these countries, and also hopes to attend the Autumn Meeting of the American Institute of Mining and Metallurgical Engineers to be held at Cleveland during the latter part of the month. He will be absent from Great Britain throughout the whole of October, but hopes to return during the early part of November. During his absence the duties of President will be carried out by the senior Vice-President, Professor D. Hanson.

List of Members.

A new edition of the List of Members is now in the press and should be ready next month. Members who desire to receive a copy should forward a request to the Secretary.

Versailles Photograph.

Copies of the photograph from which the block on p. 505 has been prepared can be obtained, price sixpence each (or in exchange for three international reply coupons) on application to the Secretary.

Group of Members and their Ladies at Versailles, September 17, 1936.

NEWLY-NOMINATED MEMBERS OF COUNCIL

W. T. Griffiths, M.Sc.

Born 1895. Educated at Cardiff University College, taking B.Sc. (Wales) in Chemistry and Physics and later the M.Sc. degree. From 1915 to 1918 served with H.M. Forces in France. On return completed University course, taking Honours in Chemistry and B.Sc. in Metallurgy.

For a short time was on the staff of the Metallurgy Department, University College, Cardiff; in April, 1921, joined the Research Department, Woolwich, and carried out researches on alloy steel, brass, &c., and development of physical apparatus.

In August, 1926, joined The Mond Nickel Company, Ltd., and for the past seven years has been Manager of the Company's Research and Development Department.

A Fellow of the Institute of Chemistry, and a Fellow of the Institute of Physics. Has published several papers on ferrous and non-ferrous metallurgy. A Member of Council or Research Committees of several research organizations, including the British Cast-Iron Research Association, British Non-Ferrous Metals Research Association, Research and Standardization Committee of the Institution of Automobile Engineers, Joint Research Committees of the Federation of British Iron and Steel Manufacturers and the Iron and Steel Institute. A member of many learned and technical societies in the United Kingdom, America, and on the Continent. Represented the Local Sections on the Council from 1930 to 1932; Honorary Secretary of the London Local Section, 1924–1930, and Chairman of the London Local Section, 1930–1932. Elected member of the Institute in 1923.

S. Robson, M.Sc.

Born 1888. Educated at Armstrong College, Newcastle-upon-Tyne, and the Imperial College of Science and Technology, London. Obtained the Johnstone Chemical Research Scholarship and a Scholarship of the Royal Exhibition of 1851. Took the degree M.Sc. (Durham), and the Diploma of the Imperial College.

Held executive positions in several important chemical and metallurgical works. A Director of the National Smelting Company who have works in Avonmouth and Swansea, and a number of its associated companies.

Responsible for various metallurgical processes mainly in connection

with the smelting and refining of zinc. In charge of large works producing spelter, pure zinc and zinc alloys, cadmium and cadmium-bearing metals and lead. Interested also in the production of magnesium and calcium alloys.

A member of the Council of the Society of Chemical Industry and Chairman of the Chemical Engineering Group. Member of the Institution of Mining and Metallurgy; member of the General Board of the National Physical Laboratory and of their Metallurgical Advisory Committee; member of the Institution of Chemical Engineers. Elected member of the Institute of Metals in 1927.

A. J. G. Smout.

Born in 1888. Educated at King Edward's School, Birmingham.

After some years as Works Director with Elliotts Metal Company, Limited, he joined Imperial Chemical Industries, Limited, in 1928. Now Group Chairman of Metal Section, Imperial Chemical Industries, Limited.

Elected member of the Institute in 1917. Was first elected to the Council in 1924.

D. Stockdale, M.A., Ph.D.

The elder son of Dr. H. F. Stockdale, sometime Director of the Royal Technical College, Glasgow, he was born in 1899. Was educated at Barnard Castle School and served for a short time in France as a R.F.A. subaltern. He went up to King's College, Cambridge, in 1919, and read for Parts I and II of the Natural Sciences Tripos. After taking his degree, he was trained in the methods of research by Colonel C. T. Heycock. He was elected a senior student of the Exhibition of 1851 in 1923. Later he was for two years on Dr. Gwyer's staff in the Research Laboratories of the British Aluminium Company, Ltd., at Warrington. He returned to Cambridge as a Fellow of King's College in 1927, and is now a University Demonstrator in Chemistry. His principal subject is Inorganic Chemistry, but he also lectures on Metallography, and much of his work is carried out under Professor R. S. Hutton in the Goldsmiths' Laboratory. He has published many papers, chiefly in the Institute's *Journal*, on the structure of metals and alloys. Elected member of the Institute in 1922.

PERSONAL NOTES

The Editor requests that his attention be directed to items of interest to members that might be included under the "Personal Notes" heading. All contributions for the November issue of the Monthly Journal *should reach him not later than October* 24.

Mr. W. J. S. Roberts, B.Sc., has recently been appointed Senior Assistant Chemist with Messrs. Thos. Firth & John Brown, Limited, at Sheffield.

Mr. H. Sutton, M.Sc., has received from the University of Manchester the degree of D.Sc.

Marriage.

Bastien : Collomé. On September 26, 1936, at the Eglise Saint Louis des Invalides, Paris, Paul Bastien, D.Sc., son of General and Madame Bastien, to Fernande Collomé, daughter of Monsieur and Madame Amédée Collomé.

Obituary.

Professor Dr.-Ing. e.h. Oswald Bauer died suddenly on August 2 in his sixtieth year. An outstanding German metallurgist, his work on metallography, corrosion, and testing was specially noteworthy. He had been a member of the Institute since 1929.

Mr. S. Cowper-Coles died on September 9 at Sunbury-on-Thames. His name is associated, through the word Sherardizing, with his zinc rust-proofing process. He was closely concerned with industrial developments connected with the electrodeposition of metals.

[Mrs. Cowper-Coles states that she is desirous of letting the well-equipped laboratories and workshops of her late husband. Situated at Sunbury-on-Thames, "they are suitable for electrometallurgical research and small manufacture; there is also living accommodation, if required."]

Professor Henry Le Chatelier, the doyen of French metallurgists, died suddenly on September 17. He was Grand Officer of the Légion d' Honneur, Member of the Institute of France, Doctor of Science and Foreign Member of the Royal Society. An Original Member of the Institute, he was elected to Honorary Membership in 1912. He served for over ten years as Honorary Corresponding Member to the Council for France.

LOCAL SECTIONS NEWS

SYNOPSES OF PAPERS TO BE READ AT COMING MEETINGS *

Birmingham Section.

Non-Ferrous Metal Tubes. By W. L. Govier. (*October* 22.)

The paper will be confined to the production of seamless tubes of copper and copper-rich alloys. A description will be given of present day methods of casting, extrusion, piercing, tube reducing, annealing, and drawing, together with a discussion of some technical problems arising during manufacture. The properties and uses of some important classes of tubes will be described.

The Present Trend in Alloy Constructional Steels. By J. A. Jones, M.Sc. (*November* 5.)

The paper will consider the purpose of alloy additions to carbon steels. The relative effects of additions of nickel, chromium, manganese, tungsten, and molybdenum, respectively, on the properties of oil-hardened and tempered steels; the effect of combinations of the above elements on such properties; and the development of nickel–chromium, nickel–manganese, chromium–molybdenum, and manganese–molybdenum oil-hardening steels will be discussed.

* For places and times of meetings the green folder programmes already issued should be consulted.

Local Sections News

London Section.

Research in the Iron and Steel Industry. By Dr. W. H. Hatfield, F.R.S. (*November* 12.)

The paper will deal with the mechanism of developing and applying research in a metallurgical industry. The necessity for sub-dividing the means and approach in the three following categories will be emphasized :

(1) The need for ensuring adequate development of fundamental knowledge, using the word fundamental in its broadest sense.
(2) The advantage of collective research on major problems of common interest to the whole of the industry, either through a system of Committees or through a definitely organized research association.
(3) The paramount need for constituent firms within the industry to develop their own research organizations for the purpose of dealing with their own specific and particular problems.

The author will proceed to indicate in some detail the manner in which the various aspects of applied science are, at the present time, being actually dealt with, within the iron and steel industry in this country, and ends by giving a number of interesting examples falling within the three categories.

Manchester Metallurgical Society.

Professor F. C. Thompson, D.Met., will deliver his Presidential Address on October 21. On November 4 a Joint Meeting will be held with the Institute of Metals. Particulars of this meeting will be forwarded to local members in due course.

North-East Coast Section.

Spectrographic Analysis of Metals. By M. Milbourn, A.R.C.S., B.Sc. (*November* 10.)

A brief description will be given of the principles which underlie the use of the spectrograph in analytical work. The technique will be discussed, dealing with methods of excitation, choice of spectrograph and photographic plate, qualitative analysis, quantitative analysis, accuracy, &c.

The analysis of two or three typical materials will be described, in order to show how the choice of technique depends on certain properties of the materials being analyzed, and on the results required.

An account of the use which is being made of spectrographic methods in an industrial metallurgical laboratory will be given, showing the quantity and type of work which is being carried out. The advantages and limitations of spectrographic methods relative to chemical methods will also be discussed.

The lecture will be illustrated with lantern slides.

Scottish Section.

The Nickel Industry. Some Recollections. By W. R. Barclay, O.B.E., President. (*November* 16.)

The paper will deal with the rise of the nickel industry in England between 1835 and 1885, with brief account of refining methods; the production of nickel and its alloys in semi-manufactured forms, including an account of some of the chief problems met with in the earlier periods; the "nickel silver" alloys; and the emergence of nickel as an important alloying element in both ferrous and non-ferrous metallurgy, with particular reference to its introduction into alloy steels and to the field of electrical resistance and heat-resisting alloys. A short account will also be given of the progress made during the War period and a few of the more noteworthy developments of the immediate post-war period, including the earlier experiments in the employment of electric furnaces for melting nickel and its alloys. The paper will deal mainly with developments in this country, but incidental reference will also be made to the vital importance of the discoveries of nickel-bearing ores in Canada to the technical progress of the industry, as well as its industrial prosperity.

Sheffield Section.

Lead Mining in Derbyshire. By L. B. Williams, B.A., B.E. (*November* 13.)

Swansea Section.

Gases and Metals. By C. J. Smithells, M.C., D.Sc. (*November* 10.)

An account will be given of the work which has been carried out during the past two years at the Research Laboratories of the General Electric Company, Ltd., on the diffusion of gases through metals, and the removal of gases from metals by various treatments. Recent theories of the mechanism of diffusion, and the effect of adsorption of gas on metal surfaces will be discussed.

DIRECTIONAL PROPERTIES IN ROLLED BRASS STRIP.*

By MAURICE COOK,† M.Sc., Ph.D., Member.

Synopsis.

The tensile properties of brass strip in directions parallel, normal, and at 45° to the rolling direction, have been determined after progressively increasing rolling reductions up to more than 90 per cent. When the rolling reduction has been sufficient to induce a directional effect the greatest strength and least ductility are obtained normal to the rolling direction, while the converse obtains in the rolling direction.

When cold-rolled brass strip is finally annealed, it may show directionality which is revealed both by tensile tests and by the occurrence of ears or waves on the edges of cups cut from the strip. In annealed strip showing directionality, the tensile strength is least and the ductility greatest at 45° to the rolling direction, and it is in this position that ears are formed. The extent to which directionality exists in rolled and annealed strip is largely determined by the conditions of the penultimate and final annealings and by the magnitude of the rolling reduction between these two annealings.

A study of the orientation of twinning planes in rolled and annealed 70 : 30 brass strip showing appreciable directionality in tensile properties and in the tendency to form ears on cups, indicates that the frequency of orientation of the twinning planes is lowest at about 45° to the direction of rolling. The direction of maximum frequency of orientation of twinning planes appears to be fortuitous in strip not showing directionality in other respects.

Introduction.

The occurrence of directional properties in strip or sheet metal is of considerable theoretical interest and practical importance. Apart from directional properties arising out of the development of fibre due to the presence of non-metallic inclusions, recent investigations have shown that in materials where such inclusions are not present to any appreciable extent, directionality may exist in the properties of the metal not only in the rolled condition, but also after annealing. When metal is fabricated into cups by blanking and forming either together in one operation, or separately, the existence of marked directionality manifests itself by the presence of ears or a waviness at the edge or mouth of the cup which may vary in position, and considerably in

* Manuscript received May 9, 1936.
† Deputy Research Manager, I.C.I. Metals, Ltd., Witton, Birmingham.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

intensity, according to the rolling and annealing treatments which the strip or sheet has received in the course of its preparation. While a number of investigations have been made on directionality, there still remains much information to be obtained which will not only be of immediate practical use, but which will also help towards a fuller understanding of the subject. The work described in the present paper was undertaken to obtain, in the case of brass, information of this kind, since few results have hitherto been published concerning directional properties in this alloy.

Price and Davidson [1] who determined, after various rolling reductions, the tensile properties of 65 : 35 brass strip, in directions parallel and normal to the direction of rolling, noted that up to reductions of about 50 per cent. in thickness the tensile strength in the two directions was not measurably different, but that thereafter the strength in the transverse direction was greater than that in the longitudinal direction. The reduction in area at the fracture was found always to be greater in the longitudinal than in the transverse direction, while elongation values in the two directions were not sensibly different up to reductions of about 35 per cent., but thereafter higher values were obtained on transverse specimens.

Kaiser [2] studied the causes giving rise to waviness on copper cups and determined the effect of such factors as the temperature of the penultimate and final annealing operations, as well as the magnitude of the final rolling reduction (*i.e.* the rolling reduction between the penultimate and final annealings) on the extent of the waviness. He concluded that, in order to minimize waviness on copper cups, the final rolling reduction should not exceed 60 per cent., the temperature of the final annealing should be as low as possible and the intermediate annealings should be carried out at 700° C. or higher temperatures.

Bauer, von Göler, and Sachs [3] determined the directional properties of copper and some copper–zinc alloys after a 92 per cent. reduction in thickness by cold-rolling, and after annealing at 500° C. Except for copper and the 98 : 2 alloy, they found the tensile strength to increase with increasing angle of the specimen to the direction of rolling, the highest value being obtained on transverse specimens. In the annealed condition the tensile strength was found to decrease, and the elongation to increase with an increasing angle.

Phillips and Bunn,[4] who determined the affect of the final rolling reduction and the temperature of the final annealing operation for tough-pitch and deoxidized copper, concluded that to avoid serious directional properties the final rolling reduction should be limited to about 50–60 per cent. and the final annealing to 500°–600° C., although

it should be noted that the results were obtained on material annealed at one temperature only at the penultimate annealing stage.

With a 90 : 10 copper–zinc alloy, Phillips and Samans [5] found that the most pronounced tensile directional properties and the greatest tendency to waviness on cups are obtained by large final rolling reductions and a high temperature in the final annealing operation. Whereas copper was found to exhibit waviness in and at right angles to the direction of rolling, it occurred in the 90 : 10 alloy at 45° to the direction of rolling.

The formation of ears or waviness on cups of cupro–nickel has been studied by Bassett and Bradley,[6] according to whom ears may be formed either at 45° to, or in, and at right angles, to the direction of rolling, their position and size being affected by the magnitude of the final rolling reduction and the temperature of the final annealing.

With mild steel Phillips and Dunkle [7] found that with strip finally rolled less than 40 per cent. ears were formed at 45° to the rolling direction, whereas with strip rolled 50 per cent. or more they occurred in the 0 and 90° positions.

Effect of Cold-Rolling on the Properties of 70 : 30 and 64 : 36 Brass Strip.

Brasses of the compositions shown in Table I were obtained at a thickness of approximately 0·3 in. after a number of rolling and annealing operations. The last rolling reduction to bring the strip to this

Table I.—*Percentage Composition of Brasses Investigated.*

	64 : 36 Brass.	70 : 30 Brass.
Copper	63·4	70·5
Tin	0·01	Nil.
Lead	0·06	0·01
Iron	0·06	0·009
Nickel	0·03	0·006
Phosphorus	Nil.	0·001
Zinc (difference)	36·44	29·47

thickness was 50 per cent., and at this stage the strip was annealed at 625° C. for 2 hrs. The annealed strip was then cold-rolled without any intermediate annealing operations, samples suitable for testing being obtained after reductions in thickness of approximately 10, 30, 50, 80, 90, and 95 per cent. Relative to the direction of rolling, samples were cut parallel, normal, and at 45°, and the results of tests made on these specimens are detailed in Tables II and III. The data obtained with the two different compositions of brass show that up to reductions

of about 50 per cent. the tensile strength is the same in the three different directions, but with greater reductions the strength at 90° is greater than at 45° to the direction of rolling, while the strength in the rolling direction is lowest. These differences in tensile strength values increase in magnitude with increasing rolling reduction. In so far as they are comparable, these results on the effect of rolling on directional tensile strength confirm those of Price and Davidson, and of Bauer, von Göler, and Sachs. A much less pronounced directionality was found

TABLE II.—*Directional Properties of* 64 : 36 *Brass after Progressively Increasing Amounts of Cold-Working.*

Reduction and Direction.		Limit of Proportionality, Tons/in.².	0·1 Per Cent. Proof Stress, Tons/in.².	Tensile Strength, Tons/in.².	Elongation on 2 in., Per Cent.	Reduction of Area, Per Cent.	D.P. Hardness, 10 Kg. Load.	Brinell Hardness, 10 Kg., 1 mm.
Per Cent.	Degrees.							
Nil.	0	4·0	6·2	20·8	66·5	70		
	45	4·1	6·2	20·3	68·0	69	64	63
	90	3·5	5·8	20·6	64·0	62		
10·7	0	8·0	14·2	23·3	48·5	65		
	45	8·0	14·0	22·5	50·0	62	105	97
	90	8·1	14·2	23·0	47·0	56		
29·2	0	12·2	24·5	29·4	20·0	56		
	45	11·9	22·0	28·2	17·0	56	141	130
	90	12·8	23·0	29·1	17·0	49		
50·0	0	15·0	30·1	37·5	8·5	50		
	45	14·5	27·9	37·2	9·0	48	176	160
	90	15·3	27·8	38·0	8·5	40		
79·4	0	17·8	33·3	44·9	4·5	47		
	45	17·6	34·2	46·1	4·5	37	200	177
	90	18·0	34·1	48·2	6·0	28		
89·6	0	18·2	35·0	47·9	3·0	46		
	45	18·3	34·5	49·8	3·0	31	216	188
	90	19·4	37·9	54·8	3·0	19		
96·4	0	...	...	51·1	2·0	46		
	45	...	...	54·2	2·0	30	223	192
	90	...	...	60·7	2·0	15		

in the values for proof stress. With rolling reductions of up to 90 per cent. no appreciable directionality could be detected in limit of proportionality values which were determined with a Lamb roller extensometer, under conditions where strain measurements accurate to $0{\cdot}5 \times 10^{-5}$ in. could be made.

Although there were small differences in elongation values in the

soft condition, the highest values being at 45°, these quickly decreased, and after rolling reductions of the order of 20–30 per cent., up to reductions in excess of 90 per cent., the elongation values in the three directions were not sensibly different. At all rolling reductions the reduction in area values at 90° to the rolling direction were lowest. In the other two directions they were not very different up to reductions of about 60 per cent., but thereafter increasingly higher values were obtained in the rolling direction than at 45°.

TABLE III.—*Directional Properties of* 70 : 30 *Brass after Progressively Increasing Amounts of Cold-Working.*

Reduction and Direction.		Limit of Proportionality, Tons/in.².	0·1 Per Cent. Proof Stress, Tons/in.².	Tensile Strength, Tons/in.².	Elongation on 2 in., Per Cent.	Reduction of Area, Per Cent.	D.P. Hardness, 10 Kg. Load.	Brinell Hardness, 10 Kg. 1 mm.
Per Cent.	Degrees.							
Nil	0	2·6	5·1	20·6	74	73		
	45	2·3	3·9	19·7	82	73	60	58
	90	2·6	4·6	20·2	75	69		
10·8	0	7·3	14·2	23·1	54	66		
	45	6·9	12·7	21·5	60	68	98	89
	90	8·0	13·2	22·5	55	55		
30·3	0	10·8	23·0	29·3	23	59		
	45	10·5	22·0	28·2	21	64	146	135
	90	12·0	22·3	29·2	22	54		
50·5	0	15·5	30·2	37·6	11	49		
	45	14·4	27·5	37·6	11	50	175	159
	90	15·3	28·4	39·0	11	43		
79·4	0	17·8	34·4	44·6	5	47		
	45	17·4	31·9	46·3	6	43	207	181
	90	18·8	33·9	49·1	6	31		
90·2	0	19·1	35·5	48·6	3	47		
	45	20·0	35·4	49·8	3	35	219	190
	90	19·8	40·6	55·1	2	22		
95·6	0	...	...	51·7	2	39		
	45	...	...	52·2	2	29	224	192
	90	...	...	59·5	1	12		

DIRECTIONAL PROPERTIES IN ANNEALED STRIP.

For the determination of directional properties in annealed strip and the conditions necessary for producing strip which would yield flat-topped cups, specimens of 70 : 30 brass strip, all from the same ingot, were obtained at thicknesses of 0·041, 0·074, and 0·370 in. One set of specimens was annealed at 550° C. for 1 hr. and

another set at 800° C. for 1 hr. They were then all rolled to a final thickness of 0·037 in. Thus at this thickness were obtained six different samples representing final rolling reductions of 10, 50, and 90 per cent. in thickness and penultimate annealings of 1 hr.'s duration at 550° and 800° C. Each of the six samples was divided into three pieces, which were annealed finally at 525°, 625°, and 725° C. for half an hour, making a total of 18 different treatments.

Cups measuring approximately 0·50 in. in diameter and 0·42 in. in height were made in one operation from each of the 18 samples, and pieces of the strip cut in three directions were also tested. The results of these tests, together with the heights of ears or waves on the cups, are given in Tables IV and V, and a series of cups illustrating a range of earing or waviness is shown in Fig. 1 (Plate I).

TABLE IV.—*Mechanical Properties of Annealed* 70 : 30 *Brass. Penultimate Annealing Temperature* 550° *C.* (1 *Hr.*)

Final Annealing Temperature. (½ Hr.). ° C.	Tensile Strength Tons/in.².			Elongation on 2 in., Per Cent.			Reduction of Area, Per Cent.			Height of Ears, Inch.	Grain-Size, Mm.
	0°.	45°.	90°.	0°.	45°.	90°.	0°.	45°.	90°.		
Final Rolling Reduction 10 Per Cent.											
525	22·6	22·0	22·2	58	60	53	75	76	69	0·006	0·03
625	21·4	20·8	21·8	59	61	58	74	74	69	0·011	0·05
725	20·3	18·7	20·1	61	63	60	74	74	73	0·023	0·08
Final Rolling Reduction 50 Per Cent.											
525	24·9	24·4	24·7	52	54	47	71	71	66	0·005	0·02
625	21·8	21·0	21·8	58	66	61	69	70	68	0·009	0·045
725	20·0	18·7	20·5	60	70	63	68	71	68	0·015	0·08
Final Rolling Reduction 90 Per Cent.											
525	26·1	24·8	25·3	46	50	46	67	74	67	0·015	0·02
625	22·5	21·2	22·0	59	65	61	73	76	71	0·022	0·04
725	19·8	18·9	20·8	63	69	66	68	74	66	0·027	0·08

The tensile test results given in Tables IV and V show that at 45° to the direction of rolling the tensile strength is least and the ductility greatest, which agrees with the observation that the ears on the cups invariably occur in this position. With regard to the intensity of the earing effect, or the height of the ears, the values given in Tables IV and V indicate that with a given penultimate annealing temperature the height of the ears increases with the temperature of the final anneal. In other words, in order to avoid undue development of directional properties, the final annealing should not be carried out at high temperatures. The connection between height of ears and directionality in respect of tensile strength is shown in Fig. 2, where heights of ears are plotted against a value obtained by dividing the difference in tensile

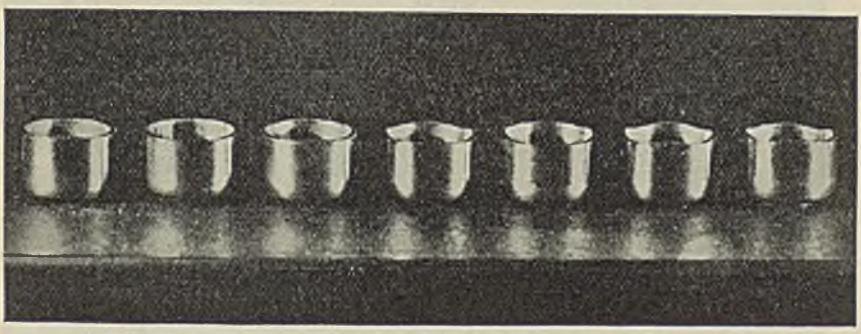

FIG. 1.—About Natural Size.

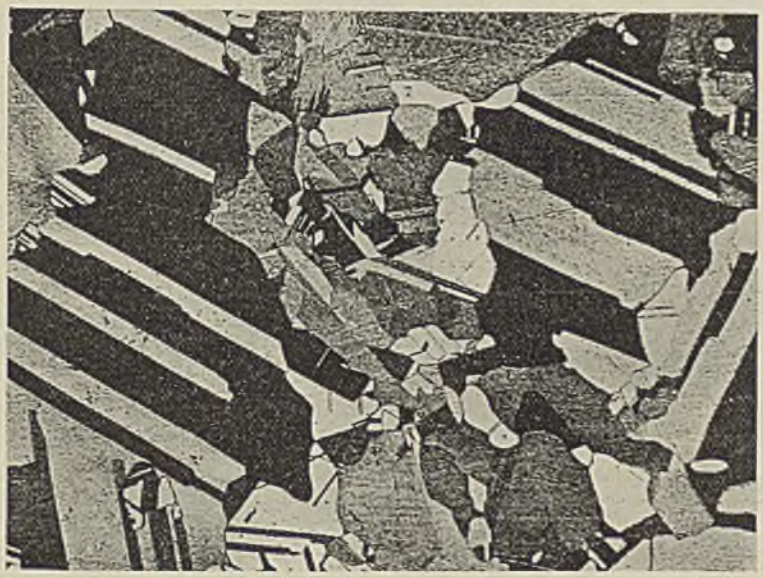

FIG. 3.—Specimen 800° C./10%/525° C. × 75.

4

6

FIG. 4.—Specimen 550° C./50%/525° C.
FIG. 5.—Specimen 550° C./90%/725° C.
FIG. 6.—Specimen 550° C./50%/725° C.
FIG. 7.—Specimen 550° C./90%/525° C.

All × 100.

strength between that at 45° and that of the average tensile strength at 0 and 90°, by the product of the two.

TABLE V.—*Mechanical Properties of Annealed* 70 : 30 *Brass. Penultimate Annealing Temperature* 800° *C.* (1 *Hr.*)

Final Annealing Temperature (½ Hr.), ° C.	Tensile Strength Tons/in.².			Elongation on 2 in., Per Cent.			Reduction of Area, Per Cent.			Height of Ears, Inch.	Grain-Size, Mm.
	0°.	45°.	90°.	0°.	45°.	90°.	0°.	45°.	90°.		
Final Rolling Reduction 10 Per Cent.											
525	19·6	18·2	19·8	45	51	49	63	74	72	0·027	0·05–0·50
625	18·8	18·2	19·1	51	60	52	70	72	68	0·017	0·10–0·50
725	18·4	18·1	18·6	61	65	62	68	72	67	0·014	0·08–0·20
Final Rolling Reduction 50 Per Cent.											
525	23·7	23·4	23·9	47	53	52	70	70	68	0·007	0·025
625	21·0	20·7	21·6	63	63	58	72	73	70	0·011	0·045
725	18·6	18·0	18·7	71	73	60	69	72	63	0·012	0·10
Final Rolling Reduction 90 Per Cent.											
525	26·1	24·9	25·3	48	48	46	74	74	72	0·007	0·02
625	21·6	21·3	22·1	53	61	55	74	74	71	0·009	0·045
725	19·4	18·5	19·6	61	64	60	68	72	65	0·016	0·10

TABLE VI.—*Height of Ears* (*Inch.*)

Penultimate Annealing Temperature, ° C.	Final Annealing Temperatures.								
	525° C.			625° C.			725° C.		
	Rolling Reduction (Final Stage).								
	10 Per Cent.	50 Per Cent.	90 Per Cent.	10 Per Cent.	50 Per Cent.	90 Per Cent.	10 Per Cent.	50 Per Cent.	90 Per Cent.
400	0·014	0·007	0·027	0·033	0·031	0·047	0·051	0·046	0·058
500	0·010	0·007	0·027	0·024	0·016	0·040	0·039	0·029	0·052
600	0·009	0·006	0·022	0·011	0·009	0·030	0·019	0·018	0·033
700	0·019	0·007	0·010	0·008	0·008	0·013	0·016	0·013	0·017
800	0·035	0·007	0·012	0·009	0·008	0·013	0·014	0·011	0·012

The only exception to the generalization that the height of the ears increases with the temperature of the final annealing is in the group subjected to a penultimate anneal at 800° C. and finally rolled 10 per cent. This reduction does not break up the large structure sufficiently for normal recrystallization and grain-growth to occur in the final annealing. This is well shown by the structure of the strip finally annealed at 525° C., which is illustrated in Fig. 3 (Plate I). In this particular group the height of the ears, the size of the crystals, and the extent of non-uniformity decrease as the final annealing temperature is increased. Apart from the material subjected to a penultimate

annealing at 800° C. and rolled with a 10 per cent. reduction, which gave rise to abnormal structural features, the height of the ears for any given penultimate annealing temperature and rolling reduction, increases with the grain-size. Without, however, so connecting it to a particular set of conditions, the height of the ears produced is not related to the grain-size. Fig. 4 (Plate II) shows the structure of a brass which gave practically flat-topped cups, while from the brass, the structure of which is shown in Fig. 5 (Plate II), cups with ears

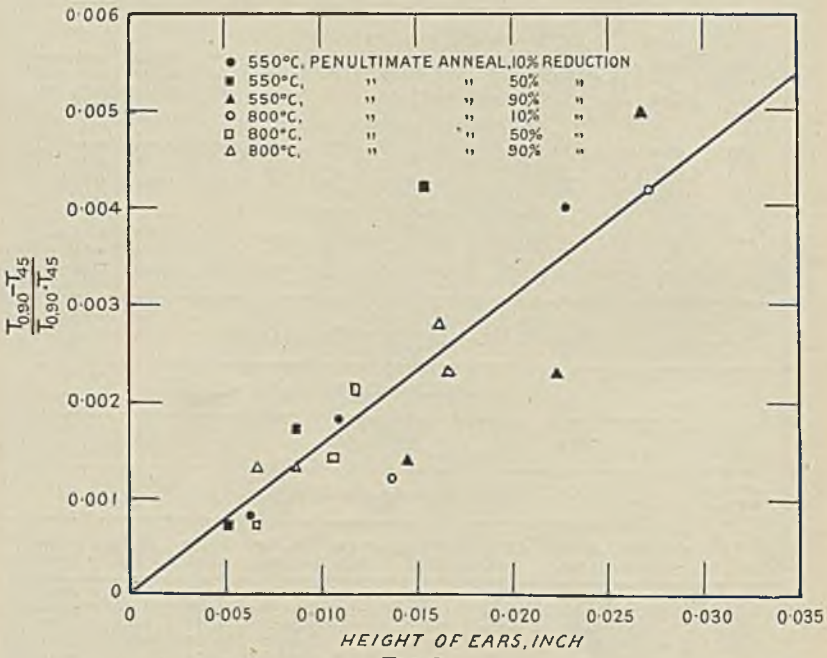

Fig. 2.

0·027 in. high were produced. On the other hand, both of the brasses, the structures of which are shown in Figs. 6 and 7 (Plate II), produced cups having ears of approximately the same height, namely 0·015 in., in spite of the large difference in grain-size. The microsections illustrated in Figs. 3, 4, 5, 6, and 7 were taken parallel to the direction and in the plane of rolling.

To obtain further evidence on the effect of the penultimate annealing temperature, this operation was carried out at 400°, 500°, 600°, 700°, and 800° C. instead of only at 550° and 800° C., as previously. The same three final rolling reductions and three final annealing tem-

peratures were adhered to, and cups of the same dimensions as those cut from the earlier strips were made from the 45 different strips so produced. The heights of the ears on these cups were measured, and the results obtained are given in Table VI.

With the exception of the strip rolled 10 per cent. and finally annealed at 525° C., the effect of increasing the penultimate annealing temperature from 400° to 800° C. is, generally, to decrease the height of the ears. This applies to the three rolling reductions and the three final annealing temperatures which have been dealt with. According to these experiments, strip yielding cups with the least amount of waviness at the mouth is obtained with a final rolling reduction of 50 per cent. in thickness and a low final annealing temperature, *i.e.* 525° C.

With this combination the effect of the temperature of the penultimate anneal on the waviness is apparently insignificant, but immediately either of these conditions is departed from, and either the magnitude of the final rolling or the temperature of the final annealing is increased, then the effect of increasing the penultimate annealing temperature in reducing the extent of waviness, becomes increasingly apparent.

Crystallographic Evidence of Directionality.

A visual examination of the microstructure of annealed brass does not suggest the existence of any directional features or preferred orientation, but recently attempts have been made to demonstrate the existence of directionality by more detailed examination of the microstructure. One of these consists of classifying the longest diameters of individual grains by plotting the direction which they make with a fixed direction, *e.g.* the direction of rolling. From a point on this fixed line, radii are marked off of lengths representing the frequency of each class. If no directionality exists the plotted radii will be more or less equal in length, while, on the other hand, any directionality would be revealed by a lengthening of the lines in preferred directions. The maximum diameter of the crystal is not definitely related to the crystal structure, and, therefore, this method for determining directionality is an arbitrary one. Twinning, which as shown by Phillips [8] takes place on the octahedral planes in alpha brass, is a real property of crystals and, therefore, the measurement of the orientation of twinning planes should serve as a means of ascertaining the existence of preferred orientation.

This interesting method of investigation, *i.e.* the determination of directionality by measuring the frequency of orientation of twinning planes, appears to have been first explored by Johnston,[9, 10] who

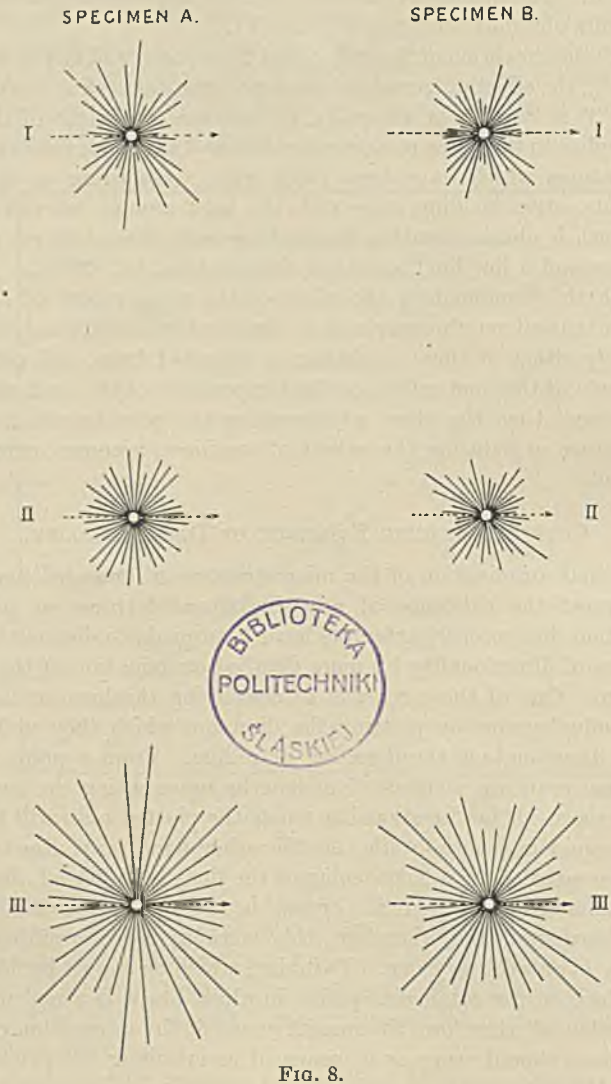

Fig. 8.

