Contains papers 716 & 717
to be printed in the half-yearly volume:
*Journal of the Institute of Metals,*
1935, Vol. LVIII.

Vol. 2. Part 10.

# *The Monthly Journal of the*

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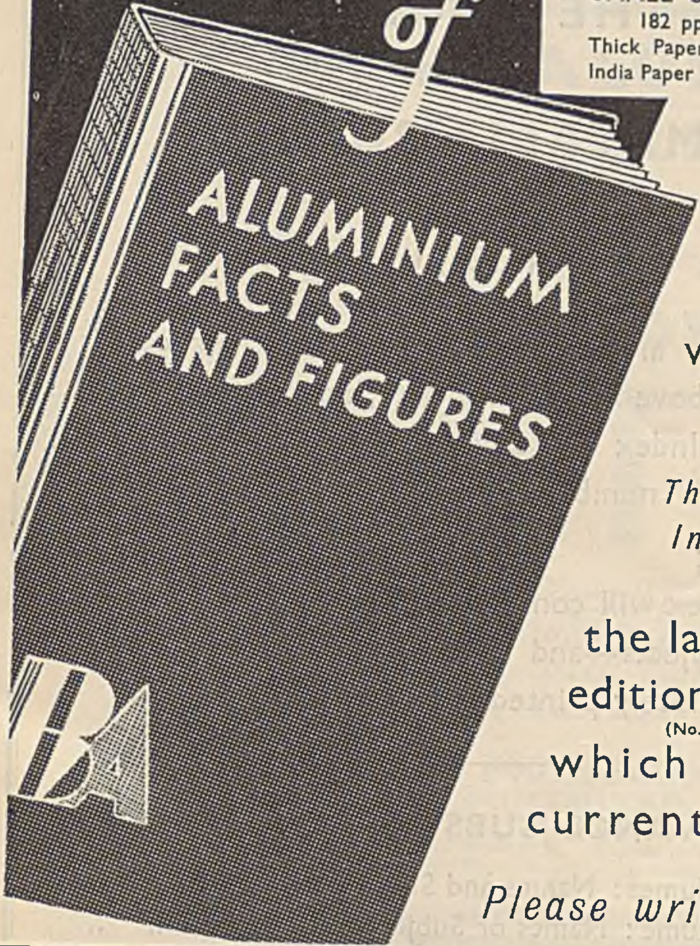
The Advertisements published in the Monthly Journal are increasing both in interest and in numbers, which may be taken as an indication that advertisers are coming to realize the particular value to them of the specialized circulation of the Institute's publications.

Advertisers judge the interest displayed in their advertisements by the enquiries received. Members are requested, therefore, when making enquiries of firms advertising in this publication, to mention the Monthly Journal of the Institute of Metals. By so doing they will be of service to the Institute.

*and*

# METALLURGICAL ABSTRACTS

OCTOBER, 1935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# GENERAL INDEX
TO
# THE JOURNAL
AND
# METALLURGICAL ABSTRACTS

Vols. 26 (1921) to 55 (1934)

Members are requested to order their copies of the above at an early date, as the publication of this Index can only be proceeded with if a sufficient number of orders are secured in advance.

The Index will consist of Two Volumes—Names and Subjects—and is expected to contain 1100 pages, closely printed in double column.

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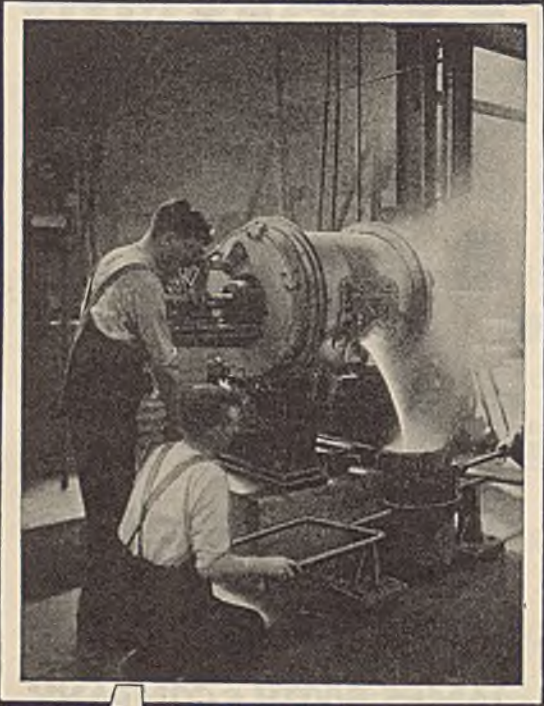

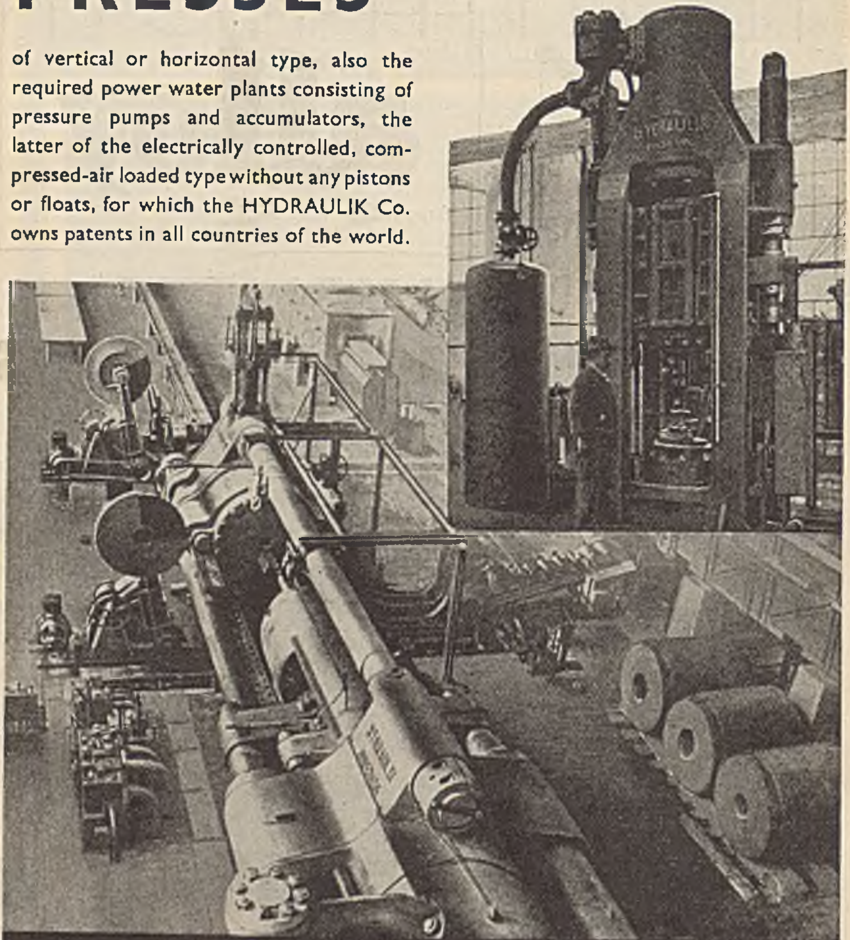

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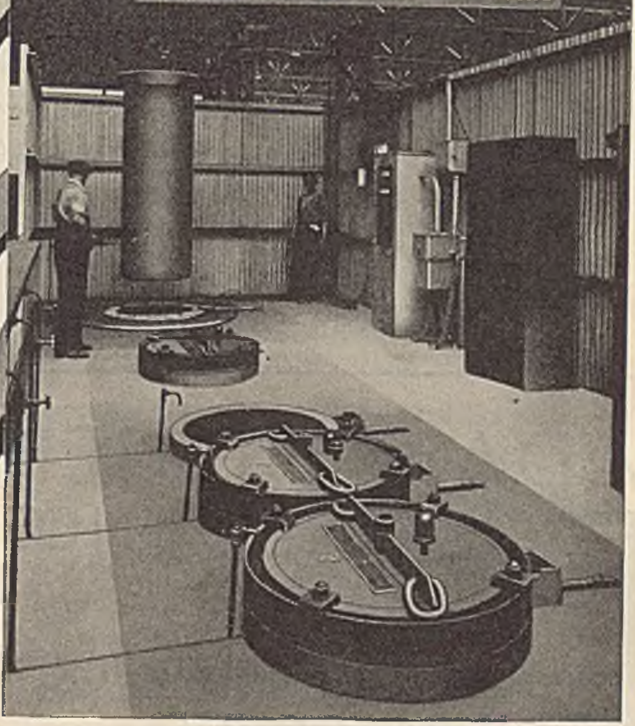

# a new service to members

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 Autumn Meeting, 1935, papers.