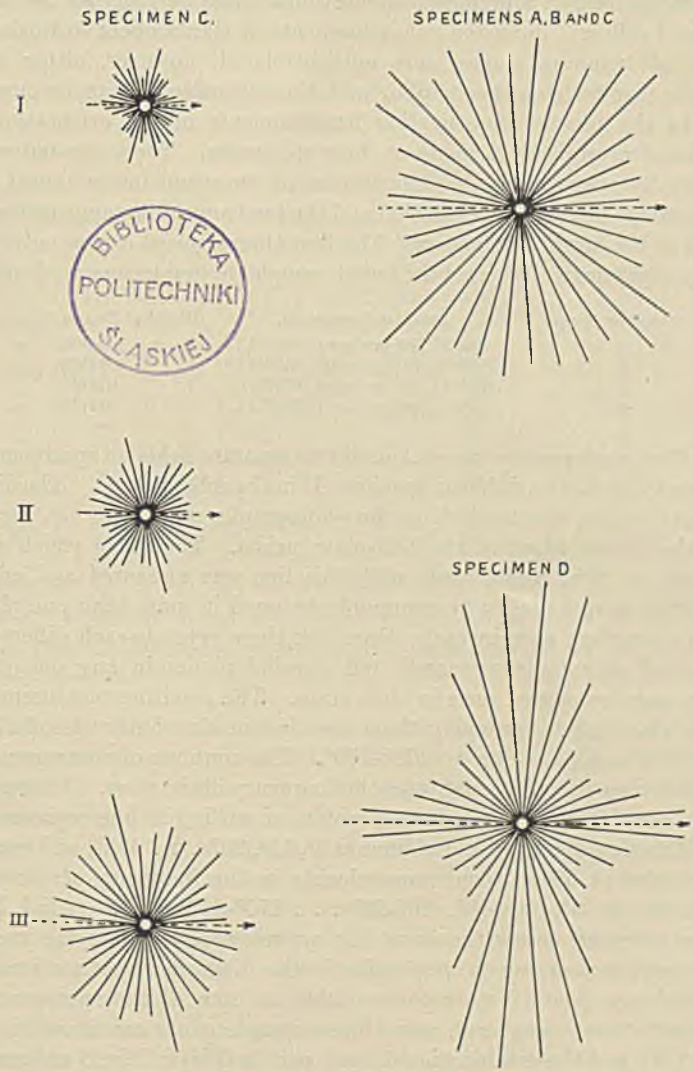

Fig. 9.

concluded that "quite strong directionality persists in the visible structure, even after strong over-annealing," and that the directionality takes the form of a preferred orientation of the grains across the direction of rolling. Johnston's measurements of the frequency of orientation of twinning planes were not correlated, however, either with mechanical tests on the strip, or with the occurrence of ears on cups.

In the present investigation measurements of the orientation of twinned crystals were made on four specimens. These are indicated below by reference to the temperature of the penultimate anneal, the percentage final rolling reduction and the final annealing temperature, as well as the height of the ears. The first three showed earing only to a very slight degree, whereas the fourth sample showed pronounced earing.

Specimen Mark.	Details of Preparation.	Height of Ears on Cups, Inch.
A	550° C./10 per cent./525° C.	0·006
B	550° C./50 per cent./625° C.	0·009
C	800° C./90 per cent./625° C.	0·009
D	550° C./90 per cent./725° C.	0·027

Photomicrographs were taken of two separate fields on specimens A, B, and C and of six fields on specimen D in the rolling plane. The direction of rolling was marked on the photographs, so that it was parallel to the longer edges of the half-plate prints. The angle which each system of twin bands made with this line was measured and noted. Crystals were found to be commonly twinned in more than one plane, and more than once in each plane. In these crystals each differently oriented plane was measured, but parallel planes in any one grain were only accounted once in that grain. The resulting measurements were classified by grouping them together in class intervals of 0°–9°, 10°–19°, and so on up to 170°–179°. The number of measurements in each class interval constitutes the frequency of the class. The results were plotted by drawing from a point, on an initial line representing the direction of rolling, radial lines at 5°, 15°, 25° . . . 175°, and lengths were marked off on them proportionate to the frequency of the class intervals 0°–9°, 10°–19°, 20°–29° . . . 170°–179°. The radial lines were extended across the basis line symmetrically, this being merely an expedient serving to emphasize in the diagram any directionality which may exist. Two separate fields on each of the specimens A, B, and C were analyzed, and these separate plots are shown in (I) and (II), and the combination of each pair in (III) in Fig. 8 and on the left portion of Fig. 9. The combination of all six fields from specimens A, B, and C is shown in the upper right part of Fig. 9, while the combined results obtained from the six separate fields on specimen D is shown in the lower right portion of the same figure. The number of

measurements made in each of the two fields on specimens A, B, and C varied between 366 and 555, the total number being 2929. More than four hundred measurements were made in each of the six fields on specimen D, totalling 2654.

TABLE VII.—*Measurements of the Frequency of Twinning Directions.*

Orientation of Twin Bands to Direction of Rolling.	Specimen A.			Specimen B.			Specimen C.			A, B, & C.	Specimen D.						
	Field.			Field.			Field.			Field.	Field.						
	I.	II.	I & II.	I.	II.	I & II.	I.	II.	I & II.	All 6.	I.	II.	III.	IV.	V.	VI.	All 6.
0– 9°	15	28	43	22	17	39	22	22	44	126	25	26	31	33	32	24	171
10– 19°	23	28	51	19	19	38	18	25	43	132	27	15	29	24	16	19	130
20– 29°	21	25	46	22	24	46	13	21	34	126	17	18	11	14	12	20	92
30– 39°	34	22	56	25	20	45	11	28	39	140	8	16	18	15	15	14	86
40– 49°	45	34	79	30	39	69	19	36	55	203	11	13	9	14	10	13	70
50– 59°	29	36	65	36	33	69	18	34	52	186	19	14	15	16	10	22	96
60– 69°	19	36	55	33	27	60	19	30	49	164	25	27	24	27	26	37	166
70– 79°	25	27	52	39	19	58	33	21	54	164	45	46	36	40	48	34	249
80– 89°	54	38	92	16	27	43	20	27	47	182	47	37	46	47	37	44	258
90– 99°	41	38	79	19	23	42	15	28	43	164	43	47	34	29	48	45	246
100–109°	15	23	38	28	33	61	29	43	72	171	47	41	41	36	35	42	242
110–119°	46	32	78	32	23	55	21	30	51	184	29	32	24	28	42	21	176
120–129°	34	29	63	26	27	53	28	23	51	167	26	19	11	13	23	11	103
130–139°	53	26	79	40	32	72	23	28	51	202	23	10	11	21	19	12	96
140–149°	36	33	69	34	42	76	17	32	49	194	9	12	12	15	17	11	76
150–159°	22	25	47	17	34	51	17	30	47	145	14	15	24	22	15	17	107
160–169°	24	27	51	13	21	34	19	32	51	136	20	15	24	22	15	23	119
170–179°	19	31	50	21	25	46	24	23	47	143	20	26	37	28	27	33	171
Total.	555	538	1093	472	485	957	366	513	879	2929	455	429	437	444	447	442	2654

The plots for the individual fields on A, B, and C suggest that the twin orientation is random and while the combined plot for these specimens is more regular, it is not suggestive of any very marked preferred orientation. This result is not surprising, since these specimens yielded flat-topped cups, and did not exhibit markedly directional properties. On the other hand, the combined plot which was obtained on a sample yielding cups with pronounced waves shows much more evidence of preferred orientation, the twinning planes occurring with greatest frequency at right angles to the direction of rolling and with least frequency at 45° to the direction of rolling. Thus, it would seem that rolled material which possesses directional properties also exhibits a preferred crystalline orientation, as shown by the direction of twinning planes, although no such evidence of directionality can be detected from a visual examination of the structure.

ACKNOWLEDGMENTS.

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THE RESISTANCE OF SOME SPECIAL BRONZES TO FATIGUE AND CORROSION-FATIGUE.*

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Synopsis.

Fatigue and corrosion-fatigue tests on four types of special bronzes have been carried out to ascertain the suitability of these materials for special aircraft purposes. The materials tested were: phosphor-bronze, aluminium bronze (10 per cent. aluminium), beryllium bronze (2·25 per cent. beryllium), and Superston L189 bronze. The results show that the corrosion-fatigue resistance of the bronzes compares favourably with that of stainless steels, the beryllium bronze in particular having the highest corrosion-fatigue resistance of any material so far investigated by the authors. The fatigue resistance in air of Superston is exceptionally high for a non-ferrous material, but the material appears to be highly susceptible to stress-concentration effects.

I. Introduction.

The fact that several bronzes have been shown by McAdam and others to have corrosion-fatigue resistances but little inferior to their fatigue resistance in air renders an investigation of these properties in the case of several special bronzes of interest. Whilst these materials must be regarded as "heavy" metals, sufficiently high resistance to corrosion-fatigue would entitle them to serious consideration as materials for use in certain parts of aircraft construction. In particular, claims have been put forward for beryllium-copper which render the further investigation of this material desirable, particularly as no data have been published concerning its resistance to corrosion-fatigue, while the available knowledge of its ordinary fatigue properties is extremely meagre.

In a useful summary by H. W. Gillett [2] of the information hitherto available as to the fatigue-resisting properties of bronzes it is stated that:

"Phosphor-bronze is relatively immune to corrosion-fatigue in salt- or fresh-water, but does not have a very high endurance limit to

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Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

TABLE I.—*List of Special Bronzes.*

Item.	Material.	Specification No.	Composition,* Per Cent.					Heat-Treatment.
			Aluminium.	Zinc.	Iron.	Nickel.	Other Elements.	
A	Beryllium bronze .	...	...	...	...	...	Be 2·4–2·55	(1) Fully heat-treated. (2) Solutionized.
B	Aluminium bronze .	D.T.D. 160	9·0–9·8	...	...	...	$\not>$ 0·75	(1) Water quenched and tempered. (2) Water quenched.
C	Al–Ni–Fe bronze . .	D.T.D. 164	9–10	...	0·5–2·5	1–3	$\not>$ 0·75	(1) Water quenched and tempered. (2) Water quenched.
D	"P.M.G." metal . .	...	...	2	...	...	"Hardener" 10	(1) As drawn. (2) Annealed.
E	High-tensile aluminium brass . . .	I.N.O.	3	37	1	...	Mn 2	
F	Phosphor-bronze. .	B.S.S. 369A.	...	...	...	...	Sn 3·5–5 P 0·1–0·4	
G	Superston L189 . .	D.T.D. 197	8–12	...	4–6	4–6	$\not>$ 0·3	

* Remainder copper in all cases.

start with. Aluminium bronze is outstanding for endurance limit and for corrosion-fatigue resistance, among commercial materials. Copper–beryllium alloys, with a precipitation-hardening treatment, appear to be, on incomplete data, of outstanding possibilities. Their high copper content should give them good corrosion-fatigue properties, though this of course needs experimental verification."

In view of the above-mentioned considerations, the programme of investigation into corrosion-fatigue now in progress at the National Physical Laboratory, on behalf of the Aeronautical Research Committee, was extended to include tests on some special bronzes.

A list is given in Table I of seven special bronzes which would appear to deserve investigation; of these, the following four were considered to be of particular interest:

(1) Phosphor–bronze (B.S.S. 369 A).
(2) Aluminium bronze (D.T.D. 160).
(3) Beryllium bronze (British manufacture).
(4) Superston bronze (D.T.D. 197).

The present paper deals with the results of tests carried out on these four materials. In each case, rotating-beam tests have been carried out both in air and in salt-spray.

II. Particulars of Materials.

The materials were supplied in the form of ¾-in. bar, except in the case of the beryllium bronze, in which case the diameter was ½ in. The condition of the materials was stated by the makers to be as follows:

Phosphor–bronze—rolled and drawn, normalized for ½ hr. at 275° C.
Aluminium bronze—extruded and drawn (not very much drawing).
Beryllium bronze—extruded and drawn (slight amount of cold-work).
Superston bronze—as forged.

It will be noted that the aluminium bronze and beryllium bronze were not in a heat-treated condition. It was considered desirable, however, to test these materials in the conditions stated prior to testing them in the heat-treated conditions mentioned in Table I, as the condition which produces the highest tensile and air fatigue strengths is not necessarily the best under corrosion-fatigue conditions, and may indeed give very poor results under such conditions. It is intended later to test these two materials in the following conditions:

Beryllium bronze— (1) Fully heat-treated (quenched from 830° to 850° C. in water).

(2) Solutionized (as (1) but age-hardened at 360° C. for 1 hr.).

Aluminium bronze—(1) Quenched from 850° to 900° C. in water.

(2) As (1), tempered at 625°–650° C., followed by slow cooling.

Chemical analyses and microscopic examinations of the materials were carried out in the Metallurgy Department of the Laboratory.

The results are given in Table II and Figs. 1–4 (Plates I and II).

TABLE II.—*Chemical Composition of Materials.*

Per Cent.	Material and Reference Mark.			
	Phosphor-Bronze. HJO.	Aluminium Bronze. HNE.	Beryllium Bronze. HMX.	Superston Bronze. HFP.
Copper .	95·56	89·5	97·26	79·83
Aluminium .	...	8·89	...	9·73
Tin . .	4·23	...	...	...
Nickel . .	...	...	0·30	4·97
Iron . .	...	0·15	0·10	5·42
Beryllium .	...	...	2·25	...
Phosphorus .	0·13	...	...	...
Zinc . .	...	1·40	...	...
Manganese .	...	...	trace	trace

The analyses fulfil the requirements of the specifications (as given in Table I) with the exception of the aluminium bronze, in which the aluminium is slightly low and the total impurities 1·55 per cent. as against the specified maximum of 0·75 per cent. The microstructures shown in Figs. 1–4 (Plates I and II) show that the conditions of the materials agree generally with those stated. The normalizing of the phosphor-bronze (Fig. 1) has not completely removed the effects of cold-work, whilst the amounts of cold-work applied to the aluminium and beryllium bronzes (Figs. 2 and 3, respectively) have not been sufficient to produce visible indications.

Table III gives results of tensile, hardness, and notched-bar tests carried out on the materials. All the materials were found to possess high values of tensile proof stress, although in some cases, particularly Superston, the tensile limit of proportionality was very low.

1

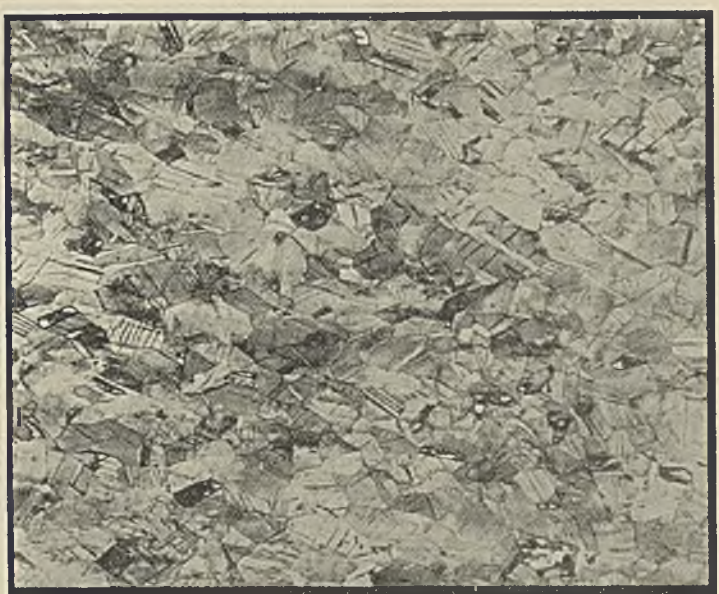

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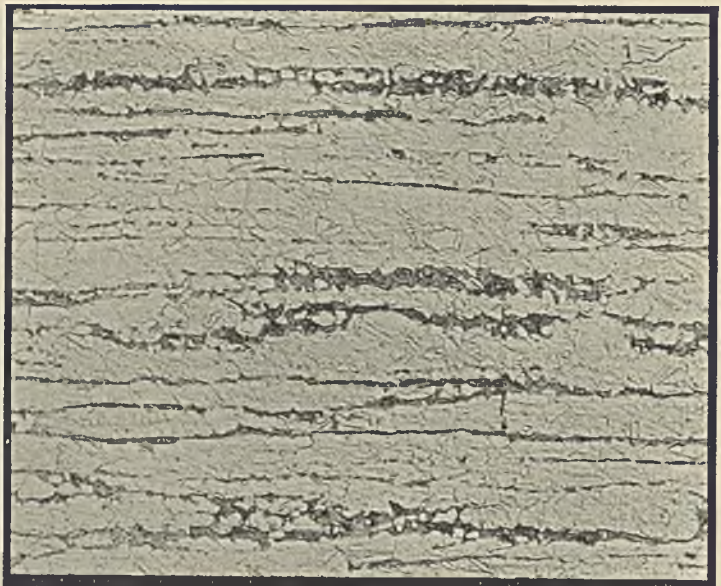
FIG. 1.—Phosphor-Bronze Etched in a Solution of Ferric Chloride. × 100.
FIG. 2.—Beryllium Bronze Etched in a Solution of Ferric Chloride. × 100.

3



4

FIG. 3.—Aluminium Bronze Etched in a Solution of Ferric Chloride. × 100.
FIG. 4.—Superston Bronze Etched Electrolytically in a 2 Per Cent. Solution of Hydrofluoric Acid in Water. × 500.

TABLE III.—*Mechanical Properties of Materials.*

Properties.	Material and Reference Mark.			
	Phosphor-Bronze. HJO.	Aluminium Bronze. HNE.	Beryllium Bronze. HMX.	Superston Bronze. HFP.
Tensile Tests (Mean of 2):				
Ultimate strength, tons/in.^{2}	27·6	35·7	41·8	51·7
Yield-stress, tons/in.^{2}	27·2	...	...	...
Proportional limit, tons/in.^{2}	11·0	7·9	13·7	2·4
0·1 per cent. Proof stress, tons/in.^{2}	25·5	18·6	30·7	32·8
0·15 per cent. Proof stress, tons/in.^{2}	26·2	20·6	33·1	34·7
Young's modulus E, lb./in.^{2} $\times 10^{-6}$	17·7	17·5	16·3	18·8
Elongation on $4\sqrt{A}$, per cent.	32·8	37·0	23·4	10·8
Reduction of area, per cent.	77·5	42·3	61·9	19·4
Notched-Bar Impact Tests (Charpy Type):				
Energy absorbed, ft.lb.	113·6–142·5	19·4–42·6	...	6·7–21·1
Mean value, ft.lb.	123·9	30·3	...	9·6
Brinell Tests:				
Hardness Number	137, 138	150, 151	166, 179	221–233
Mean value	138	150	172	226

III. APPARATUS AND SPECIMENS.

The fatigue tests were carried out in rotating-beam machines of the N.P.L. type, in which a uniform bending moment is applied over the whole length of the test portion by means of equal upward and downward loads at the enlarged outer end of the specimen. The cyclic frequency in all cases was about 2200 stress cycles per minute; all tests were made on an endurance basis of 50 million cycles.

The apparatus used for the fatigue tests in salt-spray has been fully described and illustrated in a previous paper,[3] in which are also discussed the reasons for using cycles of flexural stresses (rotating-bar machine) in preference to cycles of direct stresses. The apparatus, however, may be briefly recalled. The test portion of the specimen is enclosed in an ebonite "spray chamber" provided with holes through which project the ends of the specimen. In the side of the chamber an injector is inserted, so placed that the spray impinges directly on the middle of the test portion of the specimen. The injector is actuated by compressed air (passed through a filter to remove any oil); the solution is a 3 per cent. solution of common salt in distilled water. The resultant spray is in the form of a fine mist.

The form of specimen used is also illustrated in the previous paper,

the specimens being of form 1*a* (except the beryllium bronze specimens which, on account of the smaller diameter of the bars supplied, were of form 1*b*), the diameter of the test portion being 0·275 in. in each case.

IV. Results of Fatigue Tests.

The results of the fatigue tests in air and in salt-spray are given in Tables IV–VII; the resulting data are plotted, to logarithmic scales, in Figs. 5–8. The deduced values of the fatigue limits in air and of the endurance limits in salt-spray are summarized in Table VIII.

Table IV.—*Results of Fatigue Tests in Air and Salt-Spray on Phosphor-Bronze (Ref. Mark HJO).*

Fatigue Tests in Air.			Corrosion-Fatigue Tests in Salt-Spray.		
Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).	Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).
1A	± 15	4·98	2F	± 20	0·15
1B	± 14	4·06	2G	± 17	1·59
1C	± 13	1·82	2B	± 15	5·18
1D	± 12	8·61	2C	± 13	3·28
1E	± 11	6·05	2E	± 13	11·97
1G	± 10·5	7·67	2A	± 12	25·57
1H	± 10	4·07	2D	± 12	52·10 *
1F	± 10	50·80 *			
1K	± 9·5	53·01 *			
1J	± 9	52·59 *			

Table V.—*Results of Fatigue Tests in Air and Salt-Spray on Aluminium Bronze (Ref. Mark HNE).*

Fatigue Tests in Air.			Corrosion-Fatigue Tests in Salt-Spray.		
Specimen.	Range of Applied Stress Tons/in.².	Endurance (Millions).	Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).
1A	± 20	2·37	1G	± 20	0·91
1B	± 16	3·62	1H	± 18	1·75
1D	± 15	3·25	1V	± 16	3·58
1E	± 14·5	29·31	1K	± 14	8·93
1C	± 14	52·52 *	1L	± 12	16·58
			1M	± 11	18·51
			1N	± 10	59·30 *

* Specimens unbroken.

TABLE VI.—*Results of Fatigue Tests in Air and Salt-Spray on Beryllium Bronze (Ref. Mark HMX).*

Fatigue Tests in Air.			Corrosion-Fatigue Tests in Salt-Spray.		
Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).	Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).
1F	± 25	0·70	2H	± 21	2·01
1H	± 25	0·97	2A	± 20	0·75
1A	± 20	5·69	2E	± 20	5·51
1C	± 18	6·58	2G	± 19	11·66
1E	± 17·5	20·32	2D	± 19	19·59
1D	± 17	13·79	2B	± 18	3·76
1G	± 16·5	27·60	2F	± 18	63·47 *
1B	± 16	55·08 *	2C	± 17	21·84

TABLE VII.—*Results of Fatigue Tests in Air and Salt-Spray on Superston Bronze (Ref. Mark HFP).*

Fatigue Tests in Air.			Corrosion-Fatigue Tests in Salt-Spray.		
Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).	Specimen.	Range of Applied Stress, Tons/in.².	Endurance (Millions).
1B	± 30	0·46	8A	± 23·1	3·33
4B	± 27	1·32	8B	± 20	6·93
5B	± 25	1·21	8C	± 18	15·93
5A	± 24	9·41	9A	± 15·9	24·69
6B	± 23	6·62	10A	± 14	66·62 *
7B	± 22·5	56·82 *			
1A	± 21·7	50·05 *			

* Specimens unbroken.

DISCUSSION OF RESULTS.

The results of the fatigue tests in air are quite reasonably regular; in all cases a fatigue limit has been clearly developed or at least closely approximated to at the fifty million cycles to which the tests were carried. The value of the endurance ratio (ratio of fatigue limit for reversed stresses to ultimate tensile strength) of 0·44 recorded for Superston bronze is extremely high for non-ferrous metals, and the fatigue limit of ± 22·7 tons/in.² for this material is the highest value of which the authors are aware for any material other than a moderately high tensile steel. The material, however, appeared to be very susceptible to stress concentration effects. For instance, when the first few fatigue tests were carried out on specimens 0·3125 in. in

TABLE VIII.—*Summary of Results of Fatigue and Corrosion-Fatigue Tests.*

Material.	Ref. Mark.	Ultimate Tensile Strength, Tons/in.².	Fatigue Limit in Air, Tons/in.².	Endurance Limits in Salt-Spray, Tons/in.².			Stress Ratio.*	Variation Per Cent.	Endurance Ratios.		Ratio of Endurance Limits in Air and Salt-Spray.
				10^7 Cycles.	2×10^7 Cycles.	5×10^7 Cycles.			In Air.	In Salt-Spray.	
		T.	F_B.			f_B.			F_B/T.	f_B/T.	f_B/F_B.
Non-Ferrous Metals:											
Phosphor-bronze .	HJO	27·6	± 9·8	± 13·7	± 12·8	± 11·7	0·79	± 4	0·35	0·42	1·19
Aluminium bronze	HNE	35·7	± 14·3	± 12·8	± 11·4	± 9·8	0·68	± 5	0·40	0·27	0·68
Beryllium bronze .	HMX	41·8	± 16·3	± 18·4	± 18·0	± 17·4	0·92	± 6	0·39	0·42	1·07
Superston bronze .	HFP	51·7	± 22·7	± 18·9	± 16·9	± 14·6	0·68	± 2	0·44	0·28	0·64
Duralumin . .	EXA	28·2	± 9·2	± 4·5	± 4·0	± 3·4	0·67	± 8	0·33	0·12	0·37
Magnesium alloy (2½ per cent. Al)	EXB	16·4	± 6·8	± 1·7	± 1·0	...	0·17	± 12	0·41	(0·10)	(0·25)
Ferrous Metals:											
0·5 per cent. C steel . .	EOY	63·2	± 25·0	± 5·0	± 3·9	± 2·8	0·44	± 12	0·40	0·044	0·11
15 per cent Cr steel . .	FAO	43·3	± 24·8	± 11·2	± 10·3	± 9·1	0·73	± 4	0·57	0·21	0·37
18/8 Cr–Ni steel .	EWZ	66·3	± 23·8	± 17·5	± 16·7	± 15·8	0·87	± 5	0·36	0·24	0·67
17/1 Cr–Ni steel .	FAP	54·5	± 32·8	± 15·0	± 13·8	± 12·3	0·76	± 5	0·60	0·23	0·38

* For tenfold increase of endurance.

diameter in the test portion, with an enlarged end (carrying the ball-bearings) of 0·375 in. in diameter, failure occurred in three out of five specimens at the collars locating the ball-bearings; also, in the tensile test, failure occurred at the gauge-marks. The fatigue limit of $\pm$ 16·3 tons/in.^{2} for beryllium bronze in the soft condition may be compared with values of $\pm$ 20 and $\pm$ 13 tons/in.^{2} obtained at the National Physical Laboratory on two bronzes of similar beryllium content having an ultimate strength of about 70 tons/in.^{2}.

The corrosion-fatigue tests confirm the authors' previous experience that no indication of a corrosion-fatigue limit is obtained under these conditions of test: this applies to all the materials which they have tested. The present results for these four bronzes can most suitably be represented on the log S — log N diagram by areas enclosed between straight parallel lines as indicated in Figs. 5–8. The width of these areas is a measure of the consistency of the resistance of the material under corrosion-fatigue conditions. This width is stated in the form of a plus and minus percentage variation of stress in Table VIII. The variation in the case of Superston is extremely small, and that in beryllium bronze somewhat higher, but still reasonably small. The Superston gives quite a high ratio of corrosion-fatigue endurance limit to air fatigue limit in spite of its high notch-sensitivity, which might be expected to be accompanied by an equally high sensitivity to stress concentration at corrosion pits (see for instance [4]). The corrosion-fatigue resistances of phosphor-bronze and to a smaller degree beryllium bronze are higher, at any rate up to fifty million cycles, than the fatigue resistance in air. This apparent anomaly is explained by some previous work by the present authors,[1] in which it was shown that the intrinsic fatigue resistance of a material may be considerably higher than that developed in normal fatigue tests in air. Thus, the fatigue limit of copper (which McAdam had shown also possesses a corrosion-fatigue resistance higher than that in air) when tested *in vacuo* was 13 per cent. higher than that obtained in normal tests in air.

The data obtained in the present investigation, together with that for the six materials previously investigated, are summarized in Table VIII. In this Table a column headed "Stress Ratio" is included; this denotes the ratio of the stresses for a tenfold increase of endurance, *e.g.* from 10^6 to 10^7 cycles (for the straight portion of the corrosion-fatigue log S — log N curve or band). The stress ratio may be regarded as a measure of the damage a material sustains due to corrosion-fatigue, the actual height of the curve being influenced also by the initial fatigue strength.

The bronzes will be seen to compare very favourably with stainless

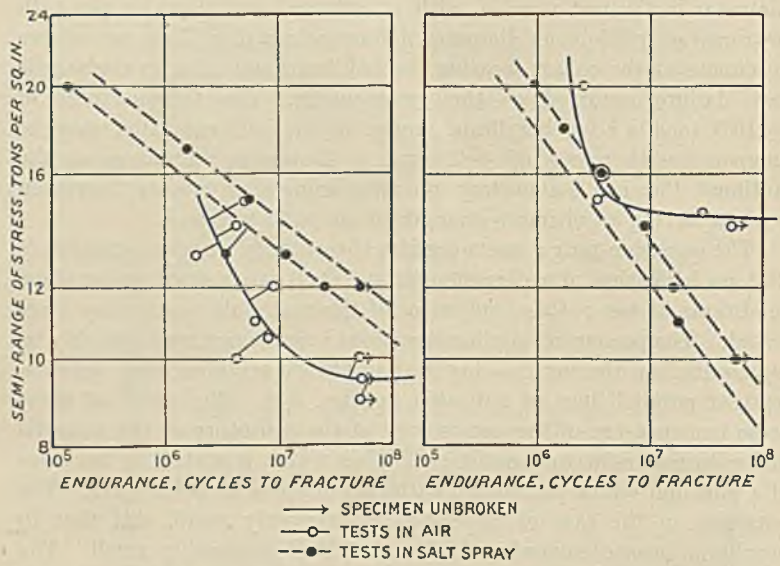


FIG. 5.—Phosphor-Bronze. (Ref. mark HJO.)

FIG. 6.—Aluminium Bronze. (Ref. mark HNE.)

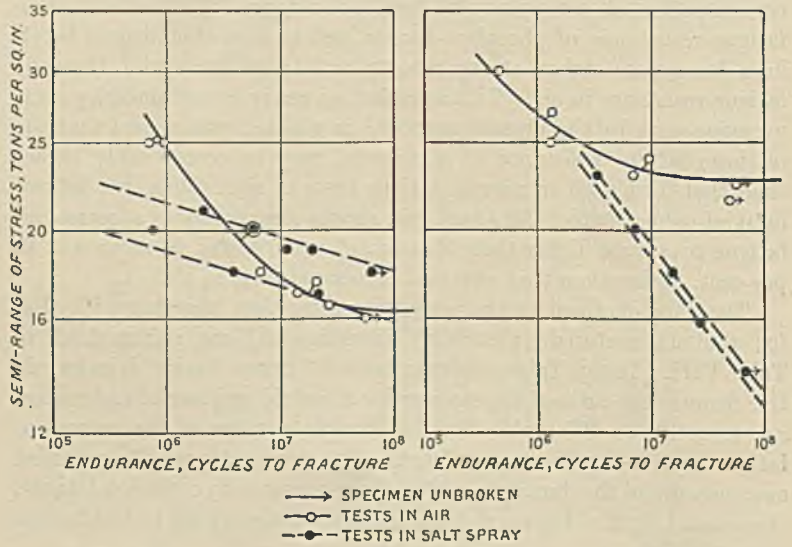


FIG. 7.—Beryllium Bronze. (Ref. mark HMX.)

FIG. 8.—Superston Bronze. (Ref. mark HFP.)

steels. Beryllium bronze * in fact is superior to the best of the stainless steels (18 : 8 Cr : Ni) investigated, the advantage increasing as the endurance increases, as the stress ratio for beryllium bronze is also the highest recorded. The variation in the case of the bronzes and the stainless steels is also of the same order (± 5 per cent.), and distinctly less than that of the materials—carbon steel, Duralumin, and magnesium alloy—of lower corrosion-fatigue resistances. Superston bronze, though not so good as beryllium bronze, is almost as good as the 18 : 8 steel. The phosphor-bronze, as stated by Gillett, has, in spite of a low fatigue limit in air, a comparatively good corrosion-fatigue resistance, the ratio of endurance limit in salt-spray to ultimate strength of 0·42 for this material being equalled only by beryllium bronze, the next highest values being 0·28 and 0·27 for Superston and aluminium bronzes, respectively. The particular aluminium bronze tested, although having a moderately high corrosion-fatigue resistance, cannot, at any rate in the condition tested, be considered as justifying Gillett's remarks quoted in the Introduction.

Acknowledgments.

The authors desire to express their indebtedness to the Director of Scientific Research, Air Ministry, for the opportunity to make these experiments and for permission to publish the results; to the Executive Committee of the National Physical Laboratory for the facilities afforded; to Mr. H. Sutton, M.Sc., of the Metallurgy Department, Royal Aircraft Establishment, Farnborough, for assistance in drawing up the programme; also to Dr. L. Aitchison and Mr. S. J. Nightingale of Messrs. Jas. Booth & Co. (1915), Ltd., and to Messrs. J. Stone & Co., Ltd., for their co-operation in the supply of material.

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[1] H. J. Gough and D. G. Sopwith, "Atmospheric Action as a Factor in Fatigue of Metals," *J. Inst. Metals*, 1932, **49**, 93.
[2] H. W. Gillett, "The Resistance of Copper and its Alloys to Repeated Stress. Part IV—The Bronzes and Special Alloys," *Metals and Alloys*, 1932, **3**, 275.
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[4] D. J. McAdam, Jr., and W. R. Clyne, "Influence of Chemically and Mechanically Formed Notches on Fatigue of Metals," *J. Res. Nat. Bur. Stand.*, 1934, **13**, 527.

* It may be pointed out that at present beryllium bronze is extremely expensive, costing about 16 times as much as the other bronzes here dealt with.

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THE CONTROL OF COMPOSITION IN THE APPLICATION OF THE DEBYE–SCHERRER METHOD OF X-RAY CRYSTAL ANALYSIS TO THE STUDY OF ALLOYS.*

By WILLIAM HUME-ROTHERY,† M.A., D.Sc., MEMBER, and PETER WILLIAM REYNOLDS, B.A., B.Sc.‡

SYNOPSIS.

The application of the Debye–Scherrer method to the study of alloys is discussed critically with special reference to errors due to uncertainty of the exact composition of the filings comprising the specimen. It is concluded that where practicable it is desirable to analyze the actual filings from which the representative small sample used in the preparation of the specimen has been sieved. Methods are described for the preparation of perfectly clean filings suitable for accurate chemical analysis. It is shown that, in the determination of phase boundaries from lattice spacing measurements of two-phase alloys, misleading results may be obtained if the temperature of the preliminary anneal of the material in lump form is not suitably related to that of the final annealing of the filings.

(1) INTRODUCTORY.

THE Debye–Scherrer or powder method of X-ray crystal analysis is now used extensively in metallurgy, both for the investigation of crystal structures and the determination of solid solubility curves. On the side of X-ray technique a satisfactory standard of accuracy has been attained provided that certain essential precautions are taken. Of these the most important are: (*a*) the use of suitable radiation to obtain "high angle lines," (*b*) allowance for film shrinkage, and (*c*) the use of some extrapolation method such as that of Bradley and Jay [1] in order to allow for errors introduced by absorption, eccentricity of the specimen, &c. If these precautions are taken the lattice constants of alloys can be measured to an accuracy of the order 1 part in 10,000 to 1 part in 50,000, or even to 1 part in 100,000 in specially favourable cases. The defect of the method lies in the uncertainty of the exact composition of the filings comprising the specimen. This point has received comparatively little attention from investigators, with the result that in

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many papers where lattice constants are claimed to be measured to an accuracy varying from 1 part in 5000 to 1 part in 50,000, the results are represented by smooth curves from which individual points may differ by 1 part in 5000 or even 1 part in 500. The present paper discusses methods by which these discrepancies may be reduced, since it is clearly unsatisfactory for the accuracy on the one axis of co-ordinates to be out of all proportion to that on the other. The matter is of great importance in determinations of solid solubility limits in view of the increasing tendency to determine these from lattice spacing–composition curves with very few points in the critical region of the homogeneous solid solution; in such cases unless the few points in the homogeneous area are entirely reliable, the whole series of solid solubility limits may be deduced wrongly. Further, as shown later, if the annealing treatment is not suitably chosen, quite incorrect values for the solubility curves may be deduced from measurements of the lattice constants of filings quenched from a temperature in the two-phase region.