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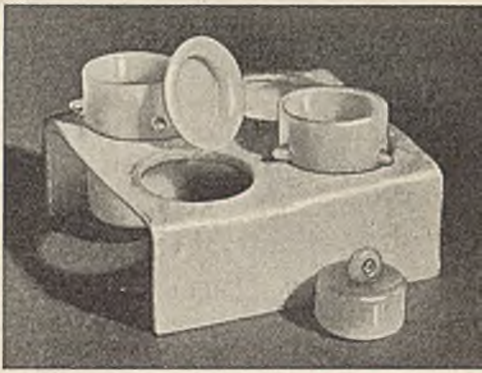


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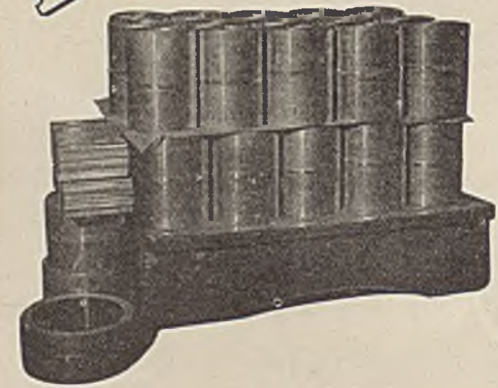
OCTOBER, 1935

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G. SHAW SCOTT,
M.Sc., F.C.I.S.

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Volume 2 OCTOBER, 1935 Part 10

## CONTENTS

### METALLURGICAL ABSTRACTS

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The monthly issue of *Metallurgical Abstracts* may be cut up for card indexes, as members will receive early in 1936 the year's abstracts in bound form.

# INSTITUTE NEWS AND ANNOUNCEMENTS

### Nomination of Officers for 1936–1937.

At the Newcastle meeting the Secretary read the following list of members nominated by the Council as Officers for the year 1936–1937. No other nominations have been received.

*President :*

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

*Vice-Presidents :*

H. W. Brownsdon, Ph.D., M.Sc.
Professor D. Hanson, D.Sc.
E. L. Morcom, M.A.

*Members of Council :*

Professor J. H. Andrew, D.Sc.
S. F. Dorey, D.Sc., Wh.Ex.
Kenneth Gray.
Lieut.-Colonel J. H. M. Greenly, C.B.E., M.A.
H. H. A. Greer, J.P.
J. L. Haughton, D.Sc.
D. J. Macnaughtan.
C. J. Smithells, M.C., D.Sc.
F. Tomlinson.

Biographical details of three of the above-mentioned members who are newly nominated to the Council are given on pp. 436–437.

### Newcastle Meeting Photograph.

Copies are now available of the photograph of members assembled at Armstrong College for the recent Autumn Meeting. The photographs can be obtained on application to Mr. C. E. Pearson, M.Met., Armstrong College, Newcastle-upon-Tyne. Orders should be accompanied by a remittance for 3*s*.

A reproduction of a photograph of a group of members, taken on the occasion of the visit to the Elswick Works of Messrs. Vickers-Armstrongs, Ltd., appears below.

### Next Month's Supper-Dance.

In co-operation with the London Local Section, the Council is arranging for a Supper-Dance to take place on Wednesday, November 27, at Thames House, Millbank, London, S.W.1. The dance will begin at 7.30 p.m. and will conclude at midnight. Tickets (price 6*s.* each) are obtainable from members of the London Local Section Committee, the Honorary Local Secretaries, or from the Secretary of the Institute. It would be of considerable help to the dance committee if members would make early application for tickets.