(2) The Choice of Annealing Temperatures.

In all but a minority of cases the preliminary treatment of an alloy should consist of an anneal in lump form, because the cored structure of a cast alloy is usually coarser than the fine filings used for the X-ray specimen. Consequently, unless one metal in a binary alloy is volatile, annealing of filings from the casting will not produce true equilibrium unless sintering and coalescence occur. Where the cast alloy is two-phase this difficulty is accentuated, since the two phases may have to react to produce equilibrium, whilst individual particles of the filings will often consist of one phase only.

After the preliminary anneal of the material in lump form, the filings are prepared, and have then to be annealed in order to relieve mechanical strain, and may be slowly cooled, or quenched from a particular temperature according to the requirements of the experiment. If the alloy contains no volatile metals, and is homogeneous at both high and low temperatures, the preliminary anneal can be carried out most quickly at a temperature as near to the melting point as possible. If the cast alloy contains constituents of low melting point which are absorbed in the annealing process, it is advisable to heat the alloy slowly to the final high temperature in order to avoid temporary fusion of the low-melting constituent with the production of a very coarse structure from which true equilibrium is only obtained after prolonged annealing. If, however, the alloy contains a volatile constituent, it is frequently advisable to anneal the lump of alloy for a comparatively long time at a moderately high temperature, rather than for a short time at a higher temperature.

This is because a short anneal at a very high temperature results in the loss of the volatile constituent from the surface, and although in some alloys, as shown by Owen and Pickup,[2] this difficulty can be overcome by removing a comparatively thin surface layer, there are other cases in which a longer annealing at a lower temperature is more satisfactory.

Where two-phase alloys are concerned, as in the determination of solid solubility limits, the position is much more difficult. We may consider an equilibrium diagram of two metals A and B where a primary solid solution α exists in equilibrium at different temperatures with two phases β and β', the form of the solubility curves being as shown in Fig. 1. We may suppose that it is desired to determine the solubility limits of the α and β or β' phases at the temperatures t_1, t_2, t_3, and t_4 from lattice constant measurements of filings of a two-phase alloy of composition x. We may suppose first that the preliminary lump anneal is at t_1, resulting in the production of α-phase of composition a_1, and β-phase of composition b_1, the structure being coarser the higher the annealing temperature. Filing of this alloy will produce fine particles most of which will consist entirely of one phase. When re-annealed at t_2, the particles of the β-phase have merely to precipitate some of the α-phase so that their composition changes from b_1 to b_2, with the production of α-phase particles of composition a_2. The particles of α-phase of composition a_1 have, however, to take up more of the solute element B in order to reach the equilibrium composition a_2, and this they are normally unable to do, although if the element B is volatile true equilibrium may be obtained.* This combination of heat-treatments may, therefore, result in the production of α-phase particles of composition a_1 and a_2. If the relative amounts of these two kinds of

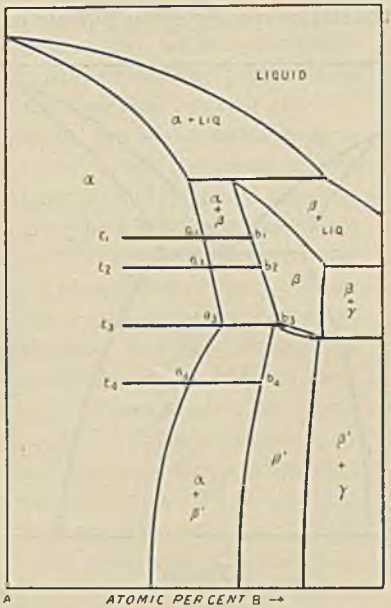

FIG. 1.

* With non-volatile metals equilibrium may be reached if sintering or coalescence of the filings occurs, but the resulting mass is, of course, generally useless.

α-phase particles are comparable, and their lattice spacings are sufficiently different, definitely fuzzy or double lines will be produced in the X-ray diffraction photograph. If, however, the compositions a_1 and a_2 do not differ widely, slightly broader lines will result, the centres of darkening of which will correspond with some point between a_1 and a_2, whilst completely misleading results may be obtained if the relative amount of a_2 is so small compared with that of a_1 that the particles of a_2 are too few to produce a line of appreciable intensity; unless care is taken this may easily be the case.

The above heat-treatment, therefore, makes it possible to determine the lattice spacing of the β-phase on the solubility curve at t_2, but leads to difficulties with the α-phase. Similar reasoning shows clearly that if the preliminary lump anneal is at t_3, the position is reversed. In this case if the filings are subsequently annealed at t_1, t_2, or t_4 the α-phase particles of composition a_3 have merely to precipitate the β-phase in order to reach the equilibrium compositions a_1, a_2, or a_4, whilst the β-phase particles of composition b_3 have to take up into solution some of the element A, and this may be impossible unless this element is volatile. This reasoning is quite general, and the conclusion may be summarized by saying that if the preliminary lump anneal is not at the same temperature as that of the filings, the two must be adjusted so that, in the final anneal, the particles of the phase under investigation precipitate a second constituent, and do not take one up into solid solution. This implies that in an equilibrium diagram of the type of Fig. 2, a single intermediate two-phase alloy annealed at a high temperature will serve for the determination of both solubility curves at lower temperatures, whereas in the diagram of Fig. 1 considerable care is necessary if misleading results are to be avoided. A critical examination has shown that in several recent papers where solid solubility curves of the type represented in Fig. 1 have been determined by X-ray methods, parts of the curves may be affected by errors of the kind

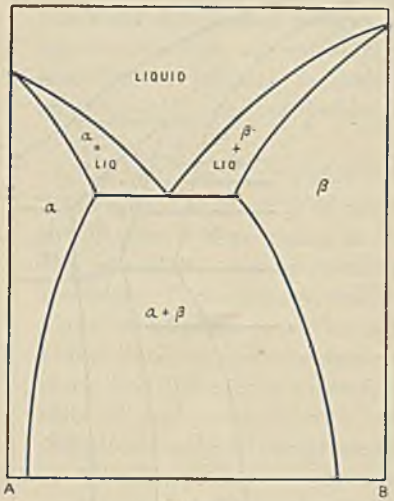

Fig. 2.

referred to above. These difficulties may be more pronounced in alloys where the filing process produces a surface film of oxide which may completely prevent interaction between different particles on annealing.

(3) The Determination of the Composition of the Specimen.

There has been a general tendency to assume that the composition of the filings in the specimen may be determined by lump analysis of the original alloy, although in cases where a volatile constituent is present the necessity for analysis of filings receiving the same heat-treatment as those of the specimen has been recognized. Even with non-volatile metals, however, the former method frequently leads to misleading results, and the authors, therefore, recommend that, where practicable, analysis should be made of the actual filings from which the representative small portion used in the preparation of the specimen has been sieved.*

In the first place, if segregation is present, errors due to differences between the compositions of the portions used for the specimen and the analysis are avoided by this method. It must be emphasized that the mere fact that sharp diffraction lines are given by a specimen made from a small quantity of filings is no indication that segregation effects are absent. It is commonly but erroneously supposed that if sharp diffraction lines are given by filings prepared from a complete cross-section of a cylindrical rod, the material is satisfactory, but this assumption ignores the possibility of longitudinal segregation. The authors have encountered this phenomenon particularly in the case of silver–tin alloys in the form of $\frac{5}{16}$-in. diameter drawn rods. Filings prepared from complete cross-sections of these rods gave perfectly sharp diffraction lines, and it was only by repeating the measurements with filings from different sections along the rod that the segregation was discovered. The rods were prepared for the authors with great care, the cast bars being subjected to a prolonged annealing treatment before being drawn down into rods. All this batch of silver–tin alloys showed this type of segregation, but there seemed to be no obvious fault in preparation, since other rods of silver alloys prepared by the same firm under supposedly identical conditions were quite free from this defect. The extent of the longitudinal segregation in the silver–tin alloys was such that if filings were prepared from a complete cross-section, and the composition determined from 1 grm. of the adjacent material, the error involved was of the order $\pm$ 0·1 per cent. by weight, whereas completely misleading

* It is important that filings used for the specimen shall be representative of the whole sample used for analysis. In practice the specimen is usually made from very fine particles sieved out from the main bulk, whilst the analysis is carried out on a mixture of those which pass through the sieve and those retained. It is important, therefore, that the whole mass used for analysis shall have been shaken on the sieve so that the fine particles are thoroughly representative.

results could be obtained if the analysis were carried out on material from another part of the rod. In other silver alloys, and also in certain copper alloys, the segregation is usually of the transverse type, and here the best results are obtained by preparing filings from a zone of material equidistant from the centre of the rod.

An indication of uniformity in the composition of the specimen is given by the resolution of the K_α doublets in *low angle* diffraction lines, provided that the specimens are of the correct thickness, and that the camera and specimen are accurately adjusted. These conditions are essential, since variations in the X-ray slit system, or faulty centering of the specimen affect the resolution considerably. In the α-solid solutions in silver, the use of cobalt radiation gives 024 and 133 lines at approximately 78° and 72°, respectively, but it is difficult to estimate the extent of segregation from these high-angle lines since the doublets are resolved in all but extreme cases. With homogeneous specimens the 400 lines at approximately 60° are distinct and well resolved, whilst the 222 and 113 lines at 49° and 46° are also definitely resolved. Resolution of these last two lines in a sample prepared from 0·5 to 1·0 grm. of material is, however, exceptional for alloys, although a satisfactorily homogeneous sample will give well resolved 400 lines.

Since accurate chemical analysis requires from 0·5 to 1·0 grm. of material, any marked segregation will usually be revealed by a fuzziness of the diffraction lines if the X-ray specimen is made from filings representative of the whole quantity prepared. The sensitivity of this test naturally depends on the extent to which the lattice spacing varies with the composition, and it must be emphasized that visual observation will not reveal segregation if the limiting compositions correspond with a difference in lattice spacing of less than 0·0005 A. The existence and direction of segregation in an alloy may often be conveniently determined by preparing an X-ray specimen from a mixture of minute amounts of filings obtained from two positions in the original specimen, this method being particularly useful in the case of rare metallic alloys where economy of material is important. The direction of segregation being known, the procedure to obtain the most homogeneous sample possible is readily determined.

If a slight inhomogeneity of the specimen cannot be avoided, analysis of the actual filings gives the most accurate results obtainable, since both the chemical analysis and the X-ray measurement tend to give a mean value. This may not apply, however, if the segregation is of such a type that the rod consists mainly of one composition (x), with a thin layer of distinctly different composition (y). In this case if the diffraction line corresponding to (y) is faint, and sufficiently different from (x), the

darkest parts of the lines may correspond with the composition (x), and not with the mean value given by chemical analysis. It is for this reason that the outermost surface layer of a lump should always be discarded.

Apart from the effects due to macroscopic segregation in an alloy, fuzziness of diffraction lines may also be due to insufficient annealing of the lump alloy. In this case fuzziness persists when the specimen is made from a minute amount of material, in contrast to fuzziness due to segregation, which can be reduced by preparing the specimen from a very small volume. In a one-phase alloy * slight fuzziness of line due to insufficient annealing is much less serious than fuzziness due to segregation. This may be illustrated by Table I which shows results obtained [4] with a second series of silver–tin alloys. In alloys 2*a*, 3*a*, and 4*a* the preliminary lump-annealing treatments were not quite sufficient to give well-resolved 400 lines, whilst in alloys 2*b*, 3*b*, and 4*b*, the resolution

TABLE I.—*Lattice Spacings of Silver–Tin Alloys* (α *Solid Solution in Silver*).

No. of Alloy.	Atomic Per Cent. Sn.	Lattice Spacing at 24° C.
2*a*	4·13	4·0945(9)
2*b*	4·13	4·0945(9)
3*a*	6·24	4·1032(5)
3*b*	6·26	4·1032(6)
4*a*	8·17	4·1122(3)
4*b*	8·20	4·1122(4)

Annealing Treatments.

Lump anneals. No. 2*a*. 20 hrs. at 650° C. + 40 hrs. at 780° C., + 11 hrs. at 860° C.
Nos. 3*a* and 4*a*. 20 hrs. at 650° C. + 4 hrs. at 780° C.
Nos. 2*b*, 3*b*, and 4*b*. 5 days at 725° C.

Filing anneals. 15 hrs. at 520° C. in all cases.

The camera was calibrated with quartz and copper radiation as described by Bradley and Jay,[3] and the alloy diffraction photographs taken with cobalt radiation. The constants involved are:

Calibration of camera.

Cu. $\lambda K\alpha_1 = 1537{\cdot}395$ X.U.
$\lambda K\alpha_2 = 1541{\cdot}232$ X.U.
Quartz at 27° $a = 4246{\cdot}53$ X.U.
$c/a = 1{\cdot}09996(5)$.

Lattice spacing measurements.

Co. $\lambda K\alpha_1 = 1785{\cdot}29$ X.U.
$\lambda K\alpha_2 = 1789{\cdot}19$ X.U.

As in the work of Bradley and Jay, the results from the α_1 and α_2 lines were averaged in the ratio $2\alpha_1 : 1\alpha_2$.

* This does not necessarily apply to two-phase alloys where the two phases have to react in order to reach equilibrium.

was satisfactory. When allowance is made for the slight differences in composition of the filings from the two portions of alloys 3 and 4, the maximum discrepancy between the two series of results is equivalent to 0·0001(1) A., so that the error introduced is less than 1 part in 40,000. This indicates that any slight fuzziness of lines not detected visually will be without effect, but it must be emphasized that the use of films with slightly fuzzy lines is justifiable only when there is conclusive proof that the fuzziness is not due to macroscopic segregation effects.

(4) The Preparation of Filings.

The considerations mentioned above suggest that results based on the analysis of filings are to be preferred, and since this involves the preparation of from 0·5 to 1·0 grm. of filings from each specimen, an automatic filing machine has been devised in order to minimize the labour involved. This machine, made by Messrs. Alfred Herbert, Ltd., of Coventry, is a modification of a small hack-saw machine. The hack-saw blade is replaced by a suitable file holder, and the specimen held in a clamp is surrounded by a paper tray to collect the filings. A long lever supports a moveable weight, by means of which the load on the file can be adjusted to suit the particular alloy concerned. The machine has been very satisfactory, and has saved much time and labour, since the filing can be accomplished with little attention whilst other work is in progress. The authors must express their thanks to Professor F. Soddy, F.R.S., for his kind interest in developing this machine, and for placing it at their disposal.

The contamination of filings with foreign matter may give rise to difficulties in analysis. It is perhaps significant that no details of complete analyses of filings appear to have been published, many investigators relying on the determination of one constituent only, even though the second metal determined by difference is present in small amount. The authors have examined this point in detail, and find that errors of the order 0·1–0·2 per cent. may easily be introduced in this way.

In the early work on silver and copper alloys, filings were prepared by hand, and it was found that even with the most careful precautions to exclude dust and other foreign matter, the sums of the percentages of the metals as determined by analysis varied between 99·8 and 100·0, whilst another investigator obtained totals as low as 99·6. This source of error has been overcome by taking the utmost precaution in the preparation, and by cleansing the filings from foreign material which even then contaminates the product. To avoid metallic contamination it is practically essential to use a new file for each specimen. The files are washed in benzene to remove grease, and are carefully freed from

foreign material by the use of a camel-hair brush; a cloth or rag must not be used for this purpose. The specimen, after removal of the surface layer, is clamped in the holder of the machine, or in a vice if hand-filing is used, and, if necessary, is cleaned with benzene. The filings are collected in a glazed-card tray, and are transferred to a stoppered weighing bottle where they are shaken up with benzene. Even after the most careful preparation, the amount of foreign material which is floated off in the benzene is often astonishing. The benzene is decanted together with suspended and dissolved impurities, and the process is repeated twice. In extreme cases carbon tetrachloride may be more suitable on account of its higher density (approximately 1·5), but, in general, benzene is more satisfactory. The filings are then washed with six successive portions of ether, and are dried in a vacuum or in a gentle current of warm air according to the nature of the product. Finally the filings are magnetted in order to remove iron particles which may have been introduced from the file, unless, of course, the filings are themselves magnetic.

By adopting these methods the authors have succeeded in preparing filings the total metallic content of which is not less than 99·90 per cent., the usual totals of the analytical percentages being about 99·98 per cent. Under these conditions a difference figure is accurate to within 0·1 per cent. if impurities are absent, but experience suggests that determination of both metals is always advisable since it gives warning of contamination, and many other possible sources of error. Filings of magnesium alloys, for example, when prepared in air may contain from 0·5 to 5·0 per cent. of oxygen and nitrogen. The filings may, however, still be used for analysis if both metals are determined, since the *ratios* of the metallic constituents will be the same as in the original lump. Experiment alone can determine whether such filings can justifiably be annealed and used for X-ray investigations, since the annealing process may produce concentration gradients in the particles, or may produce a complex alloy with the oxide or nitride, in which case the filings must be prepared out of contact with air. A further advantage of making a complete analysis of the filings is that where a particular metal is liable to contain small but variable amounts of a certain impurity, a complete analysis may enable the lattice constants of a binary alloy containing this impurity to be corrected so as to give the value for the pure alloy. Thus the effects of traces of copper on the lattice constants of solid solutions in silver can sometimes be allowed for, assuming an additive relation, from a knowledge of the effect of copper in the system copper–silver. Where a solvent metal cannot be obtained free from a particular impurity, this method may be very valuable.

Conclusion.

It is hoped that the methods outlined above may be of value in helping to improve the relative accuracy on the composition axis of lattice spacing–composition curves, and thus enable full advantage to be taken of the high accuracy which the X-ray methods afford in the determination of equilibrium diagrams. The authors do not mean, of course, to suggest that it is always advisable to base results on the analysis of from 0·5–1·0 grm. of filings. Exceptions are clearly presented by very hard alloys which cannot readily be filed, and by some ferromagnetic alloys where particles of iron from a file cannot be removed by a magnet, and may interfere with the analysis. In some cases the precautions that have been described are undoubtedly unnecessary, but, in general, this can only be proved by such extensive duplication of lattice spacing measurements or chemical analyses that the complete analysis of the actual filings is eventually the shortest method, quite apart from the numerous safeguards which it supplies. The authors' experience has shown that with copper and silver alloys, difficulties of the kind referred to above are so often encountered, that the rather common tendency to consider X-ray measurements of phase-boundaries as replacing older determinations may be criticized. The X-ray method has great potentialities, but the older microscopic and conductivity methods use larger quantities of material, and thus avoid errors which may vitiate the X-ray results unless precautions are taken which appear to be neglected in many published investigations.

Acknowledgments.

The authors desire to express their gratitude to Professor F. Soddy, F.R.S., for his kindness in providing laboratory accommodation and many other facilities which have encouraged them in this work. One of the authors (W. H.-R.) must thank the Council of the Royal Society for election to a Research Fellowship, and for generous grants towards the cost of X-ray apparatus, materials, and fees for chemical analyses. Grateful acknowledgment is also made to the Department of Scientific and Industrial Research and to the Aeronautical Research Committee for financial assistance in connection with the general research work of which this forms a part.

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THE SOLUBILITY OF SILVER AND GOLD IN SOLID MAGNESIUM.*

By WILLIAM HUME-ROTHERY,† M.A., D.Sc., MEMBER, and EWART BUTCHERS,‡ B.A., B.Sc.

SYNOPSIS.

The solid solubility of silver in solid magnesium has been investigated above 300° C., and the solidus and solid solubility curves of the magnesium-rich solid solution have been determined. The maximum solubility of silver in magnesium is 3·9 atomic per cent. (15·3 per cent. by weight) at the eutectic temperature (471° C.), and the solubility decreases with decreasing temperature to 0·9 atomic per cent. (3·9 per cent. by weight) at 300° C. The maximum solubility of gold in solid magnesium is of the order 0·1 atomic per cent. at 576° C., and the solubility decreases with decreasing temperature.

INTRODUCTION.

PREVIOUS work on alloys of copper and silver with the elements of the B Sub-Groups, including those of the first two Short Periods, led to the hypothesis of the "relative valency effect." [1] According to this, in a binary system where the metals have different valencies, the primary solid solution in the element of lower valency tends to be of greater extent than that in the element of higher valency. The object of the present investigation was to test this hypothesis for the systems silver–magnesium and gold–magnesium, where the "size-factors" [2] are favourable. The work of Schemtschushny [3] and Saeftel [4] on magnesium–silver alloys, and of Vogel [5] and Urasow [6, 7] on magnesium–gold alloys shows that silver and gold take up at least 20–30 atomic per cent.§ of magnesium into solid solution. The results obtained in the present work confirm the hypothesis of the relative valency effect, since the maximum solubilities of gold and silver in magnesium are only 3·9 and $< 0·2$ atomic per cent. respectively.

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§ The form of the magnesium–silver equilibrium diagram is at present in dispute since Saeftel claims that the α solid solution in silver extends up to 65 atomic per cent. of magnesium.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

Experimental Methods.

General.

By the kindness of the Aeronautical Research Committee and the National Physical Laboratory, the authors were presented with magnesium of 99·95 per cent. purity, and with a magnesium–gold ingot from which the magnesium–gold alloys were prepared. For the magnesium–silver alloys the magnesium was melted with 99·99 per cent. silver grain supplied by Messrs. Johnson, Matthey & Company, Ltd. The alloys were melted under flux in crucibles lined with alumina and fluorspar, and prepared by the Morgan Crucible Company, Ltd. The flux used contained 896 parts by weight of anhydrous magnesium chloride, 320 parts potassium chloride, 60 parts sodium chloride, and 40 parts calcium fluoride. The alloys were then cast into heavy copper moulds giving cylindrical ingots of $\frac{3}{8}$ in. and $\frac{1}{4}$ in. diameter, with a very fine microstructure.

For the annealing experiments the alloys were enclosed in sealed evacuated glass tubes, and heated in tubular resistance furnaces controlled by a Foster temperature regulator, by means of which the temperature was kept constant to within $\pm 2°$ C. in all the critical experiments. At the end of each annealing treatment the alloys were quenched in cold water. In the determination of the solidus curve in the system magnesium–silver, the specimens, after a preliminary annealing treatment, were heated for 30 minutes at the desired temperature before quenching; in this work the temperature was controlled by hand adjustment of the resistances in the furnace circuit, and the constancy of the control was gradually increased from $\pm 0·8°$ to $\pm 0·3°$ C. The temperature was measured by an Alumel–Chromel thermocouple with its tip touching the sealed tube containing the alloy, the thermocouple being calibrated against the melting points of aluminium, the aluminium–copper eutectic, zinc, lead, and tin.

Microscopic Examination.

After grinding on emery papers, the specimens were polished on a cloth smeared with oil and magnesia. The structures of the magnesium–gold alloys, and of the two-phase magnesium–silver alloys were easily revealed by etching with a solution containing four drops of Tinofeff's reagent * in 10 c.c. of alcohol. For the homogeneous magnesium–silver alloys the best results were obtained by repeated etching in a more concentrated solution containing 18 drops of Tinofeff's reagent to each 10 c.c. of alcohol, the specimen being polished lightly after

* This reagent consists of a mixture of 4 parts of chromic acid and 96 parts of nitric acid.

each immersion. Although this treatment revealed the crystal grains clearly, it tended also to produce etch pits, but these could readily be distinguished from the bluish particles of the second constituent in the two-phase alloys. Photomicrographs are not reproduced, since the alloys showed quite typical homogeneous or two-phase structures.

Chemical Analysis.

The magnesium–silver alloys were analyzed by one of the authors (E. B.), the silver being determined gravimetrically as chloride, and the magnesium as pyrophosphate. The sum of the percentages of the two metals determined by analysis varied between the limits 99·95 and 100·09 in all the alloys of critical composition. The magnesium–gold alloys were analyzed by Mr. R. G. Johnstone of the Midland Laboratory Guild, Ltd.; the gold was weighed as metal after precipitation from solution in hydrochloric acid by means of sulphur dioxide, and the magnesium determined as pyrophosphate. The sum of the percentages of the two metals determined by analysis varied from 99·90 to 99·95.

Experimental Results.

(a) *Magnesium–Silver.*

Table I.—*The Solidus Curve.*

Preliminary Treatment.—Before being used for the experiments described in this Table, the alloys received a preliminary annealing treatment of at least 9½ days at 450°–460° C., and all except the first and last mentioned alloys had previously been annealed for 6 days at 420° C. or 8 days at 440° C.

Silver.		Quenching Temperature, ° C.	Microstructure.
Weight Per Cent.	Atomic Per Cent.		
2·63	0·60	613 601·5	α + a little chilled liquid α
4·37	1·02	588·5 581	α + chilled liquid α
5·26	1·23	575·5 563·5	α + a little chilled liquid α
8·77	2·12	542 532	α + chilled liquid α
10·13	2·48	522·5 512	α + a little chilled liquid α
12·33	3·07	504 493	α + chilled liquid α
13·92	3·51	483·5 473	α + a little chilled liquid α

This system was investigated by Schemtschushny,[3] who observed no solid solution in magnesium, but obtained an equilibrium diagram

in which pure magnesium formed a eutectic with the compound Mg_3Ag, the eutectic horizontal being at 469° C. The present work confirms the eutectic temperature as lying between the limits 470° and 473° C., but shows that a definite solid solution exists, the limits of which decrease from a maximum of 3·9 atomic per cent. of silver (15·3

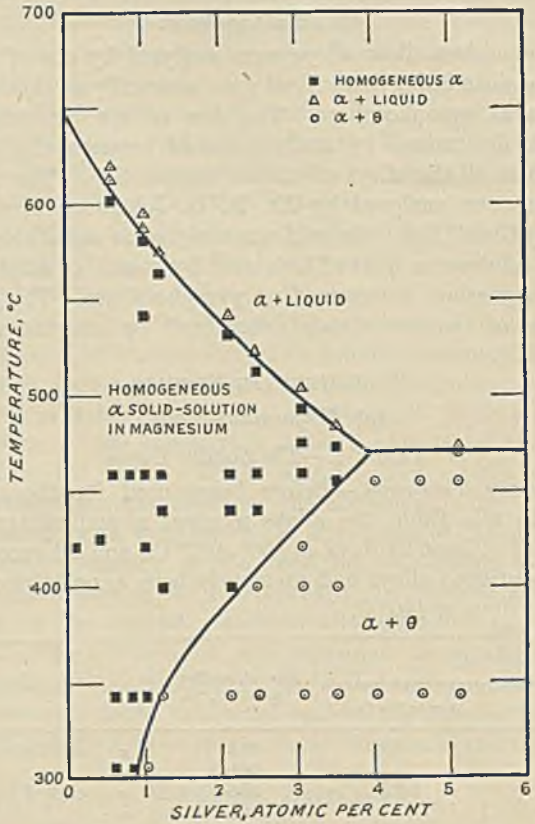

Fig. 1.

per cent. by weight) at the eutectic temperature to 0·9 atomic per cent. of silver (3·9 per cent. by weight) at 300° C.

The results of the solidus determinations are shown in Table I, and are included in Fig. 1 which also shows the results of the annealing experiments given in Table II. For abbreviation, only the critical points near to the solubility and solidus curves are given in these Tables, but the additional points obtained in the course of the work are included in Fig. 1. The Tables are self-explanatory, and the results confirm

that the solubility of silver in solid magnesium is very much less than that of magnesium in solid silver.

TABLE II.—*The Solid Solubility Curve.*

Silver Composition.		Annealing Treatment.		Micro-structure.	Remarks.
Weight Per Cent.	Atomic Per Cent.	Preliminary.	Final.		
15·68	4·02	none	13 days, 455° C.	$\alpha + \theta$	This alloy remained two-phase when re-annealed at 400°, 343°, and 306° C. after the above high-temperature treatment.
13·92 13·92	3·51 3·51	none *	13 days, 455° C. 5 days, 400° C.	α $\alpha + \theta$	This alloy remained two-phase when re-annealed at 343° and 306° C. after being made homogeneous by a preliminary anneal at 450°–460° C.
12·33 12·33	3·07 3·07	6 days, 421° C. none	9½ days, 459° C. 6 days, 421° C.	α $\alpha + \theta$	
10·13 10·13	2·48 2·48	none *	8 days, 440° C. 5 days, 400° C.	α $\alpha + \theta$	
8·77 8·77	2·12 2·12	* 8 days, 400° + 9½ days, 459° C.	5 days, 400° C. 8 days, 343° C.	α $\alpha + \theta$	
5·26 5·26	1·23 1·23	* 8 days, 440° + 9½ days, 459° C.	5 days, 400° C. 8 days, 343° C.	α $\alpha + \theta$	
4·37 4·37	1·02 1·02	6 days, 421° + 9½ days, 459° C. †	8 days, 343° C. 8 days, 306° C.	α $\alpha + \theta$	
3·59	0·83	9½ days, 459° C. + 8 days, 343° C.	8 days, 306° C.	α	

In this Table, the primary solid solution in magnesium is denoted α, and the second phase θ; if the diagram of Schemtschushny is correct, the θ phase is the compound Mg_3Ag.

* After being used for the series of experiments at 343° C., these alloys were made homogeneous by annealing at 401° C. for 5 days followed by 2 days at 460° C., and were then used for the final experiments at 400° C.

† This experiment was made with the specimen found to be homogeneous after quenching from 343° C.

Magnesium–Gold.

The equilibrium diagrams of Vogel [5] and Urasow [6] show no solid solution in magnesium, and indicate that pure magnesium forms a eutectic with the compound $AuMg_3$, the eutectic horizontal being at 576° C. In the present work the eutectic horizontal was determined by the quenching method as lying between the limits 575·5° and 580° C., in good agreement with the previous data. For the solid solubility determinations alloys containing 0·21 and 0·33 atomic per cent. of gold were prepared together with others of higher gold content. These were given a preliminary annealing treatment of 2 days at 400° C.

followed by 5 days at 518° C., and were then annealed at 567° for 10 days. After this treatment all the alloys were two-phase. The same specimens were then re-annealed at 459° for 10 days, examined microscopically, and annealed again at 343° C. for a further 8 days. The amounts of the second phase present in the alloys increased slightly, but definitely, after the final annealing treatments at the lower temperatures. From the relative amounts of the second phase in the different alloys, it was concluded that the solid solubility of gold in magnesium is of the order 0·1 atomic per cent. at the eutectic temperature, and decreases to even smaller amounts at lower temperatures. The microscopic method is not well suited to the determination of such very narrow ranges of solid solution in magnesium, and since the relative valency effect is clearly confirmed the subject was not investigated further.

ACKNOWLEDGMENTS.

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THE OLD CHEMISTRY DEPARTMENT,
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ALLOYS OF MAGNESIUM. PART IV.—THE CONSTITUTION OF THE MAGNESIUM-RICH ALLOYS OF MAGNESIUM AND SILVER.*

By R. J. M. PAYNE,† B.Sc., Member, and J. L. HAUGHTON,‡ D.Sc., Member of Council.

Synopsis.

The form of the liquidus and the values obtained for the eutectic and peritectic temperatures by other workers have been checked in magnesium–silver alloys containing up to 60 weight per cent. of silver. It was found that solid magnesium can hold in solution up to 15 weight per cent. of silver at the eutectic temperature, but less than 1 weight per cent. of silver at 200° C. The alloys should, therefore, be capable of precipitation-hardening.

This report forms Part IV [1] of the investigation into the constitution and mechanical properties of magnesium alloys which is being conducted at the National Physical Laboratory, under the direction of Dr. C. H. Desch, F.R.S., for the Metallurgy Research Board of the Department of Scientific and Industrial Research; the three previous reports were published in this *Journal*.[1,2,3]

The addition of small proportions of silver to some magnesium alloys has been found to have good effects, particularly in maintaining the tensile strength at high temperatures, and this research was carried out to confirm and to supplement existing information on the constitution of the binary alloys of magnesium and silver.

The investigation was limited at the outset to include only alloys necessary for checking the composition of the eutectic. The alloy richest in silver which was dealt with contained 59·57 weight per cent. silver.

Previous Work.

The system magnesium–silver has been studied, as a whole or in part, by Schemtschushny, by Smirnow and Kurnakow, and by Saeftel.

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Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, **60** (Advance copy).

Schemtschushny [4] studied the complete range of alloys by the methods of thermal analysis and microscopic examination; his results, up to about 65 per cent. silver, are given in Fig. 1. With regard to the magnesium-rich end of the diagram, he found the eutectic point at 17·3 atomic per cent. silver (= 48·14 weight per cent.) and at 469° C. No evidence was given for the existence of solid solubility.

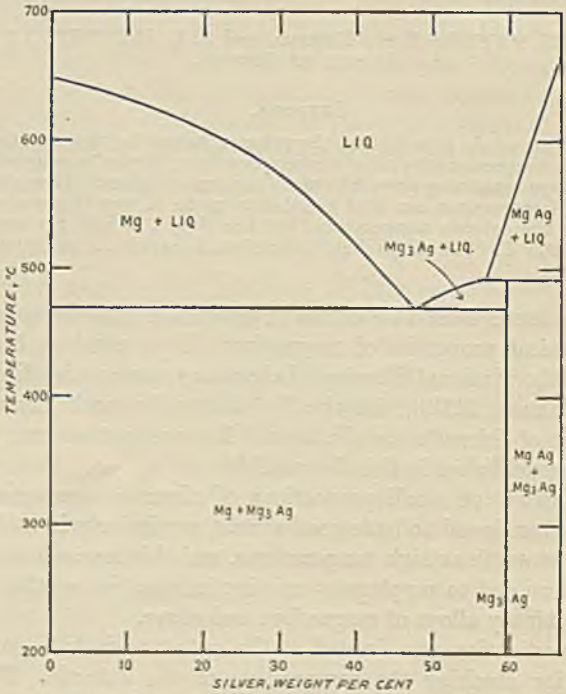

FIG. 1.—Equilibrium Diagram of the Magnesium–Silver Alloys Containing up to 65 Per Cent. Silver. (Schemtschushny.)

Smirnow and Kurnakow [5] studied the electrical properties and hardness of the alloys, and indicated that silver was soluble in solid magnesium to the extent of about 12 weight per cent. silver.

Saeftel [6] confined his investigation to the silver-rich alloys.

PREPARATION OF THE ALLOYS.

The magnesium used contained about 99·95 per cent. magnesium; the impurities being: copper 0·006, iron 0·038, and aluminium 0·010 per cent.

The silver used was supplied by the Sheffield Smelting Company, Ltd., and contained 0·0005 per cent. lead as the only impurity.

The alloys were prepared by melting the magnesium in a stainless-steel crucible under flux, and adding the silver to it. It was found necessary to exercise care to keep the surface of the alloys from contact with the air. When molten the alloys were cast into stainless-iron thermal-curve crucibles and the surface covered with a little flux, composed of magnesium chloride 450, sodium fluoride 30, calcium fluoride 20, and potassium chloride 160 grm. After making the thermal curves, the alloys were carefully remelted in the crucibles and cast into a horizontal chill ingot mould. The ignots thus obtained were analyzed, and were afterwards used to provide samples for microscopic study. Analysis showed that there was no contamination of the alloys by the material of the crucibles.

The figure given by the analysis of the material after melting and casting was considered to be as near an estimate as could be obtained of the composition of the alloy at the time when the curves were being made, in spite of a slight loss of silver which occurred during the re-melting operation. It was thought inadvisable to sample the alloys by taking drillings from the metal while it was still in the crucible, owing to the possibility of segregation.

Thermal Analysis.

Five alloys were examined by the method of thermal analysis to check the accuracy of the work of Schemtschushny. These alloys contained 19·72, 33·31, 42·88, 50·83, and 59·57 per cent. by weight of silver. It was anticipated that with alloys made from two metals of widely different densities, such as magnesium and silver, some trouble due to segregation of the silver compound would be encountered (cf. the report on alloys of magnesium and nickel).[1] The thermal analysis of these five alloys was carried out, therefore, in the apparatus which was used for the study of the magnesium–nickel alloys [7] and which was designed to minimize the effects of segregation on thermal curve samples. As will be seen, the results obtained on stirred specimens agree fairly well with those of Schemtschushny who used no stirring. The employment of the apparatus occasioned little additional trouble whether essential to accuracy or not.

The thermal curves were plotted by means of the deflection potentiometer and inverse-rate recorder. Two heating and two cooling curves were obtained for each alloy, and the close agreement between the temperatures of the liquidus arrest taken from the first and the second curve of each kind indicated that no appreciable change of composition had occurred during the making of the curves. The results are shown in Fig. 2. The liquidus for the hyper-eutectic alloys

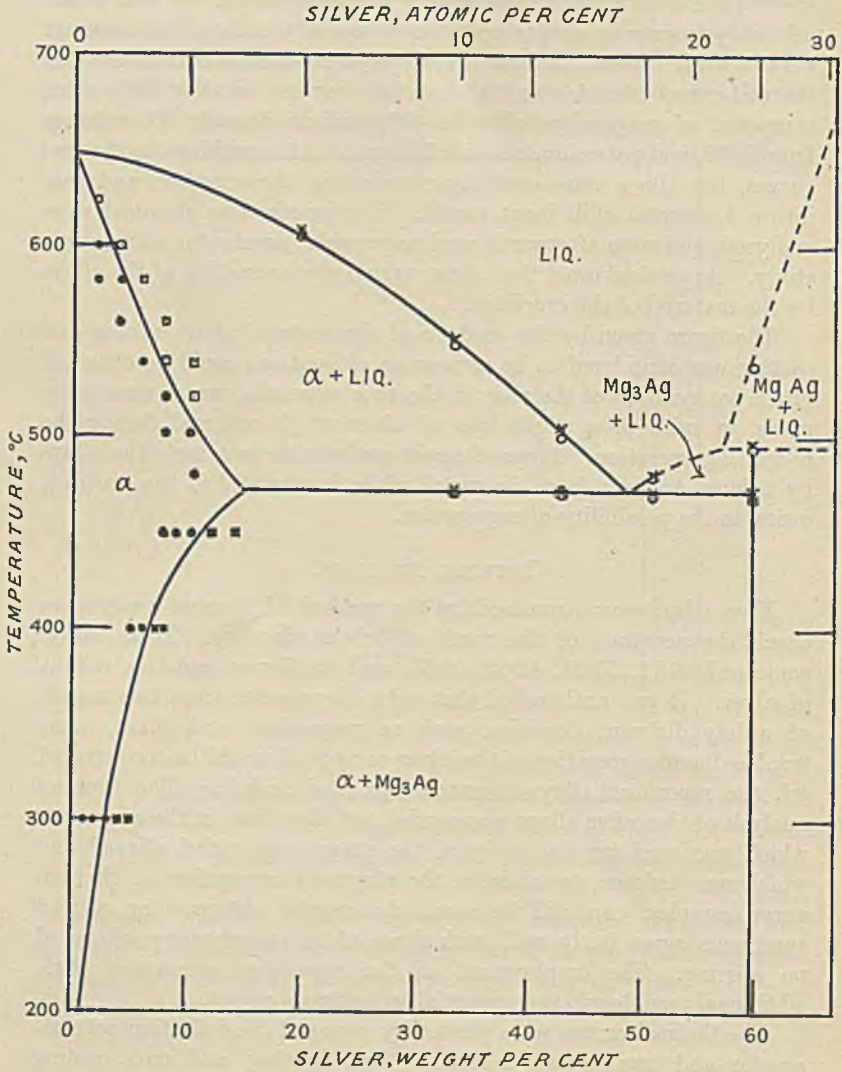

FIG. 2.—Equilibrium Diagram of the Magnesium–Silver Alloys Containing up to 65 Per Cent. Silver. (Haughton and Payne.)

(shown by a broken line) is taken from the work of Schemtschushny. Curves were taken for one alloy containing 19·72 per cent. silver down to room temperature, but no arrests were found below the eutectic temperature.

Microexamination.

The microspecimens were polished by hand with metal polish on velvet. The etching of duplex alloys presented little difficulty, a dilute solution of nitric acid in alcohol staining the α solid solution brown whilst leaving the compound Mg_3Ag unaffected. With homogeneous alloys it was found impossible to etch grain boundaries, all the reagents tried giving only the (often irregular) brown tarnish film. Moreover, reagents such as alcoholic nitric acid were found to be unreliable in action. However, when trying the effect of organic acids it was found that by adding hydrogen peroxide to a concentrated solution of tartaric acid in alcohol, an etching reagent was obtained which gave more consistent results. This mixture also stained the solid solution and enabled any compound present to be distinguished by colour contrast, but it produced a more uniform film than the nitric acid and gave more reproducible results. If no white patches were to be seen when a specimen had been etched with this mixture, properly prepared,* it could safely be concluded that the specimen was homogeneous. It was found afterwards that Smirnow and Kurnakow had recommended the use of a similar reagent (hydrogen peroxide plus alcoholic citric acid) for these alloys. The reagent was also found suitable for detecting fusion spots in those alloys which were used in determining the solidus.

The Liquidus.

The liquidus plotted from these observations will be seen to agree quite well with that of Schemtschushny: perhaps rather surprisingly well in view of the fact that no consideration was given by him to the effects of segregation. No arrest was obtained on heating curves with the alloys containing 59·57 per cent. silver.

The Peritectic Reaction.

The mean of the temperatures of the peritectic reaction obtained on heating and on cooling the only alloy which falls within this range is 495·5 C.

* This reagent was prepared by placing crystals of tartaric acid in excess in industrial methylated spirit and adding hydrogen peroxide (40 vol./c.c.) to the saturated solution in sufficient quantity to produce the film. The action of the combination is complicated by the fact that the hydrogen peroxide itself contains free acid.

The Eutectic.

Although the present work does not really establish the liquidus for hyper-eutectic alloys nor, consequently, the composition of the eutectic alloy, the liquidus point for the only hyper-eutectic alloy examined (50·83 per cent. Ag) fell exactly on the liquidus curve obtained by Schemtschushny. This was considered to be sufficient evidence that the latter was substantially correct over the part under consideration, and, taking this in conjunction with the authors' determination of the hypo-eutectic branch of the liquidus, the eutectic between magnesium and Mg_3Ag was found to occur at 48·6 per cent. Ag and at 472° C. The temperature of the eutectic arrest obtained from the heating curves of the different alloys vary less from a mean value than do those obtained from cooling curves. The maximum difference between the temperatures of the arrests on heating and cooling for any one alloy is 4° C.

The Remaining Branch of the Solidus.

This was determined by quenching samples of alloys which had been annealed at temperatures above that of the eutectic.

Alloys intended for this purpose were first annealed for 6 days at 450° C. to render them homogeneous. The high temperature annealings were (with one exception) carried out in a bath of molten flux, and specimens were held at the required temperature for 15 minutes before quenching. Fusion spots were readily detected microscopically.

The Solid Solubility of Silver in Magnesium.

This was determined by microscopic methods at 450°, 400°, 300°, and 200° C. Preliminary annealings showed that a period of 7 days was sufficient for equilibrium conditions to be attained at 400° C. A period of 4½ days was adjudged to be adequate for annealings carried out at 450° C. Specimens for annealing at 300° and 200° C. were given an initial solution treatment of 7 days at 400° C., and were slowly cooled to the final annealing temperature. All annealings were carried out *in vacuo*.

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[1] J. L. Haughton and R. J. M. Payne, "Alloys of Magnesium Research. Part I.—The Constitution of the Magnesium-Rich Alloys of Magnesium and Nickel," *J. Inst. Metals*, 1934, **54**, 275.

[2] W. E. Prytherch, "Alloys of Magnesium. Part II.—The Mechanical Properties of Some Wrought Magnesium Alloys," *J. Inst. Metals*, 1935, **56**, 133.

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[4] S. F. Schemtschushny, *Z. anorg. Chem.*, 1906, **49**, 400.

[5] W. J. Smirnow and N. S. Kurnakow, *Z. anorg. Chem.*, 1911, **72**, 31.

[6] F. Saeftel, *Z. Metallkunde*, 1927, **19**, 68.

[7] R. J. M. Payne, *J. Sci. Instruments*, 1934, **11**, 90.

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AUTHOR INDEX TO ABSTRACTS.

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 3 OCTOBER 1936 Part 10

I.—PROPERTIES OF METALS

(Continued from pp. 337–346.)

***Contribution to Our Knowledge of the Deformability of Aluminium as a Function of Its Purity.** Werner Helling (*Aluminium*, 1936, **18**, (7), 306–309).—Tables and graphs are given showing the mechanical properties of 99·29–99·977% aluminium after deformations of 0–95% reduction. The results show that the strength increases, the ductility and malleability decrease, and the hardness changes relatively slightly with increasing content of impurities. In general, the higher the content of impurity the greater is the hardening produced by cold-work, and therefore the smaller is the capacity of the metal to undergo severe deformation; this is particularly marked in the twist test, and to a smaller extent in the Erichsen test on half-hard sheet.—A. R. P.

***Electrical Conductivity Measurements on Welded Pure Aluminium.** P. Buser (*Aluminium*, 1936, **18**, (8), 364–366).—Measurements on cast and rolled aluminium show that the theoretical loss in conductivity with an infinite number of welds should not exceed 10%. Tests on actual welded rods showed losses of 4% when the welds were badly made, but a rod 1 m. long with 10 welds showed a loss of conductivity of 1·7% with 99·5% aluminium and 1·1% with 99·9% aluminium. A bus-bar (7 × 10 mm.) of pure aluminium with 11 welds in 3 m. length showed a decrease of 1·2% in conductivity. The increase in resistance produced by welding high-grade aluminium can be kept very small by maintaining a 2 : 1 iron : silicon ratio in the metal, annealing the weld at 300° C. and hammering it whilst hot.—A. R. P.

***The Rate of Crystallization of Aluminium and Gold.** Zofja Beckerówna (*Wiadomości Institutu Metalurgi i Metaloznawstwa* (*Warszawa*), 1934, **1**, (1), 7–10).—[In Polish, with French abstract.] Experiments were carried out to determine the liability of aluminium to supercooling. With aluminium of 99·5% purity the supercooling was 25°. Experiments on the rate of crystallization of aluminium and gold by Czochralski's method showed that aluminium is obtained as a single crystal or polycrystalline rod, depending on the rate of withdrawal from the molten bath; if this rate is less than 40 mm./minute, under certain conditions, single crystals are obtained. This value may be considered the maximum linear rate of crystallization of single crystal aluminium. The relation between direction of growth of the crystal, the temperature of the metal, and the speed of withdrawal of the rod were observed. Impurities decreased the rate of crystallization. Gold single crystals were obtained as dendrites; the maximum rate of linear crystallization was 24 mm./minute.—L. A. O.

Calcium. Alfred Schulze (*Chem.-Zeit.*, 1936, **60**, (72), 733–735).—A review of the preparation, properties, and uses of metallic calcium.—A. R. P.

***The Magnetic Properties of Chromium.** L. F. Bates and A. Baqi (*Proc. Phys. Soc.*, 1936, **48**, (5), 781–794).—Pure chromium was prepared from chromium amalgam, and its magnetic susceptibility was studied over the range 90°–620° K. The mass susceptibility is practically constant over this range, the slight departures from constancy being partly explainable by the effects of thermal expansion on the experimental results. The mean susceptibility is $3{\cdot}08 \times 10^{-6}$ e.m.u. per grm. at room temperature. The effects of

* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

impurities on the magnetic behaviour of chromium, which are very pronounced in the case of samples prepared at lower temperatures, are considered in detail, and the thermal and magnetic data for this element are discussed on the basis of modern theories of paramagnetism of metals.—S. G.

Columbium: From a Laboratory Curiosity to a Widely Used Commercial Product. James H. Critchett (*Trans. Electrochem. Soc.*, 1936, **69**, 62–65; and *Met. Ind.* (*Lond.*), 1936, **48**, (25), 688).—S. G.

***The Density and Coefficient of Expansion of Liquid Gallium Over a Wide Range of Temperature.** W. H. Hoather (*Proc. Phys. Soc.*, 1936, **48**, (5), 699–707; discussion, 707).—Accurate measurements of the density and coeff. of expansion of liquid gallium at 30°–1000° C. were made by a dilatometric method. The temperature was measured with a platinum resistance thermometer. An equation expressing the increase in volume as a function of the temperature was found, and from that equation values were calculated for the coeff. of expansion.—S. G.

***The Electrical Resistance of Gold and Silver at Low Temperatures.** W. J. de Haas and G. J. van den Berg (*Physica*, 1936, **3**, (6), 440–449; and *Comm. K. Onnes Lab. Leiden*, No. **241d**).—[In English.] In agreement with previous measurements (W. J. de Haas, J. de Boer, and G. J. van den Berg, *Met. Abs.*, 1935, **2**, 200), the resistance curves of the gold wires measured show a minimum. The "ideal" resistance calculated by means of Matthiessen's rule, without taking into account the points below the temperature of the minimum, increases proportionally to $T^{4\cdot2}$. The minimum shifts to higher temperatures, when the residual resistance increases. One of the samples of silver also showed a minimum. The "ideal" resistance, calculated in the same way as for gold, increases proportionally to $T^{4\cdot1}$.—S. G.

***The Rate of Crystallization of Lead and of Its Alloy with Mercury.** Irena Makowska (*Wiadomości Institutu Metalurgi i Metaloznawstwa* (*Warszawa*), 1934, **1**, (1), 14–16).—[In Polish, with French abstract.] The critical speeds of crystallization of lead and of lead–mercury alloys were measured by Czochralski's method. For lead, this speed decreased the higher the temperature of the molten metal. The maximum speed obtained at 329° C. was 170 mm./minute. The speed of crystallization of an alloy containing 5% mercury was 100 mm./minute at 309° C.—L. A. O.

***The Recrystallization Diagram of Magnesium.** I. Feldman (*Wiadomości Institutu Metalurgi i Metaloznawstwa* (*Warszawa*), 1934, **1**, (1), 21–25).—[In Polish, with German abstract.] A recrystallization diagram for magnesium was constructed, which does not differ appreciably from earlier diagrams. The reductions of the test-pieces on compression were 3, 6, 9, and 12%; further compression caused fracture. The test-pieces were annealed at various temperatures for 30 minutes; commercial magnesium was used. Test-pieces of chemically-pure, rolled magnesium, subsequently pressed together, showed different properties along different axes after annealing at 500° C. This was considered to be connected with the formation of grain structure due to rolling. A new polishing and etching method for magnesium is described, and information is given on the microscopic structure of the metal.—L. A. O.

***On a New Magnetostriction Experiment [Nickel].** J. L. Snoek (*Physica*, 1936, **3**, (4), 205–206).—[In French.] Perrier's experiment (*Helv. Phys. Acta*, 1935, **8**, 427) depends on a film of oxide, and is a variant of the Wiedemann effect.—S. G.

***The Rate of Crystallization of Tin.** Hanna Jabłońska (*Wiadomości Institutu Metalurgi i Metaloznawstwa* (*Warzsawa*), 1934, **1**, (1), 11–13).—[In Polish, with German abstract.] Tin single-crystals were prepared at 236° and 238° C. by Czochralski's method at different rates. The critical speed was 100–85 mm./minute. The relationship was determined at these temperatures, between

the mean area of cross-section and the mean volume rate of crystallization at the rate of drawing.—L. A. O.

***Measurements of the Latent Heat of Tin in Passing from the Superconductive to the Non-Superconductive State.** W. H. Keesom and P. H. van Laer (*Physica*, 1936, **3**, (6), 371–384; also *Comm. K. Onnes Lab. Leiden*, No. **242a**; and (summary) *Proc. K. Akad. Wet. Amsterdam*, 1936, **39**, (5), 573–574).—[In English.] The results are given of some latent heat measurements on tin in connection with the transition from the superconductive to the non-superconductive state while a constant magnetic field is being applied. The range of the transition region, as demonstrated by the occurrence of the transition heat, agrees almost exactly with what can be calculated in connection with the form of the block. It is concluded that in the transition, if performed in this way, no irreversible heat process takes place. The way in which the magnetic field penetrated the block is considered. Some measurements of the latent heat were made at constant temperature. The results are discussed.—S. G.

***On the Transition of a Tin Sphere from the Non-Superconductive State to the Superconductive State.** W. J. de Haas and O. A. Guinau (*Physica*, 1936, **3**, (6), 534–542; and *Comm. K. Onnes Lab. Leiden*, No. **241b**).—[In English.] Cf. *Met. Abs.*, this vol., p. 240. Two cases were studied in both of which a non-superconductive tin sphere changes into the superconductive state. It is shown that the changes of field strength at these transitions show much analogy with those of the opposite transition; yet the phenomena are certainly not exactly reversible. Lippmann's rule is not valid in the body of the sphere. The currents which should be responsible for the distribution of the field strengths found have directions opposite to those predicted from Lippmann's rule.—S. G.

***Action of a Few Gases on Metallic Titanium and Titanium Nitride.** Masami Kobayashi (*Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, (7), 291–299).—[In Japanese.] Metallic titanium (99·2% Ti) and titanium nitride (19·4% N) were heated at high temperatures in air, oxygen from bomb (containing 97·7% O_2), nitrogen from bomb (containing 1·0% O_2), pure carbon dioxide and pure carbon monoxide. Both titanium and titanium nitride were oxidized to TiO_2 by all these gases except carbon monoxide. It was found that carbon monoxide had no action on titanium nitride at 1000°–1100° C., but there was an action on titanium at 1000°–1180° C.; this was shown by an increase in weight and by total carbon (by the combustion method) in the product.—S. G.

***Tables of the Emissivity of Tungsten as a Function of Wave-Length from 0·23–2·0 μ in the Region of Temperature 1600°–3000° K.** L. S. Ornstein (*Physica*, 1936, **3**, (6), 561–562).—[In English.] Results obtained in 1934 by H. C. Hamaker for the region 0·23–1·00 μ are combined with new results obtained by D. Vermeulen and J. J. Zaalberg van Zelst for the region 0·8–2·0 μ.—S. G.

The Fundamental Equations of Elasticity with Special Reference to the Behaviour of Solids and Liquids under Extreme Pressures. F. D. Murnaghan (*Science*, 1935, **81**, (2105), 422).—Read before National Academy of Sciences, Washington. For media under uniform (hydrostatic) pressure, p, it is found that p is a function of e where $e = (V_0/V)^{2/3} - 1$. Bridgman's results for lithium, sodium, and potassium, tested within the pressure range of 2000 to 20,000 atm., agree with the formula $p = ae + be^2 + ce^3$ to within ½%. The values of the constants were found to be, lithium: $a = 179{\cdot}11 \times 10^3$; $b = 140{\cdot}0 \times 10^3$; $c = 145 \times 10^4$; sodium: $a = 94{\cdot}13 \times 10^3$; $b = 251{\cdot}8 \times 10^3$; $c = 47 \times 10^3$; potassium: $a = 44{\cdot}81 \times 10^3$; $b = 124{\cdot}72 \times 10^3$; $c = 142{\cdot}5 \times 10^3$.—J. S. G. T.

Elastic Structures under Rapidly Applied Loading. A. M. Roberts (*Mech. World*, 1936, **99**, 441–444, 470–471, 495–496, 504).—The stress induced in a structure by sudden application of a load is twice the stress produced by the

same load under static conditions. A detailed account is given of original work to determine what happens for a large number of loading conditions lying between these extremes and actually encountered in practice.—F. J.

Metals under High Pressure. —— (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 125–127).—An account of work by P. W. Bridgman, *Phys. Rev.*, 1935, [ii], **48**, 825; see *Met. Abs.*, this vol., p. 2.—S. G.

***Physical Properties of Surfaces. III.—The Surface Temperature of Sliding Metals. The Temperature of Lubricated Surfaces.** F. P. Bowden and K. E. W. Ridler (*Proc. Roy. Soc.*, 1936, [A], **154**, (883), 640–656).—A method is described for measuring the surface temperature of sliding metals. The temperature reached depends on the load, speed coeff. of friction, and thermal conductivity of the metals, and is in good agreement with theory. With readily fusible metals the surface temperature reached corresponds to the melting point of the metal. With less fusible metals the local surface temperature may exceed 1000° C. Even with lubricated surfaces the temperature (under boundary lubrication conditions) is high, and may exceed 600° C. This high surface temperature will cause a local volatilization and decomposition of the lubricant, and is a cause of the breakdown of the boundary film.—S. G.

Ultrasonic Waves. E. Hiedemann (*Stahl u. Eisen*, 1936, **56**, (21), 600–603). —The special properties of ultrasonic waves which are of use in the iron industry are discussed; they have certain general applications. Ultrasonic waves are defined as those having frequencies greater than 17 kH_z. The production of such waves by magnetostriction, piezoelectric effects, and the Galton pipe are described. The application of the transmission of the waves through large metallic bodies to the detection of cavities or of foreign bodies having different transmission characteristics is discussed. The operation of powerful ultrasonic waves results in correspondingly strong mechanical stresses, which affect the internal crystal structure. Boyle has applied these waves to the degassing of molten metal and Wood and Loomis to the preparation of extremely fine emulsions.—W. A. C. N.

***Collective Electron Specific Heat and Spin Paramagnetism in Metals.** E. C. Stoner (*Proc. Roy. Soc.*, 1936, [A], **154**, (883), 656–678).—Expressions are obtained for the spin paramagnetism and electronic specific heat, and their temperature variation, as dependent on the number of states per unit energy range, $\nu(\epsilon)$, at the top of the Fermi distribution in collective electron energy bands, and the variation of this number with energy, ϵ. A simple method is developed for determining the general character of the effect of interchange interaction. The magnetic properties of the elements in the first two columns of the periodic table, and of the transition elements and rare earths are briefly considered, and also the specific heat of nickel and platinum.—S. G.

†Crystal Structure and Ferromagnetism of the Transition Metals. Ulrich Dehlinger (*Z. Metallkunde*, 1936, **28**, (5), 116–121).—The following aspects of the subject are critically reviewed in the light of recent work: relations between crystal structure and physical properties, electronic principles of ferromagnetism, maximum possible value of the saturation magnetization, actual value for the transition metals and the causes of the difference between the theoretical and actual values for nickel, cobalt, and iron.—A. R. P.

***On the Anti-Ferromagnetic Interchange Problem at Low Temperatures.** L. Hulthén (*Proc. K. Akad. Wet. Amsterdam*, 1936, **39**, (2), 190–200).—[In German.]—S. G.

***Note on Magnetic Hysteresis and Time Effects in Superconductors.** K. Mendelssohn and R. B. Pontius (*Physica*, 1936, **3**, (5), 327–331).—[In English.] Two kinds of magnetic hysteresis in superconductors are distinguishable. The first, which the "freezing in" of a part of the flux of force produces, is ascribed to a superconducting ring-shaped region of high threshold value. This form of hysteresis appears to occur especially in impure polycrystalline

substances. The second type can be considered as a super-cooling of a condition in the other. This hysteresis was observed in single crystals or specimens which were very pure and probably consisted of a few large crystals. In connection with the setting-in of supercooling, the fact seems to be that after a sudden change of the variable condition the establishment of equilibrium between superconducting and non-superconducting material requires considerable time.—S. G.

***On the Theory of Magnetic Fields in Superconductors.** F. London (*Physica*, 1936, **3**, (6), 450–462).—[In German.] Starting from the theory of the pure superconductive state, a theory of the "intermediate" state is developed, the characteristic feature of which is the appearance of a macroscopic magnetic induction B. Considering the surface energy of the pure superconductive state, as postulated by C. J. Gorter and H. London, the energy density of such an "intermediate" state is calculated to be given by $U = -\frac{H^{T^2}}{2} + H_T|B|$. ($|B| \leq H_T$), where H_T is the magnetic threshold value.—S. G.

New Phenomena of Superconductivity. Karl K. Darrow (*Rev. Sci. Instruments*, 1936, [N.S.], **7**, (3), 124–132).—Recent researches on superconductivity are briefly reviewed, especially as regards the influence of magnetic fields on superconductors. The investigations of Meissner, Mendelssohn, Simon, and their collaborators are discussed in particular.—S. G.

Relaxation Phenomena in the Transition from the Superconductive to the Non-Superconductive State. W. H. Keesom and P. H. van Laer (*Proc. K. Akad. Wet. Amsterdam*, 1936, **39**, (2), 148–149).—[In English.] Summary of a paper printed in full elsewhere; see *Met. Abs.*, this vol., p. 245.—S. G.

Approximate Method for Calculating the Work-Function of Metals. E. H. B. Bartelink (*Physica*, 1936, **3**, (4), 193–204).—[In German.] Mathematical.
—S. G.

II.—PROPERTIES OF ALLOYS

(Continued from pp. 346–356.)

***Magnetic Susceptibility and Change of State of the Hardenable System Aluminium–Copper.** Hermann Auer (*Z. Metallkunde*, 1936, **28**, (6), 164–175). —By measuring the paramagnetic susceptibility (χ) of copper–aluminium alloys in the homogeneous quenched state and during ageing it is possible to follow the precipitation of the copper from solid solution and to determine the boundaries of the α-phase at high temperatures and the position of the solidus in hypoeutectic alloys. If the values of χ for various alloys quenched from different temperatures are plotted against the quenching temperature, the curves are all concave to the origin up to the α-phase boundary, then parallel to the axis of temperature up to the solidus, after which they rise almost vertically; the two inflection points thus established for various copper contents are in close agreement with the values for the solid solubility of copper in aluminium and the solidus established by thermal and X-ray analysis. Susceptibility–time of ageing curves for temperatures below 200° C. are straight lines when the time is plotted on a logarithmic scale; this indicates that the increment (dc) in copper-rich constituent is a logarithmic function of the temperature (T) and time of annealing (t) and can be expressed as follows: $\frac{dc}{dt} = A \cdot e^{-\beta/T} \cdot \frac{D}{t}$. The susceptibility is thus proportional to the enrichment of the copper atoms in the lattice, and is not affected by a reconstruction of the lattice after rejection of the copper atoms. The theoretical implications of these results in the study of the mechanism of precipitation from a solid solution are discussed at some length.—A. R. P.

***The Iron–Aluminium–Carbon System.** —— (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 148–149).—Summary of paper by R. Vogel and H. Mäder, *Arch. Eisenhüttenwesen*, 1935–1936, **9**, (7), 333; see *Met. Abs.*, this vol., p. 147.—S. G.

†Aluminium Alloys with a $MgZn_2$ Content as Casting Alloys. H. Schmitt and P. Bergmann (*Aluminium*, 1936, **18**, (8), 370–373).—Casting alloy G 54 with about 9% $MgZn_2$ has a density of 2·84 (chill-cast) or 2·79 (sand-cast), a shrinkage of 1·25%, and tensile strength of 13·6–14·2 (sand-cast), 16·1–17·6 (chill-cast and air-cooled from 300° C.), or 23·8–26 kg./mm.^{2} (heat-hardened) with corresponding Brinell hardness of 75–86, 88–97, and 112–133. The metal gives good castings provided that it is protected from access of gas during melting. Heat-treatment comprises quenching from 500° C. in oil and reheating at 130° C. for 14 hrs. The cast alloy has a good resistance to corrosion, which can be further improved by the Eloxal treatment.—A. R. P.

Recent Scientific and Practical Information on Silumin. E. Scheuer (*Schweiz. Archiv angew. Wiss. Tech.*, 1936, **2**, (4), 85–96).—A general paper giving a summary of data obtained within recent years on the varieties of Silumin, their constitution, casting properties, freedom from gaseous inclusions, the influence of small additions of sodium and lithium and of partial undercooling, the effect of magnesium in giving increased hardness, tensile strength, and fatigue strength.—W. A. C. N.

Castings in Silumin Gamma. G. Sachs and E. Scheuer (*Metal Treatment*, 1936, **2**, (6), 94–98; and *Found. Trade J.*, 1936, **55**, (1048), 218–220).—Abridged translations from *Metallwirtschaft*, 1935, **14**, (47), 937; (48), 972; see *Met. Abs.*, this vol., p. 36.—J. C. C.

Contribution to the Knowledge of Faults in the Working of Hardened Light Metals in Orthopædia. Herm. A. J. Stelljes (*Aluminium*, 1936, **18**, (7), 302–305).—Methods of preventing fracture and corrosion of age-hardened aluminium alloys used in orthopædic apparatus are described.—A. R. P.

***On the Nature of the Peritectic Reaction [in the System Antimony–Tin–Lead], and the Mechanism of the Grain-Refinement Resulting Therefrom.** Keizo Iwasé, Ju-n Asato, and Nobuyuki Nasu (*Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, 213–222 (in Japanese, with English summary); and *Nippon Kwagaku Kwaishi* (*J. Chem. Soc. Japan*), 1936, **57**, (4), 310–317 (in Japanese)).—The nature of the peritectic reaction is studied in the case of the ternary antimony–tin–lead alloys.—S. G.

***The Iron–Chromium Alloy System. The Brittle Non-Magnetic Phase.** Eric R. Jette and Frank Foote (*Metals and Alloys*, 1936, **7**, (8), 207–210).—Very pure alloys with a 1 : 1 atomic ratio of iron and chromium (electrolytic) undergo a transformation at 600°–800° C., the α-phase being converted into the brittle, non-magnetic Σ-phase. This takes place extremely slowly if the alloy is exceedingly pure and thoroughly homogenized by a prolonged anneal at 1300° C., but is considerably accelerated by cold-working after annealing at 1000° C., or by the presence of small quantities of silicon (*e.g.* 0·09%). The Σ-phase has a very complex X-ray structure, and appears to be a secondary solid solution (Hume-Rothery nomenclature).—A. R. P.

Beryllium–Copper–Cobalt Alloys [Trodaloy No. 1]. F. G. Benford (*Met. Ind.* (*Lond.*), 1936, **49**, (2), 40).—A brief description of the properties of Trodaloy No. 1, containing copper 97, beryllium 0·4, cobalt 2·6%. It is cheaper than the binary copper–beryllium alloy, with a superior electrical conductivity, and is suitable for electrodes for welding.—J. E. N.

***Some Metallurgical Properties of Copper–Nickel (70 : 30) Condenser Tubes.** Joseph A. Duma (*J. Amer. Soc. Naval Eng.*, 1936, **48**, (3), 397–410).—Factors affecting the cold-working of 70 : 30 copper–nickel alloy condenser tubes are hardness, which should not have too wide and too fluctuating a range; copper content which should not be in excess of 70% in straight copper–nickel

tubes and should not exceed 80% in tubes containing small proportions of other elements; oxygen content, which, if high, causes embrittlement of the tubes with splitting in belling and expanding operations; and annealing treatment, which should be at 870° C. followed by water quenching. Tubes which have been cold-worked too severely and not annealed are worthless and entirely unsuitable for cold-forming unless annealed. Factors detrimental to the corrosion-resistance of 70 : 30 tubes are the mercurous nitrate test, and boiling salt-water in which tubes having a Brinell hardness of 40–50 show the minimum corrosion.—J. W. D.

***On Hardenable Bronzes with a Copper–Nickel–Tin Basis. I.—Alloys for Sand Castings.** E. Fetz (*Korrosion u. Metallschutz*, 1935, **11**, (10), 217–229).—By an appropriate homogenizing heat-treatment all alloys with up to 10% tin and 40% nickel can be brought into a workable state and then hardened by a precipitation treatment at lower temperatures for a long period. The maximum hardening effect is obtained with a nickel : tin ratio of 1 : 1 by weight, the maximum hardness reached being directly proportional to the degree of supersaturation. Hardening curves are given for a large number of alloys, and a close relationship has been established between the melting-point and the rate of hardening of sufficiently supersaturated α-alloys. Nickel considerably improves the mechanical properties of α-bronze sand-castings, especially the elongation and limit of proportionality; apart from this, substitution of nickel for half the tin has certain economical advantages.

—A. R. P.

***On the Age-Hardening of Brass.** Kanzi Tamaru (*Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, (4), 150–155).—[In Japanese.] See *Met. Abs.*, 1935, **2**, 575.—S. G.

†High Tensile Strength Brasses. A Review of Their Properties and Uses. H. J. Miller (*Met. Ind.* (*Lond.*), 1936, **49**, (9), 201–206; (10), 229–233).—The effects of the addition to the 60 : 40 copper–zinc type of alloy of tin, manganese, iron, aluminium, lead, nickel, and silicon, singly and in groups, on the mechanical and corrosion-resisting properties are reviewed. Many tables of compositions with correlated physical properties are quoted, and there is a useful *bibliography* of 65 references.—J. E. N.

Researches on Tungum Alloy. B. C. Laws (*Shipbuilder*, 1936, **43**, (320), 442–444).—The strength of Tungum—a special brass—and its high resistance to oxidation at normal and elevated temperatures are discussed. Complete tests are given showing its mechanical properties in the soft and hard-rolled, soft-forged, and cold-forged conditions. Laboratory corrosion tests in sea-water show a rapidly diminishing rate of deterioration after 25 days, at which the wastage is 0·000413 grm./cm.^{2}, and an estimated maximum loss of 0·00055 grm./cm.^{2} after 95 days. The breaking stress of Tungum wire rope before and after two years' exposure in wind and sea-water is given as 67·3 and 64·4 tons/in.^{2}. Reference is also made to recent marine uses of Tungum alloy for deck winches, propeller shafts, and propeller brackets.—J. W. D.

***The Rate of Crystallization of Lead and of Its Alloy with Mercury.** (Makowska.) See p. 386.

***Testing the Running Properties of Various New Bearing Metals with Special Reference to the Lead Bearing Metals.** M. von Schwarz [with F. Kolb] (*Z. Metallkunde*, 1936, **28**, (5), 128–130).—The running properties of various lead-base bearing metals containing arsenic, antimony, copper, tin, zinc, cadmium, magnesium, and aluminium have been tested in the bearing testing machine described by S. in *Z.V.d.I.*, 1928, **72**, 1098. The results show that alloys with a relatively high tin content (*e.g.* 20–40%) are inferior to antimonial-lead alloys with a small percentage of copper. Addition of 5% cadmium to the 15% antimony–lead alloy gives an alloy superior to that produced by addition of copper. Zinc, on the other hand, produces a much

harder alloy having a tendency to run hot. Arsenical lead or lead–antimony alloys make satisfactory bearings for certain purposes and a 1·1% magnesium–lead alloy has excellent running properties equal to some of the best high tin-base alloys.—A. R. P.

***White Bearing Metals with a Lead–Tin Base.** (Frhr.) von Göler and F. Scheuer (*Z. Metallkunde*, 1936, **28**, (5), 121–127; (6), 176–179).—Standard German specifications for lead–tin-base bearing metals are discussed, and the properties of such metals containing antimony 13–15·5 and copper 0–5% with varying proportions of tin and lead are shown graphically. The strength increases and the capacity for deformation decreases with increase in the tin content from 0 to 10%; further increase of the tin content to 42% has little effect on the strength of the alloys, but decreases the endurance limit, capacity for deformation, and hardness at elevated temperatures. The presence of small amounts of copper in the alloys has little effect on their mechanical properties, but is beneficial in preventing undue segregation in the castings. The results obtained indicate that alloys with an intermediate tin content are inferior to the lead-rich alloys, as well as being most costly to produce. A *bibliography* of 65 references is appended.—A. R. P.

***The Magnetic Properties of Amalgams.** L. F. Bates and L. C. Tai (*Proc. Phys. Soc.*, 1936, **48**, (5), 795–809).—The magnetic susceptibilities of a series of amalgams of known concentrations of bismuth, chromium, copper, and manganese with mercury were studied at room temperature, the Gouy method of measurement being employed in all cases. A study of the drop-weight method for measuring susceptibilities showed it to be quite unreliable for measurements with amalgams. In dilute amalgams, manganese was found to possess an apparent atomic susceptibility of $+ 13{,}700 \times 10^{-6}$, bismuth $+ 133 \times 10^{-6}$, chromium $+ 23 \times 10^{-6}$, and copper about $- 7{\cdot}3 \times 10^{-6}$ e.m.u. All metals so far studied which are diamagnetic in the solid state are paramagnetic in dilute amalgams, with the possible exception of copper.—S. G.

***Electrolytic Reductions of Organic Compounds at Alloy Cathodes. I.—Reduction of Aliphatic Ketones to Hydrocarbons at Cadmium Amalgams.** Sherlock Swann, Jr., H. J. Read, and F. C. Howard (*Trans. Electrochem. Soc.*, 1936, **69**, 345–350; discussion, 350–352).—See *Met. Abs.*, this vol., p. 200.
—S. G.