# NEWLY-NOMINATED MEMBERS OF COUNCIL

*[Photo: Elliot & Fry.*

### Dr. S. F. Dorey, Wh.Ex.

Born 1891. Educated at Owen's School, London. Served apprenticeship at Chatham Royal Dockyard, 1907–1913. Obtained Whitworth Exhibition and Lloyd's Register Scholarship in Marine Engineering at Armstrong College, 1912. Took the degree of B.Sc. at Durham University, with distinction in Engineering, 1914; the M.Sc. in 1922, and the D.Sc. in 1932.

Served in Great War, first as Second Lieutenant in the Durham Light Infantry, and subsequently as Engineer Sub-Lieutenant in the Royal Navy, finally being promoted to Engineer Lieutenant-Commander, 1914–1919.

Joined Lloyd's Register of Shipping as Engineer Surveyor, November, 1919, and after serving at Swansea, Glasgow, Bristol, and Greenock, was appointed in 1924 on the staff of the late Mr. H. A. Ruck-Keene, the Society's Chief Engineer Surveyor, and late Member of Council of the Institute of Metals. On the death of Mr. Ruck-Keene, was appointed Chief Engineer Surveyor to Lloyd's Register of Shipping, 1932. Has read a number of papers before various technical institutions, and is a Gold Medallist of the Institute of Marine Engineers, and also the North-East Coast Institution of Engineers and Shipbuilders. Besides being a Member of the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Iron and Steel Institute, and the North-East Coast Institution of Engineers and Shipbuilders, is a Vice-President of the Institute of Marine Engineers, and Member of Council of the Institution of Naval Architects and the British Association of Refrigeration, and also of the Institute of Welding.

### Lieut.-Col. J. H. M. Greenly, C.B.E., M.A.

Born July 25, 1885. Educated at Charterhouse and Trinity College, Oxford. Trained as Civil Engineer with Sir John Wolfe Barry & Partners.

During the War received the C.B.E., was promoted to Lieutenant-Colonel and twice mentioned in despatches, and in 1916 was seconded from his regiment, and appointed Deputy-Controller of Inspection of Munitions of War at the Ministry of Munitions.

In 1920 became Joint Managing Director of Messrs. William Foster, Pascoe, Grenfell & Co., copper manufacturers and smelters, and subsequently Joint Managing Director of British Copper Manufacturers, Ltd. Joined the Board of Messrs. Babcock & Wilcox, Ltd., in 1929, and became Chairman of the Executive Committee, and in 1932 Deputy-Chairman of the Company.

A Member of the Council of the British Non-Ferrous Metals Research Association, and the Institution of Engineering Inspection, of which he is a Past-President. Also a member of the Council of the Institute of Fuel, Chairman of the Coal Burning Appliance Makers' Association, Director and Deputy Chairman of Messrs. Alfred Bird & Sons, Ltd., and Director of Power Securities Corporation, Ltd.

### D. J. Macnaughtan.

Born 1890. First trained in engineering and electrical engineering (Silver Medal, City and Guilds, 1907). Subsequently studied metallurgy. Became associated for several years with the late Professor Arnold, F.R.S., in various metallurgical processes relating to welding, steel production, high-strength aluminium alloys, and electrolytic extraction of magnesium. Became technical chemist on the staff of Kings Norton Metal Company Ammunition Works, and was concerned with problems relating to metals and explosives.

Joined the staff of the Research Department, Woolwich, under Dr. H. Moore, 1917. Initially engaged on researches on steel, and later became head of the section dealing with corrosion and electrodeposition of metals. Apart from work for the Services, undertook extensive investigations for the Department of Scientific and Industrial Research and the British Non-Ferrous Metals Research Association. In association with the latter body carried out a series of investigations on tin coatings produced by hot-dipping and by electrodeposition. Was appointed Director of Research of the International Tin Research and Development Council, 1932.

One of the founders of the Electrodepositors' Technical Society of Great Britain and President during the years 1933–34–35. A Member of Council of the British Non-Ferrous Metals Research Association.

Has been for some years examiner in electrometallurgy for the City and Guilds of London Institute and has acted as external examiner for the University of London for the degree of Doctor of Philosophy (Ph.D.) in electrochemistry.

Has published much scientific work and given many lectures and addresses in this country and in the U.S.A. A number of contributions on researches of the International Tin Research and Development Council relating to bearing metals, bronzes, and tin alloys have appeared in the *Journal* of the Institute.