***The Magnetic Properties of Hardened Beryllium–Nickel Alloys.** Walther Gerlach (*Z. Metallkunde*, 1936, **28**, (7), 183–188).—Graphs are given showing the relation between the magnetic properties and the temperature for beryllium–nickel alloys in the precipitation-hardened state with and without cold-working in the soft state. Alloys hardened after cold-work, and ordinary hard-drawn alloys show a very steep increase in coercivity at the Curie point, whereas those hardened directly from the quenched state do not show this anomaly; this is considered to be evidence in support of the theory that cold-working of the quenched alloy produces precipitation of part at least of the Be in supersaturated solid solution. The shape of the hysteresis curves above and below the Curie point indicates the probability that the high coercivity is due to a new state of the alloy which is formed by heating at the Curie point.—A. R. P.

Inconel. R. Hanel (*Chem. Fabrik*, 1936, **9**, (19/20), 217–220).—Information is given on the physical properties, heat-resistance, working, heat-treatment, surface treatment, welding, and uses of Inconel.—A. R. P.

***The Volume Changes in the Magnetization [of Iron–Nickel Alloys] and the Invar Alloys.** Ulrich Dehlinger (*Z. Metallkunde*, 1936, **28**, (7), 194–196).—The decrease in volume of iron–nickel alloys which is caused by demagnetization as the temperature approaches the Curie point can be calculated from the exchange integral curve derived from measurements of the saturation moments. These curves show that this decrease in volume is particularly great with the Invar

alloys, and thus an explanation is afforded of the peculiar magnetic properties of these alloys.—A. R. P.

†**Permalloys and Related Ferro-Magnetic Alloys.** J. C. Chaston (*Metal Treatment*, 1936, **2**, (6), 58–66, 71; and *Elect. Communication*, 1936, **15**, (1), 38–51).—A review. The magnetic characteristics of the easily-magnetized group of alloys are outlined and an account is given of the properties of the nickel–iron series after various heat-treatments. The development of the nickel–iron–copper, nickel–iron–molybdenum, nickel–iron–chromium, and more complex alloys, giving high values of resistivity and initial permeability after a simple heat-treatment, and of the nickel–iron–cobalt alloys having a constant value of permeability over a wide range of field strengths, is described, and various theoretical explanations outlined. The effects of crystal size, crystal orientation, cold-working (in the production of "Isoperm"), heat-treatment in a magnetic field, and impurities are also dealt with and reference made to the action of dissolved hydrogen. A *bibliography* of 36 references is appended.—J. C. C.

***The Hardness of Silver–Zinc Alloys in Relation to the Composition.** G. I. Petrenko and E. E. Tscherkaschin (*Z. anorg. Chem.*, 1936, **227**, (4), 415–416).—The Brinell hardness of silver–zinc alloys shows a feeble maximum (35) at 10% zinc in the α-phase and then falls to that of silver (30) at the limiting solid solution. With further addition of zinc there is a steep increase to 95 at the $(\alpha + \beta)$–β boundary, followed by a decrease to 85 at AgZn, a sharp increase to 200 at Ag_2Zn_3, a sharp decrease to 50 at Ag_2Zn_5, and a somewhat less steep decrease to 25 at the δ–$(\delta + \varepsilon)$ boundary. The curve then rises to a maximum of 35 at the $(\delta + \varepsilon)$–ε boundary and finally falls to 25 for pure zinc.—A. R. P.

***Tantalum–Iron Alloys and Tantalum Steels.** R. Genders and R. Harrison (*Iron Steel Inst. Advance Copy*, **1936**, Sept., 37 pp.).—The investigation described comprises a study of the constitution of the tantalum–iron system, an examination of the effect of tantalum and niobium on the structure and properties of carbon steels and of 4% nickel steel, and the development of tantalum as an alloy-steel element in nitriding steels and tool steels. The tantalum–iron system contains two eutectics formed by the compound Fe_2Ta with δ-iron and with tantalum at compositions of approximately 20% and 80% of tantalum, respectively. Below a tantalum content of 6·5% the δ solid solution is resolved, on cooling, into a eutectoid of γ-iron and Fe_2Ta. The solubility in γ-iron decreases with decrease in temperature to the γ-iron $\rightarrow$ α-iron inversion. The solubility of Fe_2Ta in α-iron is small. Tantalum–niobium mild steels conform metallographically with the main features of the pure alloys. The effect of tantalum is to decompose iron carbide, and with excess of tantalum the carbon steels consist essentially of iron–tantalum alloy with tantalum carbide, a compound which is insoluble and inert to heat-treatment. Tantalum–iron alloys nitride readily in dissociated ammonia at 500° C. and give deep penetration with increase in hardness. Extremely high hardness of the order obtainable in commercial nitriding steels is attained, together with deep penetration, by the addition of aluminium to tantalum steels. The reaction between tantalum and iron carbide provides a means of producing steels containing included carbide particles by the use of a high-carbon basis material, such as pig iron. By melting ferro–tantalum in contact with carbon, a product is obtained from which the carbide may be isolated by chemical means for use as an abrasive or sintered cutting material.—S. G.

***Investigations on Zinc–Aluminium Alloys with German Electrolytic Zinc as the Basis Metal and Copper, Magnesium, Nickel, Lithium, and Lead as Addition Metals.** W. Guertler, F. Kleweta, W. Claus, and E. Rickertsen (*Z. Metallkunde*, 1936, **28**, (5), 107–116; (6), 178–179).—Alloys made of German electrolytic zinc (99·98%) and 4% aluminium with and without additions of one or

more of the following: magnesium (0·04 and 0·1), lithium (0·03), copper (0·4 or 2·5), nickel (0·2), lead (0·5%) were cast in sand or chill moulds and their mechanical, ageing, and corrosion-resistant properties examined in the cast state and after rolling; the results are given in a series of tables and briefly discussed. The elongation of cast 4% aluminium–zinc alloys is reduced by additions of magnesium, but this defect is overcome by adding copper. Even traces of lithium reduce the tensile strength, but lithium and magnesium together are not so deleterious as either metal separately. Small quantities of nickel have no effect on the mechanical properties of castings, but if lead is also added the alloy becomes brittle and quite useless. The best alloy for rolling is that containing copper 0·4 and magnesium 0·04%. Ageing tests at 100° C. in air or in air saturated with steam show that none of the addition metals has any effect on the behaviour of the cast alloys, but that copper + magnesium prevent deterioration of the properties of rolled alloys, while lithium and lead cause a rapid breakdown of the alloys under these conditions. The presence of nickel, lithium, or lead in any of the alloys results in severe corrosion in the alternate immersion test in sea-water, the salt-spray test, and the oxidizing salt test. In an appendix the mechanical properties of sand- and chill-cast and rolled alloys with (*a*) 4% aluminium and 0·4 and 2·5% copper, and (*b*) 0·5% aluminium and 2 and 3% copper are shown in tables.—A. R. P.

***The System Iron–Zinc.** Jakob Schramm (*Z. Metallkunde*, 1936, 28, (7), 203–207).—Alloys with up to 20% iron were prepared by special melting methods designed to overcome loss of zinc by volatilization and breakage of the crucible by the high expansion, and alloys with more than 20% iron were prepared by methods of powder metallurgy using carbonyl iron and powdered 15% iron–zinc alloy and eventually homogenizing the alloys by prolonged annealing at 750°–800° C. in evacuated sealed tubes. The system was examined by X-ray, thermal and magnetic analysis, and by micrography. Four phases are stable at room temperature, *viz.*: η (hexagonal zinc-rich solid solution), δ (hexagonal, so-called $FeZn_7$), Γ (cubic, so-called $FeZn_3$ with 52 atoms in the unit cell), γ- and α-iron-rich solid solutions. The solubility of iron in solid zinc is less than 0·03% at the eutectic temperature and the eutectic point is 0·09% iron, 419·4° C. The homogeneous δ-field extends from 6·3 to 11·5% iron at 20° C. and from 5·8 to 11·5% iron at 419° C. The solidus extends in a smooth curve concave to the axis of composition from 419·4° C. at 5·8% iron to the peritectic horizontal at 668° C., 11·5% iron; this horizontal terminates at 20% iron (boundary of the $(\Gamma + \delta)$-field), after which the solidus again rises in a smooth concave curve to meet the peritectic horizontal at 780° C., 27% iron (boundary of the homogeneous Γ-phase). The boundary between the $(\gamma + \Gamma)$ and γ-fields is a straight line joining 54% iron, 780° C. with 73% iron, 623° C. The eutectoid horizontal at 623° C. extends from 80 to 27% iron, and the solid solubility of zinc in iron decreases from 20% at this temperature to 10% at 450° C. and to about 8% at 20° C. The $(\alpha + \gamma)$-field is bounded by concave lines joining 900° C. 100% iron to the 20 and 27% iron points on the eutectoid horizontal. The composition of the δ-phase is not exactly $FeZn_7$ and that of the Γ-phase is neither $FeZn_3$ nor Fe_2Zn_{10}; no alternatives are suggested.—A. R. P.

***Cold Deformation and Recovery of Alloys with an Ordered Atomic Distribution.** O. Dahl (*Z. Metallkunde*, 1936, 28, (5), 133–138).—Curves are given showing the effect of cold-work on the tensile strength and electrical resistance of alloys of the type Ni_3Fe, Ni_3Mn, and $AuCu_3$ in the quenched state (random atomic distribution) and in the tempered state (ordered atomic distribution). These show that cold-working of the tempered alloys leads to the destruction of the ordered atomic distribution; this, however, is not due primarily to work-hardening, since in the case of Ni_3Mn and $AuCu_3$ subsequent annealing at temperatures below the recrystallization temperature restores the super-

structure in the X-ray photograms without removing the work-hardness. In these alloys, therefore, the peculiar properties produced by the superstructure can be combined with the enhanced strength produced by work-hardening. In contrast with the case of precipitation-hardening, the establishment of an ordered structure is not accelerated by prior cold-work. In the case of iron–nickel alloys cold-working the tempered alloys completely removes the drop in electrical resistance produced by the tempering and restores the resistance of the original quenched alloy; subsequent annealing below the recrystallization temperature does not result in a further fall in resistance, but improves the tensile strength. Somewhat similar effects are observed with Ni_3Mn and $NiAu_3$, but neither of these alloys undergoes an increase in specific resistance in the quenched state after cold-working such as occurs with Ni_3Fe. Much further work is considered to be necessary before a satisfactory explanation of these phenomena can be given.—A. R. P.

***The Heat Content and Heat of Formation of Molten Alloys.** Hans Otto von Samson-Himmelstjerna (*Z. Metallkunde*, 1936, **28**, (7), 197–202).—A simple method is described by the aid of which the heat contents of lead–bismuth alloys at 400°, 500°, and 600° C., tin–bismuth, lead–tin, and lead–cadmium alloys at 500° C., lead–silver alloys at 1000° C., and lead–tin–bismuth alloys at 500° C. were determined. From the results obtained the heats of alloying have been calculated, and are shown graphically; the maximum values are at 500° C.: lead–bismuth + 1000, bismuth–tin + 530, lead–tin − 250, lead–cadmium − 480; at 1000° C.: lead–silver − 800 grm.-cal. per grm.-atom. The heats of formation of solid silver–zinc and copper–zinc alloys lie on two straight lines which intersect at compositions correspondiug to Ag_2Zn_3 and Cu_2Zn_3. The heats of formation of liquid alloys have been calculated from the heat contents of molten alloys at 1000° C. and the heats of formation of the solid alloys; the results show that the compounds exist in the liquid state but are strongly dissociated unless an excess of either component is present. The heats of alloying copper–nickel and iron–nickel alloys at 1500° and 1600° C. vary only slightly from the heats of formation of the corresponding solid solutions.—A. R. P.

***Properties of Metallic Solutions.** W. K. Ssementschenko (*Acta Physicochimica U.R.S.S.*, 1935, **3**, (5), 749–752; *Sci. Abs.*, 1936, [A], **39**, 238).—[In English.] The possible chemical interactions in metallic solutions are simpler than those in dielectric solutions and the interatomic forces are more powerful and more homogeneous. A study of metallic solutions is undertaken in order to examine in a simple manner the general relationships of the dissolved state. The influence of the solute on the surface tension is determined by the difference in the values, termed "generalized moments," which are given by the expression $m = \varepsilon z/r$, where ε is $4{\cdot}77 \times 10^{-10}$, z is the valency of the ion, and r is the radius of the ion; the ultimate value of the surface activity G is given by $G = RT\delta/1000 \times e^{\gamma(m_0 - m_1)}$, where γ is a constant depending on the properties of the solvent and the temperature, and m_0 and m_1 are generalized moments of the solvent and the solute. From measurements on a number of amalgams, it is shown that the physico-chemical properties of a metal may be characterized by its generalized moments.—S. G.

***On Gerlach's Thermomagnetic Electromotive Force in Some Ferromagnetic Alloys.** Norie Yamanaka (*Sci. Rep. Tôhoku Imp. Univ.*, 1936, [i], **25**, (2), 174–183).—[In English.] Y. found that the thermomagnetic e.m.f., discovered by W. Gerlach (*Met. Abs.* (*J. Inst. Metals*), 1931, **47**, 197), appears not only in nickel and iron but also in other ferromagnetic alloys. Its dependence on the magnetic field and on the temperature gradient is fully investigated.—S. G.

***Treatment in a Temperature Gradient.** —— (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 133–134).—A review of work by G. Tammann and W. Boehme, *Z. anorg. Chem.*, 1935, **226**, 87; see *Met. Abs.*, this vol., p. 116.—L. O.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

(Continued from pp. 357–361.)

Metallographic Applications of Electron Beams and Their Physical Basis. I. R. Piontelli (*Metallurgia italiana*, 1935, **27**, (12), 817–825; *C.Abs.*, 1936, **30**, 4390).—First of a series of articles on electronic waves. The theory of wave mechanics is briefly reviewed, and the electron microscope and its use are described.—S. G.

***On the Anodic Behaviour of Copper in Aqueous Solutions of Orthophosphoric Acid.** P. A. Jacquet (*Trans. Electrochem. Soc.*, 1936, **69**, 629–650; discussion, 651–655).—See *Met. Abs.*, this vol., p. 117.—S. G.

***The Recrystallization Diagram of Magnesium.** (Feldman.) See p. 386.

Industrial Applications of X-Ray Diffraction Analysis. Victor Hicks (*Instruments*, 1936, **9**, (5), 133–136).—S. G.

***The Structure of Some Metallic Deposits on a Copper Single Crystal as Determined by Electron Diffraction.** William Cochrane (*Proc. Phys. Soc.*, 1936, **48**, (5), 723–735).—Nickel, copper, zinc, cadmium, silver, chromium, and cobalt were deposited electrolytically on etched copper single crystals, and the structures of the deposits were found by electron diffraction. At small current densities the layers are oriented except in the case of zinc and cadmium. The nickel and cobalt deposits give patterns containing additional spots, lines, and irrational spots. It is shown that these are accounted for by assuming the occurrence of repeated twinning on (111) planes, the additional spots being due to twinned lattices and the lines due to twin planes. The twin planes must be considered separately and not simply as part of the lattices on either side of them. The twin sheets of lattice thus formed give rise to the irrational spots observed. Finally, a discussion is given of the factors determining the orientation of a layer of metal on the copper crystal.—S. G.

***The Atomic Factor of Zinc.** Cecilia Mossin Kotin and José Losada (*Anales soc. españ. fís. quím.*, 1935, **33**, 597–601; *C. Abs.*, 1936, **30**, 347).—The scattering factor of zinc is determined, the first obtained from an element belonging to the hexagonal system. The photometric method was used to measure the intensities of the reflections, according to which a curve of relative values is drawn. Intensity of the (101) reflection of zinc is compared to the intensity of the (200) reflection of NaCl, and for $\sin\theta/\lambda = 0{\cdot}234$, $f_{Zn} = 31{\cdot}0$, which permitted the curve of the experimental values to be drawn. Comparison of the experimental with the theoretical curve shows a greater slope for the first, and two undulations not found in the latter.—S. G.

***On the Energy States of Valency Electrons in Some Metals. I.—The Crystal Energy Levels of Valency Electrons in Zinc (1).** Mituru Satô (*Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, (3), 92–98).—[In Japanese.] From the analysis of *L*-non-diagram lines α', α'', β', β'' and of Osgood's lines the crystal energy levels of valency electrons in zinc were sought and 6 levels were determined. The energy distances from *K*-level were found to be 710·920, 711·040, 711·280, 711·297, 711·335, and 711·859 in Rydberg units. The wave-lengths corresponding to these values of $\frac{\nu}{R}$ were compared with the curves of *K*-absorption edges for zinc and zinc oxide due to Barnes (*Phys. Rev.*, 1933, [ii], **44**, 141), and some other levels, the existence of which was still in doubt, were determined.—S. G.

***On the Energy States of Valency Electrons in Some Metals. I.—The Absolute Values of Some X-Ray Levels of Zinc (2).** Mituru Satô (*Sci. Rep. Tôhoku Imp. Univ.*, 1936, [i], **25**, (2), 197–201 (in English); and *Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, (4), 142–145 (in Japanese)).—From the

L-non-diagram lines and K-absorption edges for the solid and for the vapour of zinc, the absolute value of the K-term was determined and found to be $K = 711{\cdot}880$ Rydberg units; consequently, the absolute values of the crystal levels of the valency electrons in zinc were determined and found to be $E_1 = 0{\cdot}960$, $E_2 = 0{\cdot}840$, $E_3 = 0{\cdot}600$, $E_4 = 0{\cdot}581$, $E_5 = 0{\cdot}545$, and $E_6 = 0{\cdot}021$, all expressed in the crystal Rydberg unit.—S. G.

Simple Numerical Relationships in Binary Eutectic Mixtures. D. Stockdale (*Trans. Faraday Soc.*, 1936, **32**, (9), 1365–1369).—S. has recently shown that there is a reasonable probability that the constituents of metal eutectics are present in a comparatively simple ratio; in the present paper he shows that this is also true for eutectics of salt mixtures with a common ion as well as for many eutectics between organic compounds.—A. R. P.

***Theoretical Diffraction Patterns Corresponding to Some Simple Types of Molecular Arrangement in Liquids.** J. A. Prins and H. Petersen (*Physica*, 1936, **3**, (3), 147–153).—[In English.] Theoretical diffraction patterns are computed for liquid arrangements corresponding to the following structures: A cubic and hexagonal close-packed, B body-centred cubic, C simple cubic, and D diamond structure. The co-ordination numbers of these structures are, respectively, for A 12; for B 8; for C 6; for D 4. Experimental confirmation is found by taking for: A inert gases and mercury, B alkali metals, C antimony, D silica and water. The method of "smearing out" an ideal structure (crystal lattice) to get the corresponding liquid arrangement is taken from a one-dimensional model.—S. G.

***X-Ray Investigation of the Mechanism of Transformation of Face-Centred Cubic into the Hexagonal Close-Packed Lattice.** Zenji Nishiyama (*Kinzoku no Kenkyu* (*J. Study Metals*), 1936, **13**, (7), 300–310).—[In Japanese.] The mechanism of transformation of face-centred cubic (γ) into hexagonal close-packed (h) lattice was studied for an alloy of cobalt containing 30% nickel. It was found that the change takes place in such a manner that $\gamma(111)//h\,(0001)$ and $\gamma[\bar{2}11]//h\,[1\bar{1}00]$.—S. G.

The Thermal Theory of Cathodic Sputtering. II.—The Elementary Process. N. D. Morgulis (*Zhurnal experimentalnoy i teoreticheskoy Fiziki* (*J. Exper. and Theoret. Physics*), 1935, **5**, 588–594).—Cf. *Met. Abs.*, 1935, **2**, 101. The theory of Hippel is further developed.—S. G.

IV.—CORROSION

(Continued from pp. 361–363.)

***Contribution to the Problem of the Formation of Protective Films on Aluminium Containing Magnesium.** Werner Geller (*Z. Metallkunde*, 1936, **28**, (7), 192–194).—The resistance of aluminium and its alloys to corrosion depends chiefly on the formation of a passive film and its continuous renewal during the slow dissolution of the metal. From determinations of the rate of dissolution of 99·98% aluminium with additions of 0·05–1% of magnesium in dilute reversed *aqua regia* and in 0·001, 0·01, and 20% sodium hydroxide solution, it is shown that magnesium increases the resistance of aluminium to attack by acids and very dilute alkalis, but at alkali concentrations above a certain critical value and above a critical temperature it produces rupture of the passive film and prevents healing so that a violent attack on the metal takes place.—A. R. P.

***Oxide Film of Alloys Containing Small Percentages of Aluminium.** Ichiro Iitaka and Shizuo Miyake (*Proc. Imp. Acad.* (*Tokyo*), 1935, **11**, (7), 256–257).—[In English.] See *Met. Abs.*, this vol., p. 42.—S. G.

†**The Corrosion of Hardenable Aluminium and Magnesium Alloys.** E. Söhnchen (*Korrosion u. Metallschutz*, 1936, **12**, (3), 41–46).—A lecture delivered

at the Winter Meeting of the Foundry Institute of the Technische Hochschule, Aachen. Recent work is reviewed.—A. R. P.

Corrosion of Precipitation-Hardened Alloys by Acids. ——(*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 143–144).—A brief, critical summary of papers by G. Tammann and W. Boehme, *Z. anorg. Chem.*, 1935, **226**, 82, and E. Söhnchen, *Korrosion u. Metallschutz*, 1936, **12**, 41; see *Met. Abs.*, this vol., p. 120, and preceding abstract.—L. A. O.

Corrosion. X.—Copper Alloys: Constitution and Properties. —— (*Silk and Rayon*, 1935, **9**, 582, 584, 589).—The nature and properties of the brasses are discussed, with particular reference to corrosion.—S. G.

***Corrosion Tests on Tinplate.** G. Gire (*15me. Congr. chim. indust.* (*Bruxelles, 1935*), **1936**, 783–800; *C. Abs.*, 1936, **30**, 5547).—A study of the attack of various grades of tinplate by acetic acid solutions of various concentrations. For each grade of tinplate the solution of tin and iron as a function of time was measured on the same sample; this permitted the drawing of curves which, if the weight of the tin coating was taken into consideration, showed the relative resistance of the samples to this type of corrosion. Similar tests were carried out by producing electrolytic sulphurization of the sample by electrolysis in a sodium sulphide solution with the tinplate to be corroded as anode; from the total sulphur deposited and its distribution as SnS and FeS, corrosion curves were obtained which characterized the resistance of the various samples to this type of corrosion. The results obtained in the two series were absolutely comparable and brought out the primary importance of the condition of the tinplate in its resistance to corrosion. Microscopic examination of the samples confirmed this.—S. G.

Facts About Dye Vats. G. H. Pearson (*Textile Mercury*, 1935, **92**, (2412), 509. **Corrosion-Resisting Dye Vats.** G. H. Pearson (*Textile Mercury*, 1935, **93**, (2420), 129; *J. Textile Inst.*, 1935, **26**, A528).—The advantages of stainless steel and other resistant metals over wood in the construction of dye vats is stressed and details are given of suitable thicknesses and methods of bracing and jointing.—S. G.

Diseases of Steels and Other Metals and Their Prevention. Robert S. Williams (*Amer. Dyestuff Reporter*, 1935, **24**, (13), 369–373; *J. Textile Inst.*, 1935, **26**, A528).—A general discussion of the causes and prevention of corrosion and the corrosion-resistance of various metals and alloys suitable for dyeing machinery.—S. G.

***Corrosion from Products of Combustion of Gas. III.—Tube Experiments (Contd.).** —— (*Light Metals Rev.*, 1936, **2**, (14), 236–237).—Cf. *Met. Abs.*, 1935, **2**, 693. From 36th Report of the Joint Research Committee of the Institution of Gas Engineers and Leeds University, November 1935.—S. G.

Report of the Corrosion Committee [of the Electrochemical Society]. —— (*Trans. Electrochem. Soc.*, 1936, **69**, 11–18).—A review of the literature for the year 1935.—S. G.

The Aims and Work of the Central Corrosion Committee. W. F. J. M. Krul (*Chem. Weekblad*, 1936, **33**, (22), 331).—Read before the Delft Chemical Society. Describes the work of the Committee, which has published the following papers: "The Electrochemical Theory of Corrosion," by H. van der Veen; "First Report of Corrosion Committee II for the Study of the Corrosion of Pipes by Soil"; "Second Report of Corrosion Committee II for the Study of the Corrosion of Pipes by Soil: Corrosion of Tubes"; "Report of Corrosion Committee III for the Study of the Corrosion of Cables by Soils."—L. A. O.

†**Deformation, Heat-Treatment, Solubility [of Non-Ferrous Metals].** First Report of the Committee on Non-Ferrous Metals (*Korrosion u. Metallschutz*, 1936, **12**, (1/2), 2–28).—From a critical review of recent work on the corrosion of non-ferrous metals, especially zinc–copper and nickel–copper alloys, and

the effect thereon of heat and mechanical treatment the following conclusions are reached: The solubility of non-ferrous alloys in acids is determined by the structure and by the previous mechanical and thermal history. The solubility relations of cold-worked, single-phase copper alloys containing nickel or zinc follow Heyn's law and the course of the solubility curve is not affected by the degree of drawing or by regular intermediate anneals. From the position of the solubility curve, and making certain assumptions, conclusions can be reached as to the method of manufacture of the material. The metals are more soluble in the hard-drawn state than after annealing, but the effect of the size of the recrystallized grain varies in different cases. The transition from the elastic to the plastic state produces no change in the solubility. The conductivity of the alloys increases during the course of dissolution, whilst the solution potential is decreased due to preferential dissolution of the zinc. Increasing cold-work increases the solution potential of the less noble constituent. A *bibliography* of 118 references is appended.
—A. R. P.

***Corrosion of [Metals] after Permanent and Elastic Deformation.** W. O. Kroenig and A. J. Boulitschewa (*Korrosion u. Metallschutz*, 1936, **12**, (4), 73–81).—Corrosion tests on aluminium, Duralumin, brass, and iron subjected to stresses below the limit of proportionality while in the corroding medium show that the electrode potential of the metal becomes less noble with increasing stress, *i.e.* that the rate of corrosion increases as the internal stress is increased, sometimes as much as tenfold. Under elastic stresses iron, brass, and, especially, Duralumin display a tendency to intercrystalline corrosion which is not shown by the unstressed metal. Aluminium plastically deformed by rolling shows an electrode potential which decreases with increase in the degree of reduction, while the loss in weight by corrosion simultaneously increases.—A. R. P.

***[Observations] on the Course of Corrosion [of Metals] by Means of Contact Photographs.** N. Goldowski (*Korrosion u. Metallschutz*, 1936, **12**, (5/6), 108–118).—The specimens used are thin sheets bent round and welded into the form of hollow cylinders, the test is carried out by rotating the cylinders in aerated sea-water for definite periods, and the course of corrosion is followed by taking contact prints which show up the perforations produced by corrosion. The necessary apparatus is described and illustrated. Qualitative information is afforded by the test on the questions of where and how corrosion occurs and the course it takes, *i.e.* whether it spreads out from certain points or whether new corrosion centres are being continuously formed. Quantitative results may be obtained by determining loss in weight and the changes which occur in the number and size of the perforations with the progress of corrosion. Tests on a number of metals have shown that two types of corrosion may occur: (*a*) characterized principally by increase in the number of corrosion centres according to an exponential law; (*b*) characterized by an increase in the size of the corroded places according to a parabolic law. Examples of both are described and discussed.—A. R. P.

***On the Explanation of the "Positive Difference Effect."** W. O. Kroenig and V. N. Uspenskaya (*Korrosion u. Metallschutz*, 1936, **12**, (5/6), 123–131).—When sheets of zinc and platinum are electrically connected and immersed in dilute acid the rate of evolution of hydrogen from the zinc is less than when the platinum is absent. From experiments on other couples and on 3 and 4 different metals in contact, it is shown that this so-called "positive difference effect" is not due to a change in the resistance of local elements in the less noble metal and cannot be explained by Akimov's theory of polyelectrode elements, but is due to ennoblement of the anode potential brought about by the increased anodic charge produced by coupling the metal with a new external cathode. This increase in anode potential is favoured by an increase in the ionic concen-

tration of the dissolving metal in the anodic regions produced by intensified dissolution of the anode.—A. R. P.

***On the Theory of Corrosion Phenomena. IV.—On the Application of the Theory of Local Elements to the Problem of Corrosion.** W. J. Müller (*Korrosion u. Metallschutz*, 1936, **12**, (5/6), 132–138).—According to M.'s theory of coating passivity the resistance (r_p) in the pores of the film and the resistance (r_s) of the film itself may be calculated from the expressions $r_p = r \cdot C$ and $r_s = r(1 - C)$, where $r = r_s + r_p$ and $C = K'F/[K'F + K(F_0 - F)]$; F is the total surface covered by the film, $(F_0 - F)$ the area of the pores, K' the specific conductivity of the substance forming the film, and K the conductivity of the electrolyte in the pores. The potential E of the corroded electrode is $E_{metal} - (E_{film} - E_{metal})C$, and at approximately constant rate of attack the mean current density of the local elements is 96,540 a/mt, where a is the amount of hydrogen evolved or metal dissolved, m is the chemical equivalent of the hydrogen or metal, and t is the time in seconds. By the use of these expressions it is possible to explain all the phenomena of corrosion which cannot be explained by the simple local element theory. Thus, the resistance of the film on pure aluminium is very high and therefore the metal is little attacked in dilute acids, but if metallic impurities are included in the film its resistance decreases considerably, *e.g.* to $\frac{1}{1000}$ part of the normal resistance when the metal contains 0·5% of impurities. In concentrated acids the film which is normally 10^{-4} cm. thick is partly dissolved and the conductivity of the film increases considerably owing to the action of the embedded metal particles. Calculations based on a value of K of 10^{-4} ohm^{-1} show that the free pore space in dilute acids is of the order of 10^{-4} cm.^{2}/cm.^{2}. The extremely rapid increase in the rate of dissolution of impure aluminium with increasing concentration of acid is thus explained by a thousand-fold decrease in the thickness of the film and a ten-fold increase in the size of the pores. Similar explanations are given of phenomena observed in the dissolution of iron and zinc in acids. —A. R. P.

***On the Influence of Oxygen on the Potential of Local Cathodes.** M. Straumanis (*Korrosion u. Metallschutz*, 1936, **12**, (5/6), 148–154).—Local elements to which free access of oxygen is restricted have, in ordinary cases of corrosion, only a small e.m.f. which, however, increases rapidly when oxygen is allowed free access, owing to the potential of the hydrogen-charged cathodes being rendered more positive while that of the anode remains unchanged. This effect is due to the action $2H + O = H_2O$ which is accelerated to a greater or less extent by the cathode material, as shown by experiments on platinum, nickel, and iron. The current density–potential curve of a local cathode in a hydrogen atmosphere can be considered as an overvoltage curve; if, therefore, the potential becomes more positive by the introduction of oxygen, there must be a reduction in the overvoltage caused by the diffusion of oxygen. Hence, a minimum overvoltage of hydrogen does not exist and the occurrence of an overvoltage is connected with the presence of a finite current density, which is always present in local elements. Corrosion by uneven aeration can be explained on similar lines.—A. R. P.

†The Corrosion of Metals. A Review of Recent Work. T. P. Hoar (*Met. Ind. (Lond.)*, 1936, **49**, (8), 177–203; (9), 207–212).—An excellent review of modern corrosion research. The composition, formation, breakdown, and repair of the primary oxide film on metals is discussed. The mechanism of attack in neutral electrolytes, the influence of oxygen and salt concentration, and the influence of corrosion products are clearly stated. Much work has been done recently on atmospheric corrosion and protective coatings. A *bibliography* of 140 references is given.—J. E. N.

Prevention of Corrosion by Additions to the Corroding Medium. Erich Rabald (*Chem. Fabrik*, 1936, **9**, (27/28), 310–311).—The nature and function of

inhibitors is discussed, with special reference to their use in acid pickling solutions.—A. R. P.

***Organic Inhibitors in Corrosion.** Charles A. Mann (*Trans. Electrochem. Soc.*, 1936, **69**, 115–128; discussion, 128–129).—See *Met. Abs.*, this vol., p. 205.—S. G.

Inhibitors—Safe and Dangerous. Ulick R. Evans (*Trans. Electrochem. Soc.*, 1936, **69**, 213–227; discussion, 227–231; and *Metal Cleaning and Finishing*, 1936, **8**, (5), 255–260; (6), 313–318).—See *Met. Abs.*, this vol., p. 121.—S. G.

The Electrochemical Mechanism of Corrosion. U. R. Evans (*Korrosion u. Metallschutz*, 1936, **12**, (5/6), 105–107).—The subject is discussed with especial reference to the nature of the corrosion of iron.—A. R. P.

The Modern Theory of Corrosion. W. W. Kittelberger (*Amer. Paint J.*, 1936, **20**, (June 29), 23–24, 26, 54, 56, 58; *C. Abs.*, 1936, **30**, 5547).—A brief discussion of the electrochemical theory of corrosion: corrosion by direct chemical attack, in the absence of water and in the presence of water, and corrosion in which the dissolving metal displaces hydrogen from solution, with visible evolution of hydrogen and without visible evolution of hydrogen because the discharge potential of hydrogen on the cathode surfaces is greater than the potential of the dissolving metal. Anodic control and the use of chemical inhibitors are discussed.—S. G.

The Meaning and Mechanism of Metallic Corrosion. W. J. Müller (*Internat. Rohstoffwirtschaft*, 1936, **1**, (1)).—The importance of corrosion from the economic point of view, and its electrochemical aspects particularly with reference to the passivity phenomenon, is discussed.—L. A. O.

Corrosion. Henry G. Pike (*Modern Eng.*, 1936, **10**, (6), 284–286).—A popular account of the operation of electrode potential, differential aeration, and protective films.—H. W. G. H.

Modifications in the Standardized Apparatus for Corrosion Testing by Means of a Saline Mist. Jean Lucas (*15me. Congr. chim. indust. (Bruxelles, 1935)*, **1936**, 1–5; *C. Abs.*, 1936, **30**, 5547).—A description of modifications that have been made in the design of the apparatus standardized by the (French) Committee on the Study of Corrosion of Metallurgical Products Required for Aeronautics. These have resulted in maintaining the volume and concentration of the saline bath constant, and in imposing on the saline mist in the testing box a definite path that places the test-pieces under more stable experimental conditions.—S. G.

***On the Influence of the Working Conditions on the Results of the Mylius Test.** W. Deisinger (*Aluminium*, 1936, **18**, (6), 249–252).—The effects of acid concentration, initial temperature, room temperature, heat insulation, and surface condition of the specimen on the results obtained in the Mylius test are described. The standard acid used contains 100 grm. of hydrogen chloride per litre; a deviation of 1% in the concentration of the acid results in a deviation of ± 20% in the Mylius number (total increase in temperature divided by the time of reaction in seconds, *i.e.* ° C./second). Variations of ± 2° C. from the standard initial temperature (20° C.) result in deviations of ± 6%; if the room temperature is 15° C. the results may be 9% low and if it is 20° C. as much as 32% high. With specimens covered with the usual oxide film the results are about 12% lower than with similar specimens from which the film has been removed by pickling. Under the best conditions the Mylius number is reproducible within ± 7·5%.—A. R. P.

***Contribution to the Problem of the Measurement of Corrosion in Metals—Experience with Tödt's Residual Current on Lead.** H. Nitschmann (*Schweiz. Arch. angew. Wiss. Tech.*, 1936, **2**, (4), 96–103).—After general remarks on corrosion measurement, Tödt's method is described. Results with lead are summarized and given a theoretical interpretation. They suggest the possibility of conditions in which the method may give accurate results.

Tödt's determination is based on the assumption that the strength of the current in a local electrolytic cell on the surface of a metal in a corrosive medium is proportional to the number of metallic ions going into solution. It is confined to circumstances where oxygen is active but no gaseous hydrogen is evolved. In a final summary, N. discusses the limitations of the method.
—W. A. C. N.

Modern Microscope Technique in the Service of Corrosion Research. A. Kufferath (*Korrosion u. Metallschutz*, 1936, **12**, (7), 171–175).—Some types of modern microscopes are described, and photomicrographs of corrosion phenomena on galvanized iron, brass, Duralumin, and tinplate are shown and discussed.—A. R. P.

Standard Corrosion Tests. —— (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 130–131).—A critical review of paper by O. Bauer, *Z. Metallkunde*, 1936, **28**, (2), 25; see *Met. Abs.*, this vol., p. 159.—L. A. O.

V.—PROTECTION

(Continued from pp. 363–366.)

Modern Electrochemical Processes for Protecting [Aluminium] Metal Surfaces and Their Physicochemical Principles. Hellmut Fischer (*Angew. Chem.*, 1936, **49**, (30), 493–498; and *Light Metals Research*, 1936, **5**, (2), 28–43).—A lecture. Methods of plating and anodizing aluminium are critically reviewed and their principles explained.—A. R. P.

***On the M.B.V. Treatment of Age-Hardened Aluminium Alloys [Pantal].** W. Geller (*Aluminium*, 1936, **18**, (6), 252).—Direct M.B.V. treatment of age-hardened Pantal sheets affords little or no protection against salt-spray corrosion; adequate protection is obtained, however, if the metal is first pickled for 2 minutes in 20% sodium hydroxide solution to remove the oxide film produced by the heat-treatment processes, then given the M.B.V. treatment, and finally boiled for 10 minutes in water.—A. R. P.

Improved Coatings for Duralumin. Herbert Chase (*Aero Digest*, 1936, **28**, 40; *C. Abs.*, 1936, **30**, 5819).—A brief *résumé* of the results of some tests on anodic film, paint, lacquer, and pigment coatings on Duralumin. Specimens remained in 20% salt-spray without failure for more than 4700 hrs. The best coating is a paint vehicle with aluminium powder.—S. G.

Tinning as a Protective Means. A. D. Tikhonov and N. I. Kovalev (*Voprosui Pitaniya*, 1935, **4**, (6), 88–91; *C. Abs.*, 1936, **30**, 5165).—The temperature coeff. for the solubility of tin is 41 from 15° to 70°, while for iron it is 28·5 and for copper it is almost unity. The e.m.f.–temperature relation of the systems tin–iron and tin–copper are also unfavourable.—S. G.

***A Study of the Origin of Porosity in the Tin Coating of Tinplate.** A. W. Hothersall and J. C. Prytherch (*J. Iron Steel Inst.*, 1936, **133**, 205–219; discussion, 220–224; and *Tech. Publ. Internat. Tin Res. Develop. Council, Series A*, 1936, (**38**), 15 pp.).—See *Met. Abs.*, this vol., p. 160.—S. G.

***Influence of Working Conditions on the Porosity of Tinplate.** W. E. Hoare (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 115–116).—A review abstract and discussion of a paper by Fritz Peter and Georges Le Gal, *Arch. Eisenhüttenwesen*, 1935–1936, **9**, 285–287; see *Met. Abs.*, this vol., p. 10.
—L. A. O.

***Methods of Detinning Tinplate for Examination of the Thickness and Continuity of the Alloy Layer.** A. W. Hothersall and W. N. Bradshaw (*J. Iron Steel Inst.*, 1936, **133**, 225–234; discussion, 235–237; and *Tech. Publ. Internat. Tin Res. Develop. Council, Series A*, 1936, (**37**), 10 pp.).—See *Met. Abs.*, this vol., p. 160.—S. G.

Corrosion After Pickling Major Source of Galvanizer's Dross. Wallace G. Imhoff (*Iron Age*, 1936, **138**, (6), 34–37, 95–97).—See also *Met. Abs.*, this vol., pp. 43 and 122. Describes the reducing action of molten zinc in galvanizing baths on roll scale. There is a marked resistance of roll scale to the action of molten zinc at ordinary galvanizing bath temperatures. The results of an experimental investigation into this action showed: (1) that corrosion after pickling is a major source of iron to form galvanizer's dross; (2) that material that has not been fully pickled must remain in the bath longer, and that the bath temperature must be higher to break down the scale and iron oxides, and give a perfect coating; (3) that dross crystals were produced in the tests, showing conclusively that the iron from corrosion is the same as that in the dross crystals.—J. H. W.

Alloys in the Zinc Bath. G. A. Brayton (*J. Amer. Zinc Inst.*, 1936, **17**, 87–91; discussion, 91–93; and *Amer. Metal Market*, 1936, **43**, (81), 3, 6; and (summary) *Met. Ind.* (*N.Y.*), 1936, **34**, (8) 336–337).—Lead and iron, unwanted impurities, are both detrimental to the working of the bath and to the adherence and corrosion-resistance of the coating. Tin is sometimes added to the bath and, in amounts of 1–2%, increases workability of the bath, uniformity and adherence of the coating. Antimony reduces the corrosion-resistance and adherence of the coating. Antimony, tin, aluminium, and cadmium, used in dip galvanizing, produce very attractive spangles. Aluminium produces black dirt spots in sheet galvanizing. Additions do not materially reduce the dross production.—H. W. G. H.

***The Action of Zinc on Iron and on Ordinary and Special Steels.** I. Musatti and A. La Falce (*Rev. Mét.*, 1936, **33**, (6), 362–370).—See *Met. Abs.*, this vol., p. 364.—S. G.

Testing for Adherence of Galvanized Coatings. B. P. Finkbone (*J. Amer. Zinc Inst.*, 1936, **17**, 76–79; discussion, 79–80; and *Amer. Metal Market*, 1936, **43**, (79), 6; (80), 3).—Attempts to cover the question of adherence in various specifications are reviewed, together with some suggested workshop and laboratory tests. It is concluded that no completely satisfactory test is yet available. Such a test should take into consideration: (1) severity of forming for a given weight of coating; (2) elongation of material to be expected from the forming to be done; (3) speed of deformation; (4) variation in weight of coating; and its development would only be made possible by co-operation of producers and consumers.—H. W. G. H.

***[Testing the] Zinc Coating on Galvanized Iron.** (Nash.) See p. 409.

Sweating of [Galvanized] Sheets in Transit and Storage. G. C. Bartells (*J. Amer. Zinc Inst.*, 1936, **17**, 98–102; discussion, 102–105).—A non-technical plea for greater care in packing and storing galvanized sheets. Many cases are quoted of the extremely poor behaviour in service of sheets which had been stored in piles horizontally, so that sweating and corrosion of the coating by the moisture had taken place before the sheets had been put to use. It is vigorously emphasized that galvanized sheets should be stored vertically in such a way that there is free circulation of air between them.—H. W. G. H.

Treatment of Galvanized Sheets for Painting. J. L. Schueler (*J. Amer. Zinc Inst.*, 1936, **17**, 93–96; discussion, 96–98; also *Amer. Metal Market*, 1936, **43**, (78), 5, 6; *Met. Ind.* (*N.Y.*), 1936, **34**, (6), 215–216; and *Metal Cleaning and Finishing*, 1936, **8**, (6), 339–342).—The matte-surfaced, non-spangled galvannealed sheet can be painted without special treatment, but the ordinary, smooth, spangled sheet must be treated in one of the following ways (in order of recommendation): (1) atmospheric "weathering"; (2) scouring with fine abrasive; (3) chemical etching with copper sulphate, antimony chloride, or (with great care) acids.—H. W. G. H.

†Protective Finishes on Zinc. S. W. K. Morgan and L. A. J. Lodder (*J. Electroplaters' Tech. Soc.*, 1936, **11**, 87–100; and *Aluminium and Non-Ferrous Rev.*, 1936, **1**, (6), 232–237).—See *Met. Abs.*, this vol., p. 365.—J. C. C.

Critical Considerations on Metal Coatings. J. Biert (*Schweiz. Arch. angew. Wiss. Tech.*, 1936, **2**, (1), 22–28).—A summary of the various methods of producing metal coverings—electrolysis, chemical deposition, spraying, high-temperature diffusion—followed by a discussion of their several advantages and their separate applications in the case of individual metals.
—W. A. C. N.

***The Density of Sprayed Metal Coatings.** Theo Everts (*Z. Metallkunde*, 1936, **28**, (6), 143–150; and (summary) *Light Metals Research*, 1936, **5**, (1), 5–7).—By the term "density" as applied to spray coatings is meant the resistance of the coating to penetration by a gas or liquid. The "density number" (D) represents the number of seconds required to spray a layer 0·5 mm. thick on 1 cm.^{2} of surface by 1 litre of gas at 15° C. and 1 atmosphere pressure. The values of D for copper, aluminium, zinc, lead, Monel metal, iron, and V2A steel are shown graphically as functions of the film thickness, distance of the pistol from the work, oxygen pressure, hydrogen pressure, air pressure, and rate of feed of the wire to the pistol. The minimum thickness at which the deposited layer just shows small pores when removed from the work and held to the light varies with the metal and spraying conditions; for a spray distance of 20 cm. and the optimum conditions as regards oxygen, hydrogen, and air pressures, rate of feed, and thickness of wire the minimum "sound" layer is for zinc 0·09, lead 0·13, copper 0·18, aluminium, Monel metal, and iron 0·22, and V2A steel 0·26 mm. Annealing, burnishing, polishing, and hammering the sprayed deposits results in considerable closing-up of the pores, and this improves the resistance to corrosion and protective properties of the films.—A. R. P.

Making Airplanes Weatherproof.—III. W. Hardy (*Paint Manuf.*, 1936, **6**, (6), 173–175, 182; *C. Abs.*, 1936, **30**, 5546).—A discussion of the cleaning and preparation of the surface to receive the protective coating. Anodic pickling of steel with a bath containing 1 part sulphuric acid, 2 parts water, and 3 oz. (75 grm.) potassium bichromate per gall. of acid bath is effected by making the part to be cleaned the anode, lead or graphite cathodes being used with a current density of approx. 100 amp. per sq. ft. of surface. This treatment makes steel, subsequently to be electroplated with cadmium or zinc, immune from hydrogen embrittlement. Cleansing processes include: (1) washing in hot water and drying; (2) removal of grease by organic solvents, either liquid or vapour; (3) a hot caustic solution followed by washing and drying; (4) scratch-brushing, scrubbing with pumice powder or polishing with emery, and (5) shot-blasting. Anodic oxidation is confined to aluminium and aluminium-rich alloys. The surfaces of magnesium-rich alloys are of a peculiar greasy nature. To permit adherence of organic protective materials these alloys must be pickled in an acid or alkaline bath and then treated in a chromate bath. Metal coatings on steel are discussed; none of the processes is satisfactory for all steel parts. The final treatments for aluminium and magnesium alloys are discussed.—S. G.

VI.—ELECTRODEPOSITION

(Continued from pp. 366–368.)

***Aluminium-Plating Nickelin.** N. N. Gratzianskii (*Mem. Inst. Chem. Ukrain. Acad. Sci.*, 1935, **2**, 141–148; *C. Abs.*, 1936, **30**, 5504).—[In Ukrainian.] Nickelin is aluminium plated by electrodeposition from fused $AlCl_3$–NaCl (1 amp./dm.^{2} at 250° C.), and a surface oxide layer is formed on the aluminium. The product so obtained has a lower conductivity than unplated Nickelin, and is 4–6 times as resistant to oxidation at higher temperatures.—S. G.

***Aluminium Plating from Organic Baths.** R. D. Blue and F. C. Mathers (*Trans. Electrochem. Soc.*, 1936, **69**, 519–527; discussion, 533–534; also *Met. Ind.* (*Lond.*), 1936, **49**, (5), 115–117; and (summary) *Light Metals Research*, 1936, **5**, (1), 18–19).—See *Met. Abs.*, this vol., p. 208.—S. G.

***Electrodeposition of Aluminium Alloys.** R. D. Blue and F. C. Mathers (*Trans. Electrochem. Soc.*, 1936, **69**, 529–533; discussion, 533–534).—See *Met. Abs.*, this vol., p. 208.—S. G.

***On the Critical Current Density in the Deposition of Chromium.** N. D. Biriukoff (*Korrosion u. Metallschutz*, 1936, **12**, (7), 165–171).—In the electrodeposition of chromium from chromic acid baths there is a critical current density below which no deposition occurs; this critical value is increased with rise in temperature owing to the greater rapidity with which the chromous oxide layer on the cathode is reoxidized. Addition of potassium dichromate, potassium bisulphate, potassium sulphate, chromic sulphate, sulphuric acid, or chromic hydroxide has no effect on the critical current density at any temperature, but lead chromate reduces it and chromic chromate increases it rapidly if this is produced by melting chromic acid or by boiling aqueous chromic acid with chromic hydroxide. In all cases a steep increase in critical current density occurs if the solution is heated above 25°–27° C.—A. R. P.

Behaviour of Inner Surfaces of Chromium-Plated and Nitride-Hardened Gun Barrels. O. Macchia (*Industria meccanica*, 1934, **16**, 180–182, 267–269; *C. Abs.*, 1936, **30**, 5541).—Neither chromium plating nor nitride hardening possesses advantages over the usual treatment.—S. G.

Determination of Trivalent Chromium in Chromium Plating Baths.—II. (Young.) See p. 409.

***Theory and Practice of Chromium Plating.—I–II.** N. D. Biriukov, S. P. Makarieva, and A. A. Timochin (*Korrosion u. Metallschutz*, 1935, **11**, (8), 172–179; (9), 193–201).—See *Met. Abs.*, 1935, **2**, 62.—S. G.

***Theory and Practice of Chromium Plating.—III–IV.** N. D. Biriukov and S. P. Makarieva (*Korrosion u. Metallschutz*, 1935, **11**, (12), 265–278).—See *Met. Abs.*, 1935, **2**, 235.—S. G.

***Alkaline Plating Baths Containing Ethanolamines. III.—Cobalt Plating from Triethanolamine Solutions.** C. J. Brockman and J. P. Nowlen (*Trans. Electrochem. Soc.*, 1936, **69**, 550–551; discussion, 556).—See *Met. Abs.*, this vol., p. 124.—S. G.

***Alkaline Plating Baths Containing Ethanolamines. I.—Copper Plating from Triethanolamine Solutions.** C. J. Brockman and A. L. Brewer (*Trans. Electrochem. Soc.*, 1936, **69**, 535–540; discussion, 556).—See *Met. Abs.*, this vol., p. 124.—S. G.

***The Electrodeposition of Manganese from Aqueous Solutions. I.—Chloride Electrolytes.** Harold H. Oaks and W. E. Bradt (*Trans. Electrochem. Soc.*, 1936, **69**, 567–583; discussion, 583–584).—See *Met. Abs.*, this vol., p. 162.—S. G.

***The Electrodeposition of Molybdenum from Aqueous Solutions.** Wm. P. Price and O. W. Brown (*Electrochem. Soc. Preprint*, **1936**, Oct., 67–73).—Yntema (*J. Amer. Chem. Soc.*, 1932, **34**, 3775) claimed that molybdenum can be deposited from an aqueous bath, but P. and B. were unable to obtain bright deposits by the method he outlined. Steel-grey deposits of molybdenum may be obtained from a solution prepared by the electrolytic reduction of molybdic acid anhydride dissolved in sulphuric acid (sp. gr. 1·450) using platinum electrodes, the ratio of molybdic to sulphuric acid being 2 grm. to 5 c.c., and reducing until 4 amp.-hr. of current per grm. has passed through the solution. The best conditions for plating are a current density of 36 amp./dm.^{2} and a temperature of 50°–55° C. The use of a stirrer does not aid the preparation of the solution or in obtaining deposits. No addition agent was found that would aid in obtaining bright deposits or in the formation of the plating baths.
—S. G.

†Some Properties of Nickel Electrodeposits. Robert J. McKay (*Metals and Alloys*, 1936, **7**, (8), 193–198; and (abbreviated) *Metal Cleaning and Finishing*, 1936, **8**, (8), 461–464, 468).—The effects of p_H, current density, temperature, cleanliness, and composition on the operation of nickel-plating solutions are briefly discussed and the properties of the product briefly summarized from a review of recent literature (13 references).—A. R. P.

The Ballay Process of Nickel Plating Aluminium and Aluminium Alloys. —— (*Z. Metall- u. Schmuckwaren-Fabrikation sowie Verchromung*, 1936, **17**, (5), 14; *Light Metals Research*, 1936, **5**, (1), 12).—The Ballay process consists in producing on the aluminium articles to be plated thin iron deposits to which nickel adheres very well. The articles are cleaned and degreased and are then immersed for about 30 seconds in a boiling solution of the composition: water 10 litres, hydrochloric acid 0·1 litre, saturated ferric chloride 0·3 litre (45° Bé.). After treatment in this bath the articles are rinsed with a large volume of water and are then ready for nickel plating.—L. A. O.

***Alkaline Plating Baths Containing Ethanolamines. II.—A Study of Baths Containing Triethanolamine for the Direct Nickel Plating of Zinc.** C. J. Brockman and J. P. Nowlen (*Trans. Electrochem. Soc.*, 1936, **69**, 541–549; discussion, 556).—See *Met. Abs.*, this vol., p. 124.—S. G.

***Nickel-Cobalt Alloy Plating from Acid Sulphate Solution.** C. B. F. Young and N. A. Gould (*Trans. Electrochem. Soc.*, 1936, **69**, 585–594; discussion, 594–597).—See *Met. Abs.*, this vol., p. 209.—S. G.

***Alkaline Plating Baths Containing Ethanolamines. IV.—The Deposition of Nickel-Cobalt Alloys from Solutions Containing Triethanolamine.** C. J. Brockman and J. P. Nowlen (*Trans. Electrochem. Soc.*, 1936, **69**, 553–555; discussion, 556).—See *Met. Abs.*, this vol., p. 210.—S. G.

***The Simultaneous Electrodeposition of Thallium and Zinc.** W. George Parks and I. Milton Le Baron (*Trans. Electrochem. Soc.*, 1936, **69**, 599–610).—See *Met. Abs.*, this vol., p. 163.—S. G.

Zinc Plating. C. M. Hoff (*Met. Ind.* (*N.Y.*), 1936, **34**, (3), 99–100; and *Aluminium and Non-Ferrous Rev.*, 1936, **1**, (8), 383–384).—Read before the Master Electroplaters' Institute of the Mid-West. See *Met. Abs.*, this vol., p. 44.—J. C. C.

***Electroplating of Aluminium and Its Alloys with Zinc, Cadmium, Copper, Nickel, and Chromium.** V. I. Lainer and S. I. Orlova (*Light Metals Rev.*, 1936, **2**, (18), 308–314; and *Aluminium and Non-Ferrous Rev.*, 1936, **1**, (8), 381–383).—From *Legkie Metally* (*Light Metals*), **1936**, (2), 22–33. —J. C. C.

***Effect of the Electrolyte Resistance on the Shape of the Electric Lines of Force.** A. Glazunov and A. Kukla (*15me. Congr. chim. indust.* (*Bruxelles, 1935*), **1936**, 1023–1028; *C. Abs.*, 1936, **30**, 5507).—Copper sulphate solutions of different concentrations were electrolyzed, using a copper plate as anode, and a 3 mm.-diam. silver wire placed perpendicular to the surface of the anode as cathode. During electrolysis the current density at different points on the surface of the cathode varied according to their distance from the anode. The thickness of the layer of copper deposited was proportional to the current density, being thinnest at the points farthest away from the anode. With increase in the resistance of the electrolyte, the difference in thickness of the copper coating as a function of the distance from the anode also increases. The thickness of the copper coating was determined by Glazunov's method (anodic solution) at each cm. of length of the cathode.—S. G.

†The Rôle of Films in the Electrodeposition of Metals.—I–II. R. Meyer (*Metals and Alloys*, 1936, **7**, (5), 123–126; (6), 155–159).—A correlated abstract with a *bibliography* of 153 references covering the following aspects of the subject: preferential solution films, deposited films, passive films, polishing films, structure of thin films on various substrates, relation between structure

of the basis metal and that of electrodeposits on it, films on electroplated and unplated metals.—A. R. P.

Control of the Cathodic Film in Metallic Deposition. C. G. Fink (*Chim. et Ind.*, 1936, **35**, (5), 1028–1033).—Investigations into the effects on the nature of the cathodic film of the following are summarized: speed of revolving cathode, current density, p_H values, and cathodic distance. It is recommended that for adherent, compact deposits the cathode should revolve at high speed.
—W. A. C. N.

Bright Deposits. H. Krause (*Illust. Zeit. Blechindustrie*, 1936, **65**, (31), 921–922).—The embrittlement of metallic deposits, often associated with the use of colloidal "buffers," may be obviated by the substitution of solutions of metallic salts and other materials. Suitable additions of this type are recommended for producing bright deposits of copper (cyanide or acid bath), brass, zinc, tin (acid bath), and nickel.—P. M. C. R.

The Use of Inhibitors (with Special Reference to Antimony) in the Selective Removal of Metallic Coatings and Rust. S. G. Clarke (*Trans. Electrochem. Soc.*, 1936, **69**, 131–142; discussion, 142–144).—See *Met. Abs.*, this vol., p. 164.
—S. G.

Trends in the Plating Industries. C. L. Mantell (*Metal Cleaning and Finishing*, 1936, **8**, (8), 469–471).—A brief review of recent progress in the plating of zinc, cadmium, nickel, and cobalt, and in the anodizing of aluminium.
—A. R. P.

VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY
(Other than Electrodeposition.)

(Continued from p. 368.)

The Engineering Development of Electrochemistry and Electrometallurgy. Paul Bunet (*Elect. Eng.*, 1935, **54**, (12), 1320–1331).—S. G.

***The Potential of the Antimony Electrode.** Henry Vogels (*15me. Congr. chim. indust.* (*Bruxelles, 1935*), **1936**, 1068–1073; *C. Abs.*, 1936, **30**, 5486).—V. puts forward a hypothesis, confirmed by numerous experiments, tending to assimilate the function $e_{Sb} = f(p_H)$ to a system of 3 straight lines obeying the standard equations and standardized by $de/dp_H = 0{\cdot}058$ v. at 20° C. The ordinates of these straight lines differ from one another by 0·40 v. at the origin and can be assigned to 3 successive states of oxidation of antimony in solution. The state of minimum oxidation must be represented by the ion SbO^-, as shown by measurements of decomposition tension. This hypothesis can be applied also to explain Wulff's recent experiments.—S. G.

***Drop of Potential in the Metallic Electrodes of Certain Electrolytic Cells.** Chester Snow (*J. Res. Nat. Bur. Stand.*, 1936, **17**, (1), 101–124; and *Research Paper* No. 905).—In certain precise measurements of electrolytic resistance of solutions, the platinum electrodes are necessarily very thin so that the drop in potential in them cannot be neglected. Formulæ are obtained for this drop in the case of two types of cylindrical shells: one in which the current is axial, and the other partly axial and partly radial. The potential admits of accurate evaluation in the first case, and the results obtained confirm the method outlined for the treatment of a general shape of cell.—S. G.

***Observations on the Rare Earths. XLII.—Studies in the Electrolytic Reduction of Ytterbium.** D. W. Pearce and C. R. Naeser, with B. S. Hopkins (*Trans. Electrochem. Soc.*, 1936, **69**, 557–564; discussion, 564–565).—The strong reducing influence which surrounds the cathode during an ordinary electrolysis of an aqueous solution was used to reduce ytterbium from its usual trivalent condition to the corresponding bivalent salt. In the reduced condition ytterbium resembled barium and was precipitated as the sulphate.

The precipitated $YbSO_4$ was obtained in a stable, crystalline form which was shown to be almost free from other rare earths. The precipitation was not complete, about 10% of the ytterbium being left in solution presumably in an equilibrium between Yb^{+++} and Yb^{++}. No conditions were found which were effective in removing all of the ytterbium in one process from the neighbouring elements thulium and lutecium.—S. G.

***The Effect of Certain Impurities in the Forming Acid on Plate Forming Time [in the Manufacture of Accumulators].** J. E. Hatfield and H. R. Harner (*Trans. Electrochem. Soc.*, 1936, **69**, 243–251; discussion, 251–253).—See *Met. Abs.*, this volume, p. 164.—S. G.

VIII.—REFINING

(Continued from p. 265.)

The Rhokana Copper Refinery. Archer E. Wheeler and Henry Y. Eagle (*Met. Ind. (Lond.)*, 1936, **48**, (18), 505–510).—See *Met. Abs.*, this vol., p. 210.—J. E. N.

IX.—ANALYSIS

(Continued from pp. 368–370.)

Quantitative Spectral Analysis. Raymond Breckpot (*15me. Congr. chim. indust. (Bruxelles, 1935)*, **1936**, 988–1002; *C. Abs.*, 1936, **30**, 5523).—A general discussion and review of the possibilities at the present time of the application of quantitative spectral analysis to problems of particular interest to the metallurgical industry, together with examples of the analysis of finished products, metals, ores, and intermediate products, and an explanation of the function of the spectrographic laboratory in the regular control of manufacture.—S. G.

Quantitative Spectrographic Analysis with the Logarithmic Sector. O. Fagioli (*Nuovo cimento*, 1936, **13**, (3), 111–130; *C. Abs.*, 1936, **30**, 5523).—A discussion of the advantages and disadvantages of the logarithmic sector as used in measuring the intensity of lines in the spectrographic analysis of alloys. The means of excitation used with the sector influences the result. It is proposed that the type of excitation be characterized by simultaneous values of effective and maximum current in the spark.—S. G.

Spectrum Analysis. F. Twyman (*Nature*, 1935, **136**, (3441), 609).—T. suggests the use of the term "spectrochemical analysis" to denote the analysis of materials by their spectra, and that "spectrum analysis" be used for the analysis of the structure of a spectrum.—S. G.

***A Simple Method for Differentiating the Alloys of Aluminium.** —— (*Rev. Fonderie moderne*, **1936**, (Jan. 2), 28–31.—Extract from *Rev. Aluminium*, 1935, **12**, 3009–3013; see *Met. Abs.*, 1935, **2**, 610, 707.—J. E. N.

***A New Specific Reaction for Bismuth by the Formation of Bismuthous Oxide.** N. A. Tananaeff (*Z. anal. Chem.*, 1936, **105**, (11/12), 419–422).—Addition of the feebly acid Bi solution to a concentrated solution of $K_4Mn(CN)_6$ produces a black precipitate of BiO. The test is very sensitive and is not given by any other metal.—A. R. P.

***The Quantitative Separation of Aluminium and Beryllium.** J. Dewar and P. A. Gardiner (*Analyst*, 1936, **61**, (725), 536–538).—The neutral chloride solution (50 c.c.) of the metals is treated with 6*N*-NaOH until the precipitate of hydroxides just redissolves, diluted with hot water to 400 c.c., and well stirred at 100° C. for 40 minutes to complete the precipitation of $Be(OH)_2$. If a preliminary test shows that the Al present is more than the Be a known

amount of Be is added to the test to make the Be at least equal to the Al; under these conditions accurate results are obtained in one operation.
—A. R. P.

†**On the Problem of the Separation of Bismuth from Lead and Copper.** E. A. Ostroumov (*Z. anal. Chem.*, 1936, **106**, (1/2), 36–45).—See *Met. Abs.*, this vol., p. 165.—A. R. P.

***Determination of Arsenic and Antimony in Hard Lead.** J. Willemme (*15me. Congr. chim. indust. (Bruxelles, 1935)*, **1936**, 166–171; *C. Abs.*, 1936, **30**, 5525).—The standard methods are briefly reviewed, with indications of their disadvantages. A new method is presented and described in detail. It consists essentially in reducing arsenic and antimonic compounds to the arsenious and antimonious states by means of Sn in conc. H_2SO_4 and titrating As + Sb by means of standard $KBrO_3$; reducing a second portion of the sample by means of MeOH followed by Na_2SO_3, boiling off the methyl arsenious ester, titrating Sb with $KBrO_3$, and obtaining As by difference. The method is considered to possess satisfactory accuracy and to be rapid and relatively inexpensive.—S. G.

Determination of Trivalent Chromium in Chromium Plating Baths.—II. Philena Young (*Metal Cleaning and Finishing*, 1936, **8**, (8), 473–476).—Cf. *Met. Abs.*, this vol., p. 369. Full details of the method previously recommended are given.—A. R. P.

***The Rapid Photometric Determination of Copper in Brass and Related Alloys.** Kurt Dietrich and Karl Schmitt (*Z. anal. Chem.*, 1936, **106**, (1/2), 23–27, 80).—The alloy (1 grm.) is dissolved in 15 c.c. of 1 : 1 HNO_3, the solution is diluted to 1 litre and 50 c.c. are treated with 10 c.c. of 10% NH_4OH diluted to 100 c.c. and transferred to the photometer. The extinction coefficient is then determined with an appropriate light filter and the corresponding Cu content read from a predetermined curve prepared from standard Cu solutions.
—A. R. P.

***[Testing the] Zinc Coating on Galvanized Iron.** J. A. D. Nash (*Analyst*, 1936, **61**, (725), 540–541).—Comparative tests were made with the following methods: (*a*) HCl–$SbCl_3$, (*b*) basic $(CH_3CO_2)_2Pb$, (*c*) H_2SO_4–$KMnO_4$. The average results obtained over a large sheet of galvanized Fe are approximately the same for all methods. Method (*a*) is the quickest, but (*c*) is probably the most accurate and the most economical in chemicals. Method (*c*) is carried out as follows: a weighed sample is immersed in 10% H_2SO_4 in contact with a piece of Pt foil: when the violent action ceases, the Fe is removed, washed, dried and weighed, and the Fe in the solution determined by titration with 0·1*N*-$KMnO_4$, the difference between the original weight and the sum of the two Fe weights is taken as Zn. Commercial coatings vary considerably over the standard sheet.—A. R. P.

X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

(Continued from p. 370.)

The Radio-Metallographic Laboratory of the Issy-les-Moulineaux Testing Station of the (French) Air Ministry. F. Fournier (*Bull. Soc. Franç. Elect.*, 1936, [v], **6**, (68), 805–825).—An illustrated description of the equipment and work of a modern laboratory designed for X-ray and spectrographic examination of metals.—P. M. C. R.

Metals and Minerals Polishing Machine. —— (*Instruments*, 1936, **9**, (8), 216).—A six-holder polishing machine is illustrated and briefly described.
—J. C. C.

***A Laboratory Vacuum Casting Furnace.** Jack H. Scaff and Earle E. Schumacher (*Metals and Alloys*, 1936, **7**, (8), 204–206).—An induction type of furnace for melting copper, nickel, iron, and their alloys in vacuum (0·01–0·08 mm. pressure) is described with reference to a detailed diagram. The furnace is mounted on a tilting table with an Albarene stone base to act as insulator for the electrical connections. Inside the copper induction coil is a silica tube open only at the upper end which is connected with a suitable cement and clamps to a steel head carrying a horizontal steel side tube containing the mould. The silica tube contains a silica or other refractory crucible mounted in a protective alundum tube supported on a heat insulating material. The top of the silica tube and the steel head are water-cooled and the joint is protected inside from radiant heat by a nickel reflector. All joints are fitted with matched flanges and lead gaskets, concentric rings being forced into the lead to ensure air-tightness by means of the screws which hold the flanges in place. The vacuum outfit consists of a 4-stage Gaede mercury pump backed by a 2-stage oil pump and provided with a liquid air trap in the flexible corrugated copper pipe-line joining it to the furnace.—A. R. P.

A New Dilatometer for the Thermal Analysis of Metals. A. Metz (*Giesserei*, 1936, **23**, (18), 437–439).—The new Leitz universal dilatometer is illustrated and its operation described with reference to electrical and optical diagrams. The instrument registers curves automatically and the specimens (rods up to 50 mm. long and 5 mm. in diam.) can be heated *in vacuo* or in any desired gas.—A. R. P.

Determination of Friction Coefficients Should be Standardized. A. W. Burwell and J. A. Camelford (*Nat. Petrol. News*, 1936, **28**, (33), 38–39).—An illustrated description is given of an apparatus for the determination of coeffs. of kinetic friction. It is claimed that bearing temperatures can be controlled over a wide range, alteration of bearing pressure can be effected without shock, oil supply is easily controlled, and the apparatus is sufficiently delicate to measure friction drag. The moving surface is of steel; any type of bearing metal may be used. Alternatively the properties of different lubricants can be compared with respect to a given type of bearing. A bronze containing 2% of lead is used in standardizations of this type.—P. M. C. R.

An Apparatus for Determining the Area of Cross-Section of Zinc Single Crystals. Aluin W. Hanson (*Rev. Sci. Instruments*, 1936, [N.S.], **7**, (2), 109).—S. G.

***A Machine for Drawing Pole-Figures Directly from X-Ray Diffraction Patterns.** Dan McLachlan, Jr. (*Rev. Sci. Instruments*, 1936, [N.S.], **7**, (8), 301–304).—A full description of the machine. See *Met. Abs.*, this vol., p. 370.—S. G.

Practical Apparatus for Spectroscopic Chemical Analysis. John L. Gring and George L. Clark (*Rev. Sci. Instruments*, 1936, [N.S.], **7**, (8), 305–306).—S. G.

A Rotating Sector for Quantitative Analytical Spectrography. M. F. Hasler and R. W. Lindhurst (*Rev. Sci. Instruments*, 1936, [N.S.], **7**, (3), 137–139).—A new sector arrangement is devised for use with a grating spectrograph in quantitative spectrography, which obviates certain difficulties encountered with the logarithmic sector.—S. G.

New Spectral Photometer for Quantitative Spectral Analysis. H. Moritz (*Germanskaja Tehnika* (*Z. deut. Technik*), 1936, **15**, (5), 96–98).—[In Russian.] Description of a Zeiss spectral photometer.—N. A.

XI.—PHYSICAL AND MECHANICAL TESTING, INSPECTION AND RADIOLOGY

(Continued from pp. 370-373.)

***A Method of Magnetic Testing for Sheet Material.** S. L. Burgwin (*Rev. Sci. Instruments*, 1936, [N.S.], 7, (7), 272–277).—A method for building up a magnetic circuit from strips of sheet material has been found which permits testing for magnetic properties either by d.c. or a.c. methods, just as in the case of the ring sample but without the inconvenience of the ring sample in that a permanently wound test frame similar to that of the Epstein test may be used. In testing this magnetic circuit, an approximate method may be used where simplicity of testing and consistency of results are required rather than absolute accuracy. For tests where absolute accuracy is more important than simplicity of testing, a comparative test has been developed. Satisfactory results may be obtained by these methods on materials with permeabilities as high as 100,000.—S. G.

***On a Technical Determination of the Modulus of Elasticity of Metals at High Temperatures by Means of the Creep Limit Apparatus of Dr. W. Rohn.** Helmut Krainer (*Messtechnik*, 1936, 12, (6), 111–114).—The specimen under load in the Rohn creep test at high temperature decreases slightly in length when the load is removed; this decrease may be compensated by increasing the temperature, and the number of ° C. necessary to effect this forms the basis of the calculation of the elastic modulus at the temperature of the test. A mathematical expression is deduced for determining the true creep limit by making allowance for the change in elastic modulus with rise in temperature. —A. R. P.

Fatigue Strength. H. Dinner and H. Christen (*Schweiz. tech. Zeit.*, 1936, (2), 77–81).—A general discussion of the principles underlying the determination of fatigue strength and its significance in construction work.—W. A. C. N.

Fatigue Stress and Its Diminution. H. Oschatz (*Mech. World*, 1936, 99, (2563), 161–168).—Abstract of a paper presented to the Engineers' German Circle, entitled "Fatigue Strength and Its Determination."—F. J.

***Determination of the Brinell Number of Metals.** Serge N. Petrenko, Walter Ramberg, and Bruce Wilson (*J. Res. Nat. Bur. Stand.*, 1936, 17, (1), 59–95; and *Research Paper* No. 903).—The procedure used in making Brinell tests must be closely controlled in order that two observers testing a given metal at different places shall obtain Brinell numbers that are in close agreement. Small variations in testing procedure are inevitable so that it is important to know the effect of these variations on the magnitude of the Brinell number obtained. The authors consider the effect on the Brinell number of such variations with the help of the data available in the literature supplemented by new tests wherever the existing data seemed deficient. Attention is given to the effect on the Brinell number of variations in testing procedure, *i.e.* rate of applying the load, time under nominal load, error in load, and error in measuring the diameter of the indentation. The effect of variables residing in the specimen is discussed under the headings of non-uniform properties, curvature of surface, thickness, spacing of indentations, and angle between load line and normal to the specimen. Variations in the type of ball used were considered, particular attention being devoted to differences in elastic deformation, and in permanent compression of the ball under load. The paper concludes with recommendations for a test procedure which would lead to greater concordance in the Brinell numbers obtained by different observers using a ball of a given diameter on a specimen of given metal.—S. G.