### Papers for the Journal.

Members are invited to submit papers for consideration by the Publication Committee with a view to their inclusion in the *Monthly Journal* and subsequently in the *Journal of the Institute of Metals*. Members are reminded that, as indicated in our last issue, papers in future will be accepted for publication in the *Journal* and not necessarily for presentation at any meeting. Papers for presentation and oral discussion at a meeting will be selected from those published in advance of the meeting, and written discussion will be invited on all papers published.

The first two papers to be issued under the new arrangement are contained in the present number of the *Monthly Journal.*

### Issue of Journal and Programmes.

Copies of *Metallurgical Abstracts,* Volume 1 (new series), and of the *Proceedings,* Volume LVI, No. 1, 1935, have now been dispatched; members who do not receive them should notify the Editor in order that the matter may be taken up with the carriers.

To all British members there have been sent copies of the Programmes of the Local Sections for the session 1935–1936. These include, for the first time, the programme of the Manchester Metallurgical Society, which is now in association with the Institute of Metals.

The Council trusts that members resident in areas where Local Sections exist will make a point of attending the meetings and of joining in the discussion of any papers in which they are interested.

### Overdue Subscriptions.

This issue of the *Monthly Journal* comes into the hands of those members only whose subscriptions for the current year, which became due on July 1 last, have been paid. Members whose subscriptions are still unpaid have received a letter from the Secretary reminding them of this fact and indicating that, pending the receipt of their subscriptions, their *Journals* are being withheld.

### Membership Additions.

The following were elected on July 18, 1935:

*As Members.*

Farabee, Professor Ray Littleton, B.S., Met.E., Alabama, U.S.A.

Swartz, Carl Errett, Ph.D., Cleveland, Ohio, U.S.A.

Wilkins, R. A., Rome, N.Y., U.S.A.

Winter, Herbert, Frankfurt-am-Main, Germany.

*As Student Member.*

Moorey, Ernest Henry St. Clair, Luton.

The following were elected on August 29, 1935:

*As Members.*

Barker, William John, London.

Barmé, Friedrich, Wuppertal-Barmen, Germany.

Bisiker, Ernest James, London.

Brown, William, Brentwood, Essex.

Calvet, Jean, Paris.

Cole, Carter S., New York City, N.Y., U.S.A.

Colley, Alfred George, Leeds.

Dennison, Major Gilbert, Birmingham.

Drake, Professor Ernest B., B.Ch.E., M.S., Detroit, Mich., U.S.A.

Ferris, Irwin James, B.Met.E., Armadale, Victoria, Australia.

Henbrey, Henry James, R.E., Sidcup.

Horlebein, Edwin W., Baltimore, Maryland, U.S.A.

Kawamura, Tadasu, B.Eng., Tatung Pienmen, Mukden, Manchoukuo.

Kennedy, Oswald, Newcastle-upon-Tyne.

Kermode, Donald, Bradford.

Linley, Anthony, B.Met., Assoc.Met., Sheffield.

Miyasima, Risiti, Moji, Japan.

Muniz, Lieut.-Colonel Antonio Guedes, Rio Janeiro, Brazil.

Pope, James Edward, New York City, N.Y., U.S.A.

Santiago, Manuel Cordeiro, Johannesburg, South Africa.

*As Student Members.*

Čturtečka, Anton, London.

McNeil, John Frederick, B.Met.E., Melbourne, Victoria, Australia.

Stewart-Jones, Edward Thorold, London.

# PERSONAL NOTES

Mr. J. H. Harris has been awarded the degrees of B.Sc., A.R.S.M., and the Bessemer Prize, as well as the Glorney Scholarship of the Royal School of Mines this year. In September he left England to take up a post as Assistant Chemist (Geological and Topographical Survey), Tanganyika Territory, British East Africa.

Mr. A. Glynne Lobley, M.Sc., General Manager of Messrs. Birmingham Electric Furnaces, Ltd., left on a business trip to the United States on September 18. He will take the opportunity of renewing direct contact with the company's American associates.

Mr. J. McNeil, A.R.T.C., who has acted as Honorary Secretary of the London Local Section since 1930, is leaving The Mond Nickel Company, Ltd., at the end of this month for India to take up a post as Assistant Works Manager at the Metal and Steel Factory, Ishapore. He will be greatly missed by his many friends in this country, and particularly by the members of the London Local Section whom he has served so well.

Mr. J. G. Pearce, M.Sc., was married on September 7 to Miss May Isabel Wallace, M.B., Ch.B., D.P.H., of London.

Mr. J. S. Glen Primrose, A.R.T.C., has been appointed as metallurgist to the Rover Company, Ltd., of Coventry and Birmingham. He has been provided with a newly-equipped metallurgical department at the company's works in Tyseley, Birmingham. Mr. Primrose, who is an original member of the Institute, hopes to take an active part in the meetings of the Birmingham Local Section.

Mr. E. C. Rollason, M.Sc., has relinquished his post of lecturer at the County Technical College, Wednesbury, to take a similar appointment at Birmingham University. He has recently accepted the office of Secretary of the Staffordshire Iron and Steel Institute.

# LETTERS TO THE EDITOR

## Effect of Cold-Working on Density.

I read with interest the letter from Dr. O'Neill which appeared in the July issue of the *Journal*. It prompts me to point out that a study of the literature relating to this subject makes it clear that considerable interest was shown in it during the period 1858–1861, at which time David Kirkaldy was conducting for Messrs. Napier numerous experiments, the results of which were published in the second volume of the Institution of Engineers in Scotland, in a paper read before the Scottish Shipbuilders' Association in 1861, and more particularly in Kirkaldy's book, "Experiments on Wrought Iron and Steel," which first appeared in 1862.

From the second edition of Kirkaldy's classic (1863) I quote the following paragraph :

"Dr. Robison, in *The Encyclopædia Britannica* (vol. XX, p. 756) remarks, 'It is a very curious and inexplicable fact, that by forging a metal, or by frequently drawing it through a smooth hole in a steel plate, its cohesion is greatly increased. This operation undoubtedly deranges the natural situation of the particles. They are squeezed closer together in one direction, but it is not in the direction in which they resist the fracture. In this direction they are rather separated to a greater distance. The general density, however, is augmented in all of them except lead, which grows rather rarer by wire-drawing; but its cohesion may be more than tripled by this operation. Gold, silver, and brass have their cohesion nearly tripled; copper and iron have it more than doubled. In this operation they also grow much harder. It is proper to heat them to redness after drawing a little. This is called *nealing* or *annealing*. It softens the metal again, and renders it susceptible of another drawing, without risk of cracking in the operation.' The writer's experiments on iron 'cold-rolled,' already referred to in Section XIII (168), confirms the accuracy of the above statement in so far as regards the increase in cohesion and in hardness. Dr. Robison, however, was in error in stating that 'the general density is augmented'; and the similar statement by Dr. Fairbairn. that 'the iron is consolidated' by the process, will now be shown to be incorrect in point of fact. The specific gravity of a bar (1687) in the ordinary condition was 7·6360; the mean specific gravity of four pieces (1690–1693) cold-rolled was 7·5824; that of two pieces of boiler-plate (1730, 1731) in the ordinary condition was 7·5664; and that of two other cold-rolled pieces (1732, 1733) was 7·5392. Instead of an *increase* we have a *decrease* in the specific gravity of 0·70 per cent. in the bar specimens, and 0·36 per cent. in the plate specimens, produced by the process of cold-rolling. The writer will now give proof of this fact in another form, by comparing the cubic contents of a bar previous to and after undergoing the process, thus:

| | Diameter. | Area. | Length. | Cubic Contents. |
|---|---|---|---|---|
| Ordinary state . | 0·825 | 0·5310 | 35·06 | 18·6168 |
| Cold-rolled . . | 0·764 | 0·4584 | 40·94 | 18·7669 |

We have here an *increase in the bulk* of this specimen of 0·1501 cubic inches, or 0·86 per cent."

This paragraph is followed in Kirkaldy's book by a reference to a paper which appeared in *The Engineer* for February 1, 1861, by a Mr. John Daglish, "On the Cause of the Loss of Strength in Iron-wire when Heated," from which the following (because of its application to the matter now under discussion) may be quoted:

"It will be observed that the specific gravity of hard-drawn wire (6 — 7·58) is less than that of forged iron (4 — 7·74), showing that in forging the iron is more consolidated than in drawing, although its tensile strength is much less."

Yet another early reference to the effect of cold-work on the density of an aggregate of iron was made by me in a series of articles which appeared in *The Metal Industry* in 1919, and from which the following is taken:

"As far back as 1860 the fact that certain samples of cold-rolled iron were less dense than were other samples of the same iron rolled hot was noted by Wade and Metcalf (*vide* discussion of paper by Field—*Bull. Am. Inst. Min. Eng.*, 1903, 571). It was found that the increase of length due to the rolling of clean pickled hot-rolled bars more than compensated for the reductions in area to which they had been subjected during the process of cold-rolling."

It would appear from the foregoing that if the discovery that severe cold-working reduced the density of an aggregate of iron did not precede the discovery that plastic deformation lowers the specific gravity of copper, it was not long delayed thereafter.

It may be of interest, in closing to quote certain of the conclusions at which Kirkaldy arrived, regarding the effect of plastic deformation upon the density of iron.

"61st. The specific gravity is found generally to indicate pretty correctly the quality of specimens.

"62nd. The density of iron is *decreased* by the process of wire-drawing, and by the similar process of cold-rolling, instead of *increased*, as previously imagined.

"63rd. The density in some descriptions of iron is also decreased by additional hot-rolling in the ordinary way; in others the density is very slightly increased.

"64th. The density of iron is decreased by being drawn out under a tensile strain, instead of increased as believed by some.

"65th. The most highly converted steel does not, as some may suppose, possess the greatest density.

"66th. In cast-steel the density is much greater than in puddled-steel, which is even less than in some of the superior descriptions of wrought-iron."

O. W. Ellis.

Toronto, Ontario.

### Mr. J. McNeil.

Members of the London Local Section will learn with very real regret that Mr. J. McNeil, who has acted as Honorary Secretary since 1930, will be leaving England in the autumn. I feel sure that they would not like him to go without an expression of their appreciation of the good work he has done for the Section. As he will be leaving to take up his new appointment near Calcutta before our first meeting I should be glad if you would allow me space in your columns to pay a tribute to his work. Mr. McNeil has all the qualities of the perfect Secretary and has placed them unreservedly at the disposal of the Section. The steady increase in attendance at meetings is largely the result of his influence. The office of Chairman has been robbed of most of its terrors whilst he has been Secretary. Mr. McNeil takes with him our sincere wishes for success and happiness in his new sphere of activity.

C. J. Smithells,
*Chairman*
*London Local Section.*

Wembley.

# LOCAL SECTIONS NEWS

## SYNOPSES OF PAPERS TO BE READ AT COMING MEETINGS *

### Birmingham Section.

**The Production and Control of Bronze Castings.** By F. W. Rowe, B.Sc. (*October* 24.)

Selection of raw materials; melting furnaces, moulds and moulding material; soundness and physical properties as related to moulding methods and casting temperatures; centrifugal casting and other special methods.

### London Section.

**The Ultimate Strength of Metals.** By Professor E. N. da C. Andrade, D.Sc., Ph.D., F.R.S. (*November* 7.)

The study of the mechanical properties of single crystals of metals must be the first step towards a systematic understanding of the strength of the conglomerates of crystals that constitute metals as known in industry. Perhaps the most astonishing thing about metal single crystals is their extreme weakness, for they slip on certain planes under stresses about one hundredth of the shear-strength of the metal in bulk, and, in general, the purer the metal the softer are the crystals. It is not that perfect crystals are notably weak, but rather that ordinary crystals of pure metals have certain inherent faults which constitute sources of weakness, and readily extend under stress until blocked by features which have to be considered. The mechanism of flow in metal crystals has been studied in great detail in certain cases, and

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

some advance has been made towards an understanding of the hardening that takes place. The extension of the single crystal results to a polycrystalline mass presents grave difficulties, but is likely to be fruitful in practical results in the future.

### Manchester Metallurgical Society.

At the Joint Meeting with the Institute of Metals on November 6 there will be re-presented for discussion the following papers that formed part of the programme of the recent Autumn Meeting of the Institute held in Newcastle-upon-Tyne :

Lewis, K. G., M.Sc., and U. R. Evans, M.A., Sc