The Measurement of Hardness. S. R. Williams (*Instruments*, 1936, **9**, (8), 221–223).—In a penetration hardness test, the resistance to penetration depends on the angle of the penetrator and the frictional resistance between it and the test-piece (both properties of the testing instrument) as well as on the cohesion and the internal friction of the material. It is suggested that more fundamental knowledge of hardness might be derived from studies of resistivity, its change with varying magnetic fields, and similar properties which depend on the internal forces holding the material together. Some tests on carbon steels are briefly described.—J. C. C.

A Direct-Reading Hardness Testing Machine. —— (*Engineer*, 1936, **161**, (4198), 687).—An illustrated description of a machine which is designed to give direct readings for routine hardness tests of materials ranging from 0·35 to 0·6 mm. in thickness. 60–200 Brinell degrees of hardness are given by the penetration of two opposed points between which the test-piece is gripped. The indicator records the sum of the depths of the two penetrations and measures the mean hardness of the opposite faces of the test-piece.—R. Gr.

Hardness Tester. —— (*Instruments*, 1936, **9**, (8), 213).—The "Diamo-Brinell" hardness testing machine is briefly described. [*Note by abstractor:* This appears to resemble closely the Vickers diamond pyramid tester.]
—J. C. C.

RADIOLOGY.

†The Application of X-Rays to Metallurgy.—II. C. Hubert Plant (*Metallurgia*, 1936, **14**, (82). 101–103).—The practical working of X-ray apparatus, and the results which can be obtained without a knowledge of the higher branches of physics, or without having to understand intricate analytical mathematics are considered, and the fundamental principles involved in the application of X-rays to the study of crystals and in the determination of the crystal structure are discussed. Two different types of crystal lattice—the face-centred cubic and the body-centred cubic—are dealt with, and a method of drawing a unit cell from the body-centred cube is described. On the practical side of the subject, the Laue method of crystal analysis is considered in brief detail.—J. W. D.

Radiography of Metal. Kent R. Van Horn (*Metal Progress*, 1936, **30**, (2), 45–51).—A summary of current methods of X-ray examination of metals.
—P. M. C. R.

Modern Distinguishing Signs in Radiography. F. Wulff (*Elektroschweissung*, 1936, **7**, (5), 89–92).—Various methods for marking the objects to be radiographed, in order to recognize the exact location of each exposure, are described, with particular reference to weld-seams. A new method is presented, which is claimed to be free from all the disadvantages of the others, and which permits exact comparison of picture and seam even after the lapse of considerable time. The application of this method to the case of a welded locomotive firebox is explained in detail.—H. W. G. H.

***Non-Destructive Testing of Steel Weld Seams by Means of Gamma Radiation.** M. Widemann (*Autogene Metallbearbeitung*, 1936, **29**, (13), 196–199).—Radiation from mesothorium was used to examine a series of welds, and the limiting dimensions of defect (incomplete junction, crack, slag inclusion, blow-hole, or surface cavity) which could be detected, were determined. The results show that the method is very much less sensitive than X-ray examination.
—H. W. G. H.

XII.—TEMPERATURE MEASUREMENT AND CONTROL

(Continued from p. 373.)

Measurements with a New Colour Pyrometer. K. Guthmann (*Stahl u. Eisen*, 1936, **56**, (17), 481–489).—A description of the features and uses of the Bioptix pyrometer. The greatest differences in temperature measurement by means of the latter and by a standard radiation instrument, occurred when dealing with flame and metal melting temperatures. The accuracy of the new instrument is said to be ± 10° C.—W. A. C. N.

***Comparison of Platinum Resistance Thermometers with the Helium Thermometer from − 190° C. to − 258° C.** W. H. Keesom and A. Bijl (*Physica*, 1936, **3**, (6), 418–424; also *Comm. K. Onnes Lab. Leiden*, No. **242b**; and (summary) *Proc. K. Akad. Wet. Amsterdam*, 1936, **39**, (5), 574–575).—[In English.] The resistance curves of 4 platinum resistance thermometers were determined between − 190° and − 258° C. The curves show considerable differences. The rather complicated resistance curve of platinum at lower temperatures makes it doubtful whether this metal is suitable as a standard metal for resistance thermometry below − 190° C.; gold may be more suitable in this range. Henning and Otto's formula is applicable to 3 of the thermometers.—S. G.

XIII.—FOUNDRY PRACTICE AND APPLIANCES

(Continued from pp. 374–375.)

The Castability of Metals and Alloys. Wilhelm Patterson (*Giesserei*, 1936, **23**, (17), 405–410).—A summary and review of recent work.—A. R. P.

***On the Artificial Production of Metal Nuclei in Metal Melts During Solidification.** Erich Scheil (*Z. Metallkunde*, 1936, **28**, (8), 228–229).—The grain-size of cast ingots can be refined appreciably by inserting wires of the metal in the mould before casting. The resulting grain-size is a function of the number and diameter of the wires used, and for every metal there are critical values of these which give the best grain-size. The effects are illustrated by experiments on a 3% silicon-steel and on pure aluminium.—A. R. P.

Casting and Moulding [in the Aluminium Foundry]. Oskar Summa (*Aluminium*, 1936, **18**, (4), 135–138).—The precautions to be taken in designing complicated shapes to be cast in aluminium are critically discussed with reference to several examples.—A. R. P.

The Casting of Elektron and Hydronalium Alloys. P. Spitaler (*Aluminium*, 1936, **18**, (19), 429–432; and *Light Metals Rev.*, 1936, **2**, (22), 391–392).—Summaries from *Giesserei*, 1936, **23**, (8), 177; see *Met. Abs.*, this vol., p. 171.—L. A. O.

Copper-Tin Alloys in Power Transmission. Centrifugal Casting of Bronze Gears. R. C. Stockton (*Met. Ind.* (*Lond.*), 1936, **49**, (5), 103–105).—A concise description of the process, moulds, and cores. The suitability of alloys is discussed.—J. E. N.

†The Casting of Nickel Silvers. M. Ballay and R. Chavy (*Met. Ind.* (*Lond.*), 1936, **48**, (12), 347–351; (13), 375–378, 389; also *Rev. Nickel*, 1936, **7**, (1), 2–14; and *Cuivre et Bronze*, 1936, **9**, (72), 3–21).—Read before the Congrès International des Mines, de la Métallurgie, et de la Géologie appliquée (this paper is not being printed in the official report of the Congress). The principal properties of and specifications for nickel brasses are summarized, and the defects commonly met with in castings of these alloys are described. Laboratory and foundry tests were carried out to determine the best conditions for obtaining sound castings. In the former, the fuel was town gas, and heavy oil furnaces or coke crucible furnaces were used in the latter. When the alloy contains small quantities of gas, high temperature (1300°–1350° C.) melting and superheating are recommended. Gas absorption is very different in the

three types of firing. The addition of a reducing metal, as manganese or aluminium, before casting gives freedom from blow-holes. A large number of practical recommendations are given as to the make-up of the charge, use of fluxes, charging, melting, casting, gas elimination, moulding sand, and moulding. 21 references are given.—J. H. W.

Production and Use of Lead Bearing Metals. R. Schmidt (*Stahl u. Eisen*, 1936, **56**, (8), 228–231).—The properties of suitable lead bearing metals are described, and the processes for the hardening of lead by the addition of sulphur, alkalis, or alkaline earth metals are explained. The manufacture, properties, and applications of "Union" bearing metal having the composition—lead 98, magnesium 1·5, and calcium 0·2% are given.—W. A. C. N.

Recommended Practices for Sand-Cast Magnesium Alloys. Report of Non-Ferrous Division Committee [of A.F.A.] on Recommended Practices. —— (*Trans. Amer. Found. Assoc.*, 1936, **44**, 33–50; and (abridged) *Found. Trade J.*, 1936, **55**, (1047), 197–199, 202).—See also *Met. Abs.*, this vol., p. 319. This, the second of a series of recommended practices, drawn up by those considered to be specialists, is a comprehensive review of magnesium alloy foundry practice. The preparation of the special moulding sand and facings, cores, gates, and risers are concisely described. Special attention must be paid to the fluxing, melting, and alloying, and the melting pot and casting ladle are illustrated. Further sections deal with finishing processes for castings, heat-treatment, defects, their cause and prevention, properties and applications, and the last section gives the trade names of the principal American products.—J. E. N.

Production of Nickel–Chromium Alloys for Electrical Heating Elements. W. F. Randall (*Wild-Barfield Heat-Treat. J.*, 1936, **1**, (8), 98–102).—Purity of the constituent metals is essential, and the refractories used should be well seasoned. A viscous slag for the exclusion of air during melting is suggested. Evacuated furnaces have been tried. The metal should not be superheated. Moulds should be preheated to 500°–600° C. An unbroken stream and the prevention of slag carry-over are essential. The ingot surfaces will usually have to be milled or scalped to remove imperfections, and this is best done after the initial hot-working. Hot-working is normally carried out at 1300° C. —W. A. C. N.

General-Purpose Babbitt Metalling Mould. —— (*Mech. World*, 1936, **100**, (2586), 82).—A jig suitable for dealing with the smaller types of half-bearings is illustrated and described.—F. J.

***Deformation and Resilience of Moulding Sand.** H. W. Dietert and R. A. Dietert (*Trans. Amer. Found. Assoc.*, 1936, **44**, 139–156; discussion, 157).—The deformation and resilience are two properties of moulding sands which have received little attention. They have been studied by stress–strain diagrams on A.F.A. standard test-pieces, in which one variable of the sand has been modified at one time. The importance of the two properties in relation to the moulding, and handling properties of moulds are discussed. The deformation is the strain measured on the standard compression test, and the resilience is derived from the work done in breaking the specimen, and combines the deformation and compression strength. As a result of their investigation the authors find that deformation increases as moisture increases, as the sand becomes finer, as the clay content is high or low, as the mould hardness increases, and as the sea-coal increases. They also found that sand resilience is increased by increasing moisture content, fine material, clay content, mould hardness, and sea-coal content. The significance of these properties was emphasized in the discussion, and it was pointed out that resilience was probably the property which previously had been apparent only to a moulder by the feel of the sand.—J. E. N.

Mechanical Sand Handling for Low-Tonnage Foundries. E. W. Beach (*Trans. Amer. Found. Assoc.*, 1935, **43**, 415–422; discussion, 422–426).—S. G.

***Surface and Venting Property of Moulding Sands.** J. Verö (*Bányamérnöki és Erdömérnöki Föiskola bányászati és kohászati osztalyának Köszlémyeiből* (*Mitt. berg. hütt. Abt. Kg. ung. Hochschule für Berg- u. Forstwesen zu Sopron*), 1934, **6**, 99–119; *C. Abs.*, 1936, **30**, 5539).—Tests were carried out with Steinitzer's apparatus to investigate the effect of grain-size on the venting property of moulding sands; only quartz sand free of clay and dust was used. A linear relationship exists between the factors expressing the venting property, namely the time occupied by the passage of a gas, and the difference of pressure effected by the passage of a gas. Another linear relation exists between the square root of the resistance and the reciprocal dimensions of the grains, but only for grains of equal size and sands free of mixtures; the latter have always a greater resistance than pure quartz sand. The surface factor, *i.e.* the whole surface of grains contained in a unit volume or weight, is of deciding influence. —S. G.

Fifteen Years of Foundry Apprenticeship at the Falk Corporation. V. J. Hydar (*Trans. Amer. Found. Assoc.*, 1935, **43**, 321–327).—S. G.

Some Suggestions for Starting and Carrying on a Foundry Apprenticeship System. J. E. Goss (*Trans. Amer. Found. Assoc.*, 1935, **43**, 328–342).—S. G.

Foundry Apprenticeship: Discussion. —— (*Trans. Amer. Found. Assoc.*, 1935, **43**, 343–350).—Discussion of papers by V. J. Hydar and J. E. Goss (preceding abstracts).—S. G.

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

(Continued from p. 375.)

On the Problem of the Working-Up of Aluminium Scrap. W. Guertler (*Aluminium*, 1936, **18**, (6), 256–261).—Methods of sorting the scrap and furnaces for melting it are described, and practical hints are given for obtaining good yields of recovered metal.—A. R. P.

XV.—FURNACES AND FUELS

(Continued from pp. 375–376.)

Gas Firing of Metallurgical Furnaces. —— (*Metallurgia*, 1936, **14**, (82), 107).—The subject of high-pressure and low-pressure gas-firing of metallurgical furnaces is discussed from the view-points of accurate control, stability of flame, uniformity of heating, use of hot and dirty gas, and use of preheated air, and the advantages of low-pressure firing are stressed. The basic principle of the design of burner used for such firing is the passage of air and gas in alternate thin layers, one or both of which are given a whirling motion by means of spiral guides and passages.—J. W. D.

Gas in Industry and Commerce. Dean Chandler (London: **1936**, 47 pp.; and (summary) *Met. Ind.* (*Lond.*), 1936, **48**, (10), 295–299).—Address delivered at a Joint National Gas Conference held at the British Industries Fair. After a brief discussion of the present position and future prospects of the gas industry, numerous applications of coal-gas are illustrated and described, including air heating, vitreous enamelling, non-ferrous metal melting, heat-treatment of metals, and soldering. The questions of atmosphere and temperature control for metallurgical applications are dealt with, and, in both, the use of gas is shown to have advantages over other fuels.—H. W. G. H.

Practical Applications of Controlled Atmosphere Furnaces. T. B. Bechtel (*Indust. Heating*, 1936, **3**, (4), 221–228).—An illustrated article dealing with

furnaces in which the atmosphere consists of the products of partial combustion of suitable gases. The analysis is usually within the following ranges: hydrogen 2–18, carbon monoxide 3–11%. Most benefit is said to be obtained from the use of a controlled atmosphere when heating and cooling are carried on within the furnace or in near-by auxiliary equipment. The applications of the method in brazing and annealing are discussed. The conditions to be met in erecting the necessary plant are reviewed.—W. A. C. N.

The Deblanchal Rotary Melting Furnace. C. F. Herington (*Heat-Treat. and Forging*, 1936, **22**, (2), 93).—See *Met. Abs.*, this vol., p. 129.—J. E. N.

Heating Furnaces for Hot-Pressing Aluminium Parts. K. Robertz (*Aluminium*, 1936, **18**, (7), 291–297).—Various types of electric furnaces with automatic temperature regulators are described.—A. R. P.

Electrically Heated Industrial Furnaces. R. Boye (*Eng. Progress*, 1935, **16**, (11), 265–272).—A review.—S. G.

Improved Tungsten-Wound Furnaces for High Temperatures. H. Ciceiorra and W. Dawihl (*Keram. Rundschau*, 1936, **44**, 171–172; *C. Abs.*, 1936, **30**, 4406).—A tungsten-wound furnace is illustrated and described. By increasing the number of turns near the ends more constant temperature is maintained. Hydrogen or hydrogen + carbon monoxide is passed through the refractory body. When an impervious alumina tube is used, a temperature of 1800° C. may be maintained with an oxidizing atmosphere within the tube. —S. G.

Electric Furnaces with Carbon Radiator. Henri George (*Elect. Eng.*, 1935, **54**, (11), 1195–1199).—See *Met. Abs.*, 1935, **2**, 254.—S. G.

Coreless Induction Furnaces. —— (*Mech. World*, 1936, **99**, (2574), 450).—Technical details and advantages of the high-frequency induction furnace are briefly set forth.—F. J.

Frequency Changers for Induction Furnaces. Robert W. Wieseman (*Electrochem. Soc. Preprint*, **1936**, Oct., 81–98).—Synchronous machines can be built with a rotating armature and a stationary field (this type is now seldom used); with a rotating field and a stationary armature (conventional type for commercial frequencies); with a rotating field structure and a stationary armature, but with the field winding stationary (inductor type); and, finally, with a single stationary winding which serves both as an armature and as a field winding (reaction type). From this variety of machine constructions the inductor type is recommended for induction furnace high-frequency power generation because of its reliability and high efficiency. W. describes the construction and performance characteristics of high-frequency inductor generators.—S. G.

XVI.—REFRACTORIES AND FURNACE MATERIALS

(Continued from pp. 376–377.)

A New Refractory. —— Sachot (*Chaleur et Industrie*, 1935, **16**, (181), 265–266).—"Duralite," a French neutral refractory, can either be poured as a cement into moulds, when it sets hard in the cold after a few hours, or used as a plastic cement for hot-patching.—J. C. C.

Some Factors Affecting the Durability of Refractories. J. F. Hyslop (*Metal Treatment*, 1936, **2**, (6), 86–88; and (summary) *Found. Trade J.*, 1936, **55**, (1046), 179, 182).—The durability of a refractory depends on its thermal expansion, volume stability, strength under load, and resistance to spalling, corrosion, abrasion, and furnace atmospheres, even more than on its refractoriness. These characteristics, their evaluation, and the properties of some important refractories are briefly discussed.—J. C. C.

XVIII.—WORKING

(Continued from p. 377.)

Working Copper and Copper–Zinc Alloys. William Ashcroft (*Metallurgia*, 1936, **14**, (82), 99–100).—The copper and copper–zinc alloys are discussed from the points of view of hot- and cold-working, the importance of correct annealing is stressed and the need for temperature controlled furnaces is emphasized. The effect of impurities is also dealt with, and the range of copper–zinc alloys available for working is considered in relation to their crystal structure, on which the ease of annealing and working depends. Reference is also made to internal stresses set up by cold-working, and the removal of such stresses by heat-treatment or by altering the composition.—J. W. D.

***Cold-Deformation and Recovery of Alloys with an Ordered Atomic Distribution.** (Dahl.) See p. 394.

Spread in Rolling with Different Rolling Speeds and Steel Compositions. A. Spenlé (*Stahl u. Eisen*, 1936, **56**, (19), 544–549).—The results show that changes in composition materially affect the spread.—W. A. C. N.

Spread in Rolling and Its Dependence on Speed of Rolling, Roll Diameter, and the Composition of the Material Rolled. O. Emicke and E. Pachaly (*Stahl u. Eisen*, 1936, **56**, (21), 589–599).—Although dealing principally with the rolling of steel, the principles enunciated are of interest in non-ferrous work. Two equations, involving the different factors, by Geuze and Sedlaczek, respectively, are compared. It is shown that the calibration method of Emicke, based on the Sedlaczek formula, best fits the phenomena of spreading during rolling.—W. A. C. N.

Metallurgical Control in the Production of Non-Ferrous Sheet and Strip. A. F. Dunbar (*Modern Eng.*, 1935, **9**, (9), 346–351; (10), 404–407).—See *Met. Abs.*, this vol., p. 56.—H. W. G. H.

The Roll Problem in Backed-Up Mills for Cold-Reduction. Geo. A. V. Russell and S. S. Smith (*Iron Steel Inst. Advance Copy*, **1936**, Sept., 26 pp.; and (summary) *Met. Ind.* (*Lond.*), 1936, **49**, (14), 335–340).—The development of heavy cold-rolling operations on mills of the backed-up type has directed attention to the rolls employed. The paper is a record of experience with both the working and backing rolls in a large installation. The various types of roll used or now available are considered from the points of view of use and manufacture, and characteristic modes of failure are illustrated and examined. The stress relationships occurring are then contrasted with those obtaining in the rolls of mills of the ordinary two-high type. Finally, some suggestions are advanced for improving backed-up roll performance.—S. G.

Prospects of Gold Thread Manufacture in South India. D. M. Amalsad (*Indian Textile J.*, 1935, **45**, (539), 372–375; *J. Textile Inst.*, 1935, **26**, A614).—A description is given of the manufacture of gold thread by drawing silver into a flattened wire (lametta), coiling it round silk thread, and gilding it by electrodeposition of gold. A diagram of the gilding machine is given. Reference is made to production costs. Tables are given showing the quantity and value of silver and gold thread imported into India and into the Madras Presidency during the period 1921–1934.—S. G.

Ardoloy-Tipped Drawing Dies. —— (*Met. Ind.* (*Lond.*), 1936, **49**, (10), 235).—A brief illustrated description of adjustable drawing dies faced with Ardoloy for drawing wire, rods, and tubes.—J. E. N.

Preparation of Flattened Copper Tubing Coils. Edward P. Barrett and William L. Barrett (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1936, **8**, (4), 311).—Circular tubing is drawn through special dies to produce the flattened tube which is then wound into coils for induction furnaces over a mandrel in a lathe. Silver solder is used for making any necessary joints in the coils.—A. R. P.

The Manufacture of Copper Tubing. O. Z. Klopsch (*Mech. World*, 1936, **99**, (2558), 35–36).—Abstract of a paper read before the American Society for Metals. Cf. *Met. Abs.*, this vol., p. 280.—F. J.

Some Causes for the Failure of Lead and Lead Pipes and Suggested Remedies. E. King and K. Gray (*J. Trans. Junior Inst. Eng.*, 1935, **45**, 123–138).—The manufacture of lead pipes by extrusion is first described. The various types of failure are then reviewed. (I.—) Mechanical, due to (*a*) variation in wall thickness, (*b*) stress of freezing water, (*c*) fatigue in long pipe runs subjected to variable loads; (II.—) Chemical corrosion by (*a*) cement, (*b*) chemical constituents of soil, (*c*) water and air in combination, (*d*) damp timber; (III.—) Electrolytic corrosion by (*a*) stray currents from electrical systems, (*b*) action of impurities; (IV.—) Inclusions, principally oxides. In each instance remedial or preventive measures are suggested. The stability of ancient lead pipes, notably free from impurities, is discussed.—W. A. C. N.

***The Influence of Inhomogeneity of the Metal in the Flow Process in the Dick Extrusion Press.** Hermann Unckel (*Z. Metallkunde*, 1936, **28**, (6), 151–154; and (summary) *Light Metals Research*, 1936, **5**, (1), 10–12).—Comparison of the flow-lines exhibited by wax–chalk mixtures and hot aluminium in extrusion from the Dick press shows that the region of principal flow in the metal is much more extensive than in the wax, and a radial component of the velocity of flow is set up just below the piston which leads to instability in the flow of the metal through the die. These difficulties can be overcome by using a piston with a concave lower end, by heating the receiver and by using a die with a conical opening.—A. R. P.

Metallurgical Aspects of Deep-Drawing. IV.—A Forecast of Possible and Desirable Improvements in Deep-Drawing Metal and Practice. J. D. Jevons (*Met. Ind.* (*Lond.*), 1936, **49**, (1), 6–10; (3), 62–65).—See also *Met. Abs.*, this vol., pp. 175, 218, and 275. It is suggested that improvement in the quality of deep-drawing metal will be achieved by attention to melting practice, ingot size, annealing under ideal conditions, and development in rolling-mill plant. On the part of the user progress may be made in drawing practice by design and pressure application methods, tools, lubricants, warm drawing, and inter-stage annealing. Reference is made to polishing and plating the finished articles and the possible use of plated sheet is mentioned. Progress will be considerably aided by co-operative research and by intelligent application of the results of current fundamental research.—J. E. N.

The Deep-Drawing Capacity of Aluminium. —— (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 139–141).—A critical summary of a paper by Werner Helling, *Metallwirtschaft*, 1936, **15**, (17), 388, 409; see *Met. Abs.*, this vol., p. 322.

†Drop Stamping Plant and Practice for Non-Ferrous Metals. John Stewart (*Met. Ind.* (*Lond.*), 1936, **49**, (11), 251–255).—The two types of stamps in general use are friction drive or steam or air. Practical working details of each type are described. The anvil must be 14–20 times the weight of the tup, and is the important limiting factor in the size of stamps. A table shows the weights of the relative parts, power, stroke, speed, &c., and the production, maintenance, and repair of dies is described.—J. E. N.

XIX.—CLEANING AND FINISHING

(Continued from pp. 377–378.)

†The Spoilage of Non-Ferrous Components by Acid Treatments. E. E. Halls (*Metallurgia*, 1936, **14**, (82), 91–93).—In the acid-dip treatment of non-ferrous metals and alloys, as a preparatory process to electroplating, bright acid treatments, and various clear lacquer finishes, it is necessary to control the

formulation of acid mixtures, immersion temperatures, and immersion times. Data are given showing the reduction in thickness of 70 : 30 brass sheet in cold nitric acid solutions and in hot and cold nitric/sulphuric acid mixtures for an immersion time of 30 seconds; and the reduction in dimensions of phosphor-bronze and nickel-brasses in hot and cold nitric acid, and nitro-sulphuric acid pickles for a similar period. Recommendations are made for suitable acid-dips for the removal of heat-treatment oxide, for use prior to nickel-plating, and for bright finishing, with brass, phosphor-bronze, and nickel-brass.

—J. W. D.

Inhibitors in Pickling. P. R. Russell (*J. Amer. Zinc Inst.*, 1936, **17**, 81–85; discussion, 85–87).—The functions and desirable properties of inhibitors are discussed in a general way, and some recommendations are given for pickling various types of steel.—H. W. G. H.

XX.—JOINING

(Continued from p. 378.)

***Researches with Reaction Solders for Aluminium.** —— Neubauer-Nicolini (*Aluminium*, 1936, **18**, (4), 139–142).—A mixture of zinc chloride 90, ammonium bromide 8, and sodium fluoride 2% has been recommended for use in soldering aluminium, since at high temperatures it reacts with the aluminium forming zinc which then behaves as a solder and aluminium chloride which acts as a flux. N.-N. finds that the reaction commences at 420°–430° C., and a still higher temperature is required to produce a good joint. This overheating results in a loss of tensile strength and a decrease in corrosion-resistance. To overcome these difficulties N.-N. carried out a series of tests in which the ammonium bromide was replaced by ammonium chloride and the zinc chloride wholly or partly by stannous chloride. Although the use of the tin salt reduced the reaction temperature, the joints obtained were not so strong owing to the poorer diffusing power of tin into aluminium. The use of ammonium chloride instead of ammonium bromide is advantageous; omission of the fluoride constituent makes a less ductile joint, and the use of the double zinc ammonium chloride produces too fluid a slag.—A. R. P.

***Soldered Joints in Aluminium Cables.** G. Kramer (*Elektrotech. Z.*, 1936, **57**, (24), 675; and *Aluminium*, 1936, **18**, (7), 299–302).—A method of joining stranded cables by means of a so-called "reaction solder" and special flux (nature of neither is stated) is described. The apparatus required is the same as that for soldering copper cables and the resulting joints are claimed to be strong and corrosion-resistant.—A. R. P.

The Soldering of Nickel and Its Non-Ferrous Alloys. A. Boutté (*Rev. Nickel*, 1935, **6**, (3), 127–131).—A general description of the soldering of pure nickel by electrical methods, the autogenous welding of Monel metal and white metal, and the soldering of Inconel.—W. A. C. N.

Fluxes and Solders. E. R. Wagner (*Radio Eng.*, 1936, **16**, (Apr.), 8–9; (May), 10–11, 14; *C. Abs.*, 1936, **30**, 5547).—Soldering fluxes are classified as water-soluble and water-insoluble; examples are given of both. The choice of solder is affected by melting point, fluidity at working temperature, rate of solidification, hardness and tensile strength. Common fluxes and lead-tin-antimony solders are listed. Physiological considerations are necessary in soldering work in confined spaces.—S. G.

Progress in Electric Furnace Brazing. H. M. Webber (*Iron Age*, 1936, **138**, (6), 24–27, 50).—Describes the applications of the electric furnace brazing process.—J. H. W.

The Welding of Aluminium. —— (*Soudure et Oxy-Coupage*, 1936, **13**, (73), 294).—Advice is given to welders who have had no experience of aluminium.

The leftward method is recommended, the blowpipe having a capacity of 75–100 litres of acetylene per hr. per mm. thickness of material.—H. W. G. H.

Repairing of Aluminium Castings by Welding Processes. W. Herrmann and Edmund R. Thews (*Welding Ind.*, 1936, **4**, (3), 90–94).—The advantages of welding are pointed out and the principles to be considered are explained. The preparation of the parts to be welded, careful preheating, the use of suitable fluxes, the welding technique, and after-treatment of the finished articles are discussed. Heat-treatment of the welded casting is said to be unnecessary if preheating, welding, and cooling are carried out as recommended.—H. H.

†Position of Electrical Spot-Welding for Aluminium and Its Alloys. F. Bollenrath and W. Bungardt (*Aluminium*, 1936, **18**, (4), 125–133).—Present practice in the spot-welding of aluminium and its alloys is critically reviewed. The physical, chemical, and structural properties of the alloys, especially the hardenable alloys, necessitates a specially built machine and a specialized technique. The Sciaky and the Bollenrath machines are so designed as to use the correct pressure and current to produce a weld by pure recrystallization which gives the best structure and properties.—A. R. P.

Methods of Welding Aluminium and Its Alloys. Jacques Douchement (*Metallurgist* (Suppt. to *Engineer*), 1936, **10**, 155–156).—Summary of a paper by D. in *Rev. Mét.*, 1936, **33**, 189; see *Met. Abs.*, this vol., pp. 131, 277.—L. A. O.

***Electrical Conductivity Measurements on Welded Pure Aluminium.** (Buser.) See p. 385.

Jointing of Materials by Welding–Applications in the Aircraft Industry. R. H. Dobson and R. F. Taylor (*Welding Ind.*, 1936, **4**, (3), 99–104).—Aluminium and magnesium alloys are briefly touched upon.—H. W. G. H.

Bronze-Welded Monel Metal. O. C. Jones (*J. Amer. Weld. Soc.*, 1936, **15**, (7), 18–19).—Monel metal laundry plant is reconditioned by bronze-welding. —H. W. G. H.

The Comparative Efficiency of Fuel Gases for Welding and Cutting Steel. George V. Slottman (*Internat. Acet. Assoc. Proc.*, 1934, 40–51; and *Indust. Gases*, 1935, **16**, (1), 41–44).—It is shown by theoretical reasoning that acetylene is more efficient than propane for welding and cutting. Test data on cutting are quoted to confirm this reasoning.—H. W. G. H.

Hydraulic Valves to Resist Back-Fire and Explosion Pressure. Otto Mues (*Autogene Metallbearbeitung*, 1936, **29**, (12), 179–181).—The stringent regulations and tests for safety hydraulic valves in Germany are explained, and two forms of apparatus fulfilling the requirements are described.—H. W. G. H.

Theory of Electric Arc Welding. W. Fink (*Elect. Welding*, 1936, **5**, (29), 150–152; (30), 205–213).—The passage of electrons in the d.c. arc, the ionization of the gap, and the "freezing" of the cathode spot are explained. The arc characteristic is then considered in relation to the generator characteristic with current regulation by alteration of no-load voltage or choke resistance. The a.c. arc is briefly discussed, and, finally, the possibility of overhead welding is explained by the pinch effect theory.—H. W. G. H.

Electric Arc Welding Machines. J. M. Willey (*Welding Ind.*, 1936, **4**, (5), 202–212).—Read before N.-E. Branch of Institute of Welding. The paper is divided into three sections: in the first, the static and dynamic characteristics of d.c. welding generators are examined, the significance of open-circuit voltage, ratio of current peak to steady short-circuit current, the reserve voltage, and the recovery time being explained. The second part deals with the relative economy of single and multi-operator welding sets, detailed figures being given to show that the running costs depend entirely on operating time. Finally, a new high-frequency a.c. welding machine is described, which is especially suitable for welding thin plate and with which difficulties due to magnetic deflection of the arc are eliminated.—H. W. G. H.

Resistance Welding. L. H. Frost (*Welding Eng.*, 1936, **21**, (5), 47–48; (6), 44–46).—A continuation of previous articles (see *Met. Abs.*, this vol., p. 278)

dealing with contact tip design and materials. The welding of coated materials—tinplate, terne plate, &c.—and of brasses, bronzes, and aluminium is also considered. For the last, ball-ended contact tips of special alloy are thought essential. Transformer capacities approximately 5 times those for steel are required.—H. W. G. H.

Accurate Time Control for Resistance Welding. R. T. Gillette (*J. Amer. Weld. Soc.*, 1936, **15**, (6), 6–8).—The advantages of thyratron control for seam welding are enumerated, and its application in the manufacture of refrigerator parts is described.—H. W. G. H.

Jigs and Fixtures for Resistance Welding Machines. H. C. Cogan (*J. Amer. Weld. Soc.*, 1936, **15**, (7), 9–15).—Thirteen rules for the design and operation of jigs and fixtures are given, and examples of applications to spot-, seam-, flash-, and projection-welding are described.—H. W. G. H.

Concerning Some Difficulties in the Practice of Spot-Welding. R. de Longcamp (*Bull. Soc. Ing. Soudeurs*, 1936, **7**, (39), 2123–2130).—Variations in the quality of spot welds are shown to be due, not only to avoidable variations in electrode pressure, area of contact, cleanliness of surface, &c., but also to differences of resistivity and energy losses which are not completely compensated by such devices as the wattmeter control. A new method of current control, based on the reduction of resistivity of the sheets to be joined at the moment of fusion, is thought to be of great interest. The use of small contact tips, of special material, is recommended in preference to the large tips commonly employed. The need for a reliable non-destructive test for spot welds, and for further research on the design of transformers, is emphasized.—H. W. G. H.

The "Wist" Process of Electric Welding. L. Kirste (*Aéronautique*, 1936, **18**, (206), 149–150).—In this process a long, pointed flame, having a temperature of 3500°–4500° C., is produced by blowing water gas or alcohol vapour through an arc between concentric carbon electrodes. The high temperature of the flame enables very high welding speeds to be attained.—J. C. C.

"The Invisible Ray." It Welds—It Smelts. T. W. Lippert (*Iron Age*, 1936, **138**, (8), 26–31).—A critical description of Antonio Longoria's electromagnetic process of welding thin non-ferrous metal strips.—J. H. W.

Simple Fixtures Assure Correct Welding. Fred B. Jacobs (*Welding Eng.*, 1936, **21**, (7), 26–28).—Jigs for welding small frames, boxes, and heavy rings are illustrated and described, with particular reference to the saving of time effected by careful design of the operating mechanism.—H. W. G. H.

A Method of Determining the Properties of Welding Generators. L. A. Ferney (*Welding Ind.*, 1936, **4**, (6), 216–218).—A theoretical consideration of the "fictitious resistance" of welding generators—the ratio of the open circuit voltage to the peak short-circuit current.—H. W. G. H.

Qualification and Classification of Welders. —— (*Rev. Soudure Autogène*, 1936, **28**, (269), 2–9; and *Soudure et Oxy-Coupage*, 1936, **13**, (74), 297–304).—A programme prepared by the Institut de Soudure Autogène for the classification and certification of welders, who are divided into the following categories: professional welders (blowpipe or arc), specialized welders (blowpipe, arc, or resistance), and assistants. The qualifications required and the tests to be passed for the first category are described.—H. W. G. H.

Tests for the Selection of Operators of Welding Equipment (Tentative). —— (*Internat. Acet. Assoc. Oxy-Acetylene Cttee. Publ.*, Section 6, **1935**, 18 pp.).—Suitable test-welds and tests are suggested for ferrous materials, copper, bronze, aluminium, nickel, and Monel metal. The tests recommended are: tensile, on a test-piece with the weld reinforcement retained; nick-break test, the sample being held in a vice and struck with a hammer; free-bend test, on a machined specimen; and backward bend test, to stretch the metal at the bottom of the vee.—H. W. G. H.

XXI.—INDUSTRIAL USES AND APPLICATIONS

(Continued from pp. 378–380.)

The Introduction of Aluminium into the Norwegian Fish Preserving Industry. —— Nickelsen (*Aluminium*, 1936, **18**, (6), 234–237).—Aluminium cans have recently been used for packing sild and brisling as well as other fish by Norwegian packers. The cans do not become blackened internally, impart no smell or taste to the fish, are more readily opened than tinplate cans, and are much lighter. In 1935 over 12 million cans were used equivalent to over 300 tons of aluminium. Autoclaves, cooking boilers, and sterilizers have also been made of aluminium with very satisfactory results in service.—A. R. P.

Aluminium: a German Material for the Construction of Apparatus. H. Röhrig (*Chem. Fabrik*, **1935**, 487–489).—The suitability of aluminium for different apparatus and methods to increase its corrosion-resistance and to facilitate welding are discussed.—S. G.

Aluminium and Aluminium Alloys in the Chemical Industry. Fritz Ohl (*Werkstoffe u. Korrosion* (Suppt. to *Chem. Apparatur*), 1935, **10**, (10), 45–47).—Aluminium is corrosion-resistant to many organic substances. Addition of silicon increases, and copper, zinc, or nickel decrease, the resistance to corrosion.—L. A. O.

Aluminium in the Building Industry. Arne Bruick (*Aluminium*, 1936, **18**, (6), 237–241).—Recently many new shops and offices in Norway have been provided with exterior and interior fittings of aluminium or its alloys; examples of shop fronts, doors, staircases, counters, kiosks, &c., are illustrated. —A. R. P.

Italian Experience with Telephone Wires. G. Dassetto (*Aluminium*, 1936, **18**, (6), 253–256).—Tables are given showing the mechanical and electrical properties of telephone wires of bronze, steel, and Aldrey, and details are given of the methods used in mounting and joining Aldrey wires.—A. R. P.

Aluminium in Bridge Construction. Structural Applications in America. —— (*Met. Ind.* (*Lond.*), 1936, **49**, (10), 234–235).—" 27 S.T.," an aluminium alloy having a tensile strength of nearly 27 tons/in.^{2} and an elongation of 12%, with a Brinell number of 118, has been adopted by the American military authorities for portable bridges. The dimensions and structural details of such bridges are described. It is proposed to re-floor Brooklyn bridge with redesigned trusses and stays in this alloy. In the case of a bridge in Pittsburg a saving of 700 tons in weight was effected by replacing wrought iron and timber by aluminium. It is suggested that old bridges, costly to rebuild, can be modernized economically by the extended use of similar alloys. [*Note by abstractor:* Methods and costs of protection against corrosion are not referred to in the article.]—J. E. N.

Aluminium in the Service of Transportation. Alexander Klemin (*Trans. Electrochem. Soc.*, 1936, **69**, 47–54).—Address on the occasion of the 50th anniversary of the discovery of Hall's electrolytic process for producing aluminium.—S. G.

Aluminium in Norwegian Transport. Arne Bruick (*Aluminium*, 1936, **18**, (6), 242–249).—Many interesting examples of the use of aluminium alloys in the coachwork of road and railway vehicles are illustrated by diagrams and photographs, and details of their dimensions, weight, and performance are given in the text.—A. R. P.

The Design of the Coaches for Suburban Services of the Chemin de Fer de l'Est. —— Poncet and —— Forestier (*Rev. gén. Chemins de Fer*, 1936, **55**, (2), 91–104).—An estimated reduction of 23% has been effected in the weight of the railway coaches on the Est suburban services, partly by the adoption of welded tubular construction, and to a great extent by the substitution of light alloys for steel. Roofing and much of the interior and exterior panelling will be

of Almasilium sheet; sliding doors will be of Duralinox (an aluminium-base alloy containing 5·5–7% magnesium); the smaller stressed members will be of Duralumin: magnesium-base materials will be used in decorative metal work, and an aluminium–copper alloy will be used for racks, rails, handles, &c., which are normally painted. Light alloy channels are used in the flooring.—P. R.

Lautal as Material for the Construction of Airplanes. P. Brenner (*Light Metals Rev.*, 1936, **2**, (24), 448–450).—Summarized from *Luftfahrtforschung*, 1928, **1**, (2), 35; see *J. Inst. Metals*, 1928, **39**, 713, and 1929, **42**, 603.—L. O.

***Technological Developments of the Curtiss-Wright Coupé.** Albert E. Lombard, Jr. (*J. Aeronaut. Sci.*, 1936, **3**, (8), 267–275).—Tests are described on a series of 15 panels of Alclad sheet, in which various types of stiffeners were used. A "formed-up" stiffener of thin Alclad sheet proved the most satisfactory, two extruded sections of "24 S.T." alloy being next in order of merit. The alloy would prove stronger than Alclad if used as thin sheet, but its use in this form is inadvisable on account of its liability to corrosion.—P. R.

Aluminium Sand- or Die-Casting (Not Suitable for Pistons). —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 287**, 1935, 3 pp.).—Covers the materials generally known as Ceralumin B and N.A. 111 alloy.—S. G.

Aluminium Alloy Sand or Die-Castings (Not Suitable for Pistons). —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 298**, 1936, 3 pp.).—Covers the material generally known as N.A. 225/W91 alloy.—S. G.

Aluminium Alloy Sand or Die-Castings (Not Suitable for Pistons). —— ((*Brit*). *Air Min. Specification* No. **D.T.D. 304**, 1936, 3 pp.).—Covers the material generally known as N.A. 225/T92 alloy.—S. G.

Wrought Light Aluminium Alloy Sheets and Strips. —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 206**, 1936, 8 pp.).—Covers the alloy generally known as Hiduminium R.R. 56 (sp. gr. $\not>$ 2·80).—S. G.

Soft Aluminium Alloy Sheets and Strips. —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 292**, 1936, 4 pp.).—Covers the alloy generally known as N.A. 57 S (sp. gr. $\not>$ 2·85).—S. G.

Aluminium Alloy Bars, Extruded Sections, and Forgings. —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 293**, 1935, 7 pp.).—Covers the materials generally known as Ceralumin F, N.A. 15 S alloy, and Duralumin T; sp. gr. not greater than 2·85.—S. G.

Aluminium Alloy Bars, Extruded Sections, and Forgings. —— (*Amendments* (*Brit.*) *Air Min. Specification* No. **D.T.D. 293**, Amendment No. 1, 1936, 1 p.).—Clause 17(*a*) is deleted and a new paragraph regarding hardness requirements is substituted.—S. G.

Seven Per Cent. Magnesium-Aluminium Alloy Tubes (Annealed). —— (*Provisional* (*Brit.*) *Air Min. Specification* No. **D.T.D. 190**, 1936, 4 pp.).—Covers the material generally known as M.G. 7 alloy (sp. gr. = 2·63).—S. G.

Beryllium-Copper Used in Electrical Switch Spring. A. L. Riche (*Trans. Electrochem. Soc.*, 1936, **69**, 493–494).—See *Met. Abs.*, this vol., p. 179.—S. G.

Wear Resistance. —— (*Automobile Eng.*, 1936, **26**, (348), 319–320).—New methods of chromium-plating camshafts, crankshafts, and cylinder bores are considered, and the reasons involving the adoption of such methods, the procedure in carrying out the new methods, and the types of deposits obtained are discussed. Consideration is also given to the grinding of chromium deposits to the speeds used, and to the most satisfactory type of grinding wheels. Graphs are given showing the rate of wear of cylinder liners so treated with the rates of wear of different cylinder materials.—J. W. D.

Anti-Friction Lead-Copper Alloys. M. A. Ricard (*Cuivre et Laiton*, 1936, **9**, (171), 127–130; and *Rev. Fonderie moderne*, 1936, **2**, (Feb.), 72–73).—Read before the Société des Ingénieurs de l'Automobile. A summary of the general properties of these alloys, their special characteristics as anti-friction metals,

the conditions under which they are employed and examples from actual use. The development of these alloys on a wider scale is discussed.—W. A. C. N.

Magnesium Alloy Sheets (Suitable for Welding). —— ((*Brit.*) *Air Min. Specification* No. **D.T.D. 120 A**, 1936, 2 pp.).—Replaces Specification No. D.T.D. 120; covers the materials generally known as Elektron AZM and Magnuminium alloy; (sp. gr. $\not>$ 1·83). Only simple bending or shaping operations can be made on this material without heating. Most operations can be successfully performed at a temperature of approx. 300° C., but the material must not be heated above 350° C.—S. G.

A New Hard Metal [Titanit-U]. H. Strauch (*Tech. Zent. prakt. Metallbearbeitung*, 1935, **45**, (5/6), 132).—The use of Titanit-U as a cutting medium is described.—W. A. C. N.

***Greenhouse Wires and Pipes Galvanized with Zinc React with Sulphur Dioxide to Form Soluble Zinc Salts.** K. J. Kadow, W. A. Ruth, and H. W. Anderson (*Phytopathology*, 1936, **26**, 609–610; *C. Abs.*, 1936, **30**, 5353).—Several instances of injury to greenhouse crops have been traced to the toxic action of soluble zinc salts which were added to the soil through the dripping of condensed moisture from wires and pipes corroded by sulphur dioxide fumigation. —S. G.

New Fields for Zinc Die-Castings. Herbert Chase (*Met. Ind.* (*Lond.*), 1936, **49**, (1), 11–13).—See also *Met. Abs.*, this vol., p. 282. Compares the present position of zinc die-casting in this country and America and indicates lines of future development. Large numbers of motor-car radiator grilles, up to 23 lb. in weight each show the size and intricacy of work now done. On the other hand machines capable of casting 1000 times per hr. produce small parts economically. Domestic applications are discussed, and the combination of die-castings with plastics is mentioned.—J. E. N.

The Uses of Non-Ferrous Metals. A. R. Powell (*Financial News*, **1936**, April 20, 9–10).—An account of the effect of metallurgical progress in extending the scope and nature of the uses of non-ferrous metals and alloys.—H. H.

Bearings on the German National Railway. —— Garbers (*Organ Fortschritte Eisenbahnwesens*, 1936, **91**, (14), 295–312).—An account of the design and lubrication of bearings is followed by a discussion of the qualities desirable in shells and bearing surfaces. The high brasses are preferred as shell-material, but recent restrictions on the use of copper have led to the introduction of steel-reinforced brass; this has been effected without modification of the actual shape of the shell. The use of copper–nickel–aluminium alloys is not advised, as causing excessive contamination in remelted scrap. No completely satisfactory bearing metal for railway use is known. The properties and method of running of the lead–alkali metal bearings in general use for coaches and of the tin-base white metal mainly used in locomotive bearings are described: an account is also given of the centrifugal casting and die-casting of bearings. Photomicrographs illustrate the influence of rotation speeds on centrifugal castings. The standard methods of testing are fully described.—P. M. C. R.

The Lining of Bearings. Edmund R. Thews (*Mech. World*, 1936, **99**, (2575), 465–466).—Some of the most important reasons for lining failures are discussed under the headings: (1) proper preparation of bearing surfaces; (2) sand-blasting, grinding, brushing, scratching, &c.; (3) cleaning of mechanically-treated surfaces; (4) etching of contact surfaces; (5) tinning of contact faces; (6) lining operation.—F. J.

Replacing Metals by Resins. —— (*Wool Record*, 1935, **48**, 1001–1005). —Laminated resinoid tubing has proved suitable for the construction of static eliminator bars for removing electrical charges developed in carding, warping, and weaving.—S. G.

XXII.—MISCELLANEOUS

(Continued from pp. 380-381.)

What Does the Recent Development in the Technique of Non-Ferrous Metallurgy Offer to the Iron Metallurgist? G. Masing (*Stahl u. Eisen*, 1936, **56**, (16), 457–465).—A general review of the progress of non-ferrous metallurgy and the points of contact with work on iron and steel, Among the subjects thus reviewed are: transformations, equilibrium diagrams, aluminium and its alloys, degassing, copper and its alloys, zinc ferromagnetic alloys, metallic coatings.—W. A. C. N.

Advance in Scientific Metallurgy. (Sir) Robert Hadfield (*Engineer*, 1936, **161**, (4196), 626–627).—Mainly a review of ferrous metallurgical progress, with special reference to alloy steels.—R. Gr.

Chemical and Metallurgical Industries in India. E. Spencer (*Indust. Chemist*, 1936, **12**, 254–256).—S. G.

The Non-Ferrous Mining and Metallurgical Industry in Spain. E. Jimeno and F. R. Morral (*Metals and Alloys*, 1935, **6**, (11), 317, 321).—S. G.

The Rôle of Patents in Modern Metallurgy. Anthony William Deller (*Metals and Alloys*, 1935, **6**, (11), 303–306).—S. G.

Charles Martin Hall. Francis C. Frary (*Trans. Electrochem. Soc.*, 1936, **69**, 39–43).—Address on the occasion of the 50th anniversary of the discovery of Hall's electrolytic process for the production of aluminium.—S. G.

The Early Beginnings of the Aluminium Industry. Arthur V. Davis (*Trans. Electrochem. Soc.*, 1936, **69**, 54–60).—Address on the occasion of the 50th anniversary of the discovery of Hall's electrolytic process for producing aluminium.—S. G.

The Aluminium Industry of Norway. Arne Bruick (*Aluminium*, 1936, **18**, (6), 231–233).—A brief history is given of the development and present position of the aluminium industry in Norway.—A. R. P.

Fifty Years' Progress in Research. Frederick M. Beckett (*Trans. Electrochem. Soc.*, 1936, **69**, 43–47).—Address on the occasion of the 50th anniversary of the discovery of Hall's electrolytic process for producing aluminium.—S. G.

The Operation of a Modern Research Laboratory in the Development of Aluminium Alloys. A. von Zeerleder (*Aluminium*, 1936, **18**, (7), 297–298).—A very large number of patents for aluminium alloys have been granted in most industrial countries but very few of the alloys have had any extensive practical applications. The reasons for this state of affairs are discussed and proper methods of testing new alloys are described.—A. R. P.

Aluminium and Magnesium. —— (*Financial News*, **1936**, (April 20), 16, 18).—Particulars are given of the world's producers, their capacity and organization, and estimated production statistics.—H. W. G. H.

The Metallurgy of Silver and Mercury. A. Gálvez-Canero (*IX Congr. internat. quim. pura applicada, Madrid*, 1934, **3**, 104–138; *C. Abs.*, 1936, **30**, 5535).—A historical review of Spanish metallurgical research and development of silver and mercury.—S. G.

Alloy Steel Metals [Vanadium, Titanium, Tungsten, Cobalt]. O. W. Roskill (*Financial News*, **1936**, (April 20), 15–16).—Gives the principal uses of the metals and brief details of their sources and production.—H. W. G. H.

Growth of the [British] Empire Zinc Industry. (Sir) Robert Horne (*Financial News*, **1936**, (April 20), 12–13).—A review of the progress of the scheme to develop an Empire zinc industry smelting Empire ore and to make the Empire independent of foreign supplies of zinc.—H. W. G. H.

The European and World Zinc Situation in 1935. O. W. Roskill (*J. Amer. Zinc Inst.*, 1936, **17**, 111–119).—S. G.

The Purposes and Objectives of the American Hot-Dip Galvanizers Association. T. M. Gregory (*J. Amer. Zinc Inst.*, 1936, **17**, 105–108; discussion, 108).—S. G.

Modern Research Methods. Clyde E. Williams (*J. Amer. Zinc Inst.*, 1936, **17**, 57–60; and (condensed) *Met. Ind.* (*Lond.*), 1936, **49**, (8), 187–188).—J. E. N.

Accidents Caused by Arsine in Industry. G. Batta, J. Firket, and E. Leclerc (*15me. Congr. chim. indust.* (*Bruxelles, 1935*), **1936**, 897–920; *C. Abs.*, 1936, **30**, 5677).—The symptoms of arsine intoxication, according to its gravity, are described; the order of magnitude of the toxic doses is indicated; methods proposed for the detection of arsine are reviewed; experiments on the evolution of arsine during the recovery of cadmium and during pickling are described, and measures are suggested for preventing this professional hazard. When arsenious compounds are precipitated by zinc powder in solutions containing approx. 5 grm. sulphuric acid per litre, arsine can be evolved in toxic amounts; the presence of sulphates in the solution decreases the evolution of arsine, and cadmium sulphate exerts an inhibiting influence. Increasing the acidity or increasing the temperature favours evolution of arsine. Precipitated arsenic sludge, when introduced in fresh acid solution, can be reconverted into arsine on addition of zinc dust. Cadmium seems to act as a retarder on the evolution of arsine when the acidity of the solution is low, but not in strongly acid solution. In *pickling zinc* by arsenic-containing acid, the evolution of arsine can reach 40 grm. in 30 minutes per sq. m. of zinc attacked.—S. G.

Reading Technical Matter. F. Young (*Mech. World*, 1936, **99**, (2579), 566).—A technique for the effective and speedy reading and comprehension of technical matter is described. A simple apparatus is used as an aid to concentration, and annotation and analysis advocated as aids to memory and future reference.—F. J.

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XXIV.—BOOK REVIEWS

(Continued from pp. 333–336.)

Métallurgie, a l'usage des Ingénieurs, Maitres de forges, Directeurs et contremaitres d'usines métallurgiques de fonderies de métaux, &c. Par R. Cazaud. (Agenda Dunod.) 52e. édition. 9·5 × 14·5 cm. Pp. xxiv + 323 + xcvi. 1936. Paris: Dunod. (Rel. pégam., 24.40 francs; France and colonies, 20.85 francs.)

This is a small handbook in which a multitude of metallurgical data is collected. The contents of its five sections may be summarized as follows: (1) fuels, refractories, furnaces heated by gas and electricity; (2) mechanical testing, thermal analysis, corrosion tests, microscopical and macroscopical examination; (3) pyrometric control, thermo-chemical treatment (cementation), general heat-treatment; (4) ferrous metallurgy; (5) non-ferrous metals and alloys. A section of 87 pages at the end of the book is devoted to a statement of legislation dealing with the control and protection of labour in France. This includes conditions governing apprenticeship, forms of contract, distribution of labour, strikes, professional classes, accidents, dangerous trades, hygiene, employment of foreign workers, factory inspection, night work, and employment of juveniles.—W. A. C. Newman.

Elementary Metallurgy for Engineers. By G. F. C. Gordon. Second Edition, Revised and Enlarged. Post 8vo. Pp. ix + 166, with 27 illustrations. 1936. London: Constable & Co., Ltd. (8*s*. 6*d*.)

The second edition of this useful book for young engineers and for those of more advanced knowledge has been revised and brought up-to-date to the extent of an additional ten pages. The chapter on the testing of materials has been augmented by notes on proof testing, creep tests, and a reference to the Vickers diamond hardness tester. A description of the cupola and of recent improvements in the cupola is added with advantage to the chapter on iron, while the chapter on the production of structural steels is improved by additional reference to basic Bessemer steel, electric steel furnaces, and to the production of clean steel free from non-metallic inclusions. A short paragraph on alloys, suitable for heating elements, and further information on high-tensile brass propellers are useful additions to the chapter on non-ferrous metals.

The revision and additions enhance considerably the value of the book in presenting to engineering students modern metallurgical knowledge in simple and brief outline.

—J. W. Donaldson.

Foundry Calculations and Drawing. By Leslie Booth. (Griffins' Industrial Textbooks. Edited by P. Longmuir.) Med. 8vo. Pp. ix + 133, with 71 illustrations. 1936. London: Charles Griffin and Co., Ltd. (4*s*. net.)

The sub-title of this book is "A Handbook for Moulders, Pattern Makers, and Students of Foundry Practice," and it certainly contains much that will be of real value to the student of foundry practice. To the average moulder with little or no scientific training, and whose mathematics are usually limited to simple arithmetic, it is not sufficiently elementary or explicit to be of any real help for private study. In the first introductory chapter he will find simple multiplication and division followed by logarithms and the use of the slide rule. In the second chapter he progresses from simple geometrical figures to trigonometry and solution of triangles. Such rate of progress surely implies some previous knowledge of this branch of mathematics.

In the foreword the editor says, "Intimate contact with foundry workers indicates a natural reluctance to work out an original sum," and this handling of the problems does not appear likely to offer much encouragement in overcoming this reluctance. The chapters on the con-

struction and use of graphs, sketching and drawing, weight estimation and calculations for foundry charges are written in the same concise style.

This little volume will be excellent to supplement a course of lectures on the subject but is too condensed to meet the requirements of all but the most exceptional moulders and pattern makers.—J. E. NEWSON.

Freiformschmiede. Erster Teil—**Grundlagen, Werkstoff der Schmiede, Technologie des Schmiedens.** Von F. W. Duesing und A. Stodt. Zweite, völlig neu bearbeitete Auflage des zuerst von P. H. Schweissguth bearbeiteten Heftes. (Werkstattsbücher für Betriebsbeamte, Konstrukteure und Facharbeiter. Herausgeber Eugen Simon. Heft 11.) Med. 8vo. Pp. 60, with 161 illustrations. 1934. Berlin: Julius Springer. (R.M. 2.)

This is the second edition of one of a series of technological handbooks which are remarkable for their clarity and comprehensiveness. The first section deals with the fundamental principles of forging in particular and of the flow of metals under compression due to dynamic forces in general. It is mostly abstracted from Siebel's book on a similar subject. In the second section steel suitable for forging is discussed. The effect of the structure on the course of deformation in all its phases is carefully detailed. There follow descriptions of various forging methods—forming, thinning, cutting, bending, twisting. A short chapter on welding is included. Illustrations to the number of 161 assist greatly in amplifying the text.

—W. A. C. NEWMAN.

Der Facharbeiter im Flugzeugbau. Von Richard Hofmann. Cr. 8vo. Band 4: **Der Leichtmetall-Schlosser.** Pp. 112, with 82 illustrations. 1935. (R.M. 2.10.) Band 5: **Der Flugzeug-Schweisser.** Pp. 89, with 53 illustrations. 1936. (R.M. 2.20.) Halle a. S.: Carl Marhold.

Der Leichtmetall-Schlosser.—The light alloys commonly used in Germany for aircraft work are enumerated, and the most suitable methods of machining and forming them are described. Drilling and tapping, milling, shearing, sawing, bending, folding, pressing, and riveting are dealt with. Tables of physical properties and machining data form an appendix.

Der Flugzeug-Schweisser.—The principles of oxy-acetylene, arc, and resistance welding of light metals are explained. Several proprietary soldering and brazing materials are described and instructions are given for using them. Various acetylene generators, distribution, and controlling devices are also described. Appended are tables of welding data.

These booklets are intended for the use of craftsmen who have not had previous experience in aircraft work, and will supply them with useful and up-to-date information. It is necessary, however, to issue the warning that undue emphasis is sometimes laid on matters of secondary importance.—H. W. G. HIGNETT.

Secondary Copper: Its Production, Consumption, and Market Effect. By Percy E. Barbour. Med. 8vo. Pp. vii + 85, with 11 illustrations. 1936. New York: Mining and Metallurgical Society of America, 90 Broad St. ($1.50.)

In 1931 Mr. Barbour presented a paper to the A.I.M.E. on "The Effect of Secondary Copper on the Metal Market," in which the official American statistics relating to primary and secondary copper were examined from a new angle, directing attention to the correct interpretation of many of the relevant facts and exploding a number of fallacies. Such a paper naturally aroused considerable interest and discussion, and the present work carries the investigation a stage further in the light of the present industrial situation. It is essentially a critical analysis of the official statistics of the secondary copper position in the United States, and the author is at some pains to distinguish between secondary metallic copper and secondary copper-bearing alloys such as brass, which return to industry unchanged in the alloyed state, but which have been included as secondary copper in the official figures. He suggests that the following definition would help to give a truer perspective: "Secondary copper is that copper metal reclaimed from scrap returned by industry to be retreated and refashioned into marketable forms."

Adopting this classification the author then reviews the production of secondary copper and its influence on the copper market, and directs attention to the increasing amounts of secondary metal now being handled by primary plants. Amongst the logical, well-reasoned conclusions which he reaches from his analysis, the following are of especial interest: "the quantity of secondary copper produced is involuntary and depends entirely on the progress of industry as a whole," and "Secondary copper has no effect on the market price of copper except in times of recession in industry as a whole and then only of minor importance." The price at which this little book is offered to non-members of the Society is very reasonable, and it is worthy of careful study by all interested in the production or buying of copper.

—J. E. NEWSON.

Handbuch der Dosenfertigung. Von Waldemar Friebel. 15 × 21 cm. Pp. 100, with 121 illustrations. 1936. Berlin: V.D.I.-Verlag G.m.b.H. (Br., R.M. 10; V.D.I.-Mitgl., R.M. 9.)

Technical literature contains little in the way of comprehensive reviews of the manufacture of the tinplate can, although the number of cans made throughout the world every year, for the conservation of food alone, amounts to many thousand millions. The present book, dealing with an important and expanding industry on which relatively little has been written, is therefore to be welcomed.

The book begins with a chapter on tinplate, with special reference to its requirements for can-making. The testing of tinplate is briefly described. Then follow chapters on the formation of the can body and soldering of the side seam, the stamping of the can ends, application of sealing compositions, and production of the double seam. Special consideration is given to the methods for examining and testing the seams of finished cans, and the main causes of faults are traced. Deep-drawn cans are dealt with in a separate chapter.

The treatment of the subject-matter is essentially practical, and the book is clearly intended to be used by those in charge of operations in the industry. The numerous illustrations and tables make the arguments and descriptions of processes particularly easy to follow, and there is no doubt that the book will be of the greatest use, not only to practical technicians, but also to all who are interested in the tinplate, can-making, and canning industries.—E. S. Hedges.

Sheet Metal Workers' Manual. By L. Broemel. Fcap. 8vo. Pp. 552, with numerous illustrations. 1935. Chicago, Ill.: Frederick J. Drake and Co. ($2.00.)

This book divides itself into three main parts: the first, comprising sections 1 to 6, consists of a description of the machinery and tools employed in sheet metal working and a course of practical instruction. The second part deals with the various welding methods (sections 7, 8, and 9), hand-forging (section 10), and brazing (section 11). The remaining sections are devoted to pipe bending, the properties of metals and alloys, practical geometry, and useful tables.

Although the descriptions of machinery provide opportunities for advertisement, which the author cannot resist completely, nevertheless they are clear and informative. The welding sections are not up-to-date; rightward welding, deoxidized copper, synchronous control of resistance welders, are notable omissions. The metallurgical section is too elementary and too brief to be of value. In sum, however, this book should be found useful by metal-working apprentices.—H. W. G. Hignett.

Industrielle Elektrowärme. Herausgegeben von der Wirtschaftsgruppe Elektrizitätsversorgung bearbeitet von —— Masukowitz unter Mitarbeit von —— Knoops. Teil 1.—**Entwicklung, Eigenschaften Wirtschaftlichkeit, Bedeutung, Bauformen.** 2. unveränderte Auflage. Pp. 1–63. Berlin: Arbeitsgemeinschaft zur Förderung der Elektrowirtschaft, Buchenstrasse 5 (W. 35).

This admirable little book is issued for the information of prospective furnace users by an Association in Germany for the promotion of electric heating. It has been prepared by two well-known authorities on electric furnace practice.

The development of electric heating is well portrayed by means of graphs and statistics. Then follows a description of the various types of plant for melting, heat-treatment, and electrothermal processes, while the advantages of these over fuel-fired methods of heating are cleverly illustrated by contrasting photographs and effective diagrams. The reader is also made acquainted with the principles of electric heating such as different types of heating elements, the various forms of insulation, methods of applying inductive heating, and so on.

The book does not aim to be anything more than an introduction to the subject—an object which it admirably fulfils. It is illustrated with some 99 photographs and diagrams while the printing and paper are good.—A. G. Robiette.

Étude des flammes de soudure, précedée d'un exposé sur les chaleurs spécifiques des gaz aux températures élevées. Par D. Séférian. Préface de G. Ribaud. Med. 8vo. Pp. 64, with 15 illustrations. Paris: Institut de Soudure autogène, 32 Boul. de la Chapelle (18e). (Broché, 12 francs.)

The first section of this booklet explains the thermodynamic calculation of high flame temperatures, emphasizing the value of recent work by Ribaud (who contributes a preface to the book) and Montagne on the specific heats of gases at high temperatures. Using the data provided by this work, and the results of spectrographic determination of the degree of dissociation of the products of combustion, Dr. Séférian calculates the temperatures of the oxy-

acetylene, atomic hydrogen, oxy-hydrogen, oxy-methane, and oxy-butane flames, comparing his results with those obtained experimentally and theoretically by other workers. A valuable summary of the practical implications and a bibliography of 36 references are given. The author concludes by pointing out the peculiar advantages of the oxy-acetylene flame for welding and paying a typically graceful tribute to the pioneers in its development.

It need scarcely be mentioned that no welder's library is complete without this little book.

—H. W. G. HIGNETT.

Forschungsarbeiten auf dem Gebiete des Schweissens und Schneidens mittels Sauerstoff und Azetylen. Zehnte Folge. Herausgegeben im Auftrage des Deutschen Azetylenvereins von W. Rimarski. 21 × 30 cm. Pp. 104, illustrated. 1935. Halle a. S.: Carl Marhold. (R.M. 4.)

This tenth collection of research reports contains the following papers (printed in German), which have previously been abstracted: "Welding of Zinc Sheet," by Hans A. Horn (*Met. Abs.*, 1935, 2, 447); "Lead Welding by the Oxy-Acetylene Flame," by F. Schulze and J. Staebler (*Met. Abs.*, 1935, 2, 363); "Researches on Jointing Aluminium to Other Metals," by H. Holler and —— Maier (*Met. Abs.*, 1935, 2, 447); and "X-Ray Examination of Gas-welded Copper Fireboxes," by W. Grimm (*Met. Abs.*, 1935, 2, 111).

In addition, there are papers on ferrous welding and on explosion risks in the use of acetylene. This volume, like its predecessors, is indispensable to all welders who have no access to the back numbers of *Autogene Metallbearbeitung*.—H. W. G. HIGNETT.

La Diffraction des Électrons dans ses Applications. Par Jean J. Trillat. (Actualités scientifiques et industrielles, No. 269.) Roy. 8vo. Pp. 59, with 6 plates and 13 illustrations in the text. 1935. Paris: Hermann et Cie. (18 francs.)

This monograph follows the author's equally commendable work "Les preuves expérimentales Mécanique Ondulatoire. Diffraction des électrons et des corpuscules matériels," published in the same series in 1934. M. J. J. Trillat, having himself contributed largely to the progress of this new technique, has in this work given us a clear and concise account, which affords a valuable introduction to a subject of great importance to the metallurgist, for in the application of electron diffraction we have an unrivalled method for the study of surface processes such as tarnishing and polishing, and a useful tool in the study of thin metallic films. The electron beam, in fact, besides giving independent confirmation of the results of X-ray investigation, supplies just those opportunities in the study of matter which are denied to the older method.

It is the first half of the book which is of particular interest to the metallurgist, since this is concerned with the general experimental technique of electron diffraction and its application to the study of metallic surfaces and thin metallic films. The remaining three chapters deal with the applications to the study of carbon, organic compounds, and free molecules (gases and vapours), and with the diffraction of slow electrons. The treatment is general and qualitative in the main, while for those who would proceed to a deeper study of the subject there is a useful bibliography at the end of the book.—PETER W. REYNOLDS.

Practical Photomicrography. By J. E. Barnard and Frank V. Welch. Third Edition, Demy 8vo. Pp. xii + 352, with 121 illustrations. 1936. London: Edward Arnold and Co. (21*s*. net.)

In the third edition of this well-known book (the second edition was reviewed ten years ago, *J. Inst. Metals*, 1926, 35), the authors have revised the text and added a considerable amount of new matter. The most interesting of the additions is perhaps the new chapter on "Photo-Micrography by Means of Ultra-Violet Light" a subject on which the authors, in view of Mr. Barnard's pioneer work, are so well qualified to write. In this chapter a brief account is given of the principles involved in the use of ultra-violet light and of the special apparatus required. The subject is illustrated by a plate of very fine photographs. A short section on the use of infra-red radiation is also now included. The book is mainly concerned with the photomicrography of biological subjects, but the photography of metal surfaces and opaque objects is also included and is dealt with more fully than in the previous edition. In this connection the authors acknowledge the assistance of H. Wrighton, and a few of his excellent photographs are used to illustrate this side of the subject.

Although not specially written for the metallurgist, this is a book which should be read and studied by all concerned with photography in connection with metallographic work.

—O. F. HUDSON.

Electrical Engineering in Radiology. A Treatise on the Nature and Function of Electrical Equipment for X-Ray Work in Medicine and Industry. By L. G. H. Sarsfield. With a Foreword by V. E. Pullin. Demy 8vo. Pp. xiii + 284, with 199 illustrations. 1936. London: Chapman and Hall, Ltd. (25*s*. net.)

This excellent book is described as a treatise on the nature and function of electrical equipment for X-ray work in medicine and in industry.

As a text-book it is made unusually interesting by the inclusion of many references to actual work done in the Radiological Research Department at Woolwich. The experience of the author in this field has resulted in the inclusion of valuable additional chapters on "Maintenance" and "Electrical Safety." So many metallurgical firms are installing X-ray equipment for the location of defects, that a text-book is necessary for the untrained worker who is called upon to manipulate such equipment. As usually happens the apparatus is chosen first, and some one with a ground-work of knowledge in physics is called upon to run the unit. This is a special line, and the new-comer will find this text-book an all-round guide to any kind of X-ray apparatus that he may be called upon to use. The chapters on "Maintenance" and "Electrical Safety" should answer all the new-comer's questions on these ever-present problems.—N. C. Hypher.

Die Allotropie der Chemischen Elemente und die Ergebnisse der Röntgenographie. Von M. C. Neuburger. (Sammlung chemischer und chemisch-technischer Vorträge. Begründet von F. B. Ahrens. Herausgegeben von R. Pummerer-Erlangen, Neue Folge, Heft 30.) Med. 8vo. Pp. 106, with 32 illustrations. 1936. Stuttgart: Ferdinand Enke. (R.M. 9.30.)

What exactly constitutes an allotropic change? Is the $\alpha \rightleftharpoons \beta$ magnetic transformation in iron an allotropic change or not? These and similar questions are old favourites, and many of us will remember them in school and University lectures and examination papers. To Dr. Neuburger the critical test is a change of crystal structure—"Die verschiedene Kristallstruktur ist somit das Kennzeichen der allotropen Modifikationen." In many cases, however, the allotropic changes are at high temperatures, and X-ray crystal analyses above and below the transformation temperature have not yet been carried out. In such cases Dr. Neuburger considers a discontinuity in the graph connecting a physical property with the temperature as evidence for an allotropic transformation. In the change from α to β cobalt, for example, when hysteresis effects are absent, the graph connecting the specific resistance with the temperature shows a discontinuity at the transformation temperature, in contrast to the magnetic transformation where the curve shows an abrupt change in direction, but no discontinuity. Discretion is necessary here, since if we plot, not the resistance, but the temperature coefficient of resistance against the temperature we shall obtain a discontinuity in the curve at the magnetic transformation, and some people may argue that the difference in temperature coefficients is sufficient to justify the use of the term allotropic change. To some extent this is a matter of definition, and if we accept Dr. Neuburger's point of view we can only express our gratitude for this extremely valuable book in which the evidence for the allotropy of the elements is summarized, with more than a thousand references to original papers. Each element is discussed in turn, and the conclusion from the viewpoint described above is then given, together with details of the crystal structure, and values of the lattice constants. These are mostly taken from Dr. Neuburger's "Gitterkonstanten für das Jahr 1936" (*Z. Krist.*, 1936, **93**, 1), and we notice that incorrect values for the interatomic distances in α-manganese are again reproduced; the correct values are given by Bradley and Thewlis (*Proc. Roy. Soc.*, 1927, [A], **115**, 456).

We can recommend Dr. Neuburger's book wholeheartedly, both for the interest of its subject-matter, and as a convenient source of references to original papers.—W. Hume-Rothery.

Electrical Engineering Materials, Tables, and Properties. By Frank G. Sublet. Cr. 8vo. Pp. 147. 1936. London: Oxford University Press (Humphrey Milford). (10*s*. 6*d*. net.)

This is a collection, mainly derived from trade catalogues and data sheets, of 123 tables selected as being of value to the designer and student of electrical engineering. Wire tables, current capacity tables for conductors and certain resistance wires, tables of conversion factors, and mathematical tables occupy most of the book. There is a brief preliminary section on the general properties of some selected materials—metallic and non-metallic. The tables are clearly printed, but it is doubtful whether they contain much which is not already conveniently available in many standard "pocket-books."—J. C. Chaston.

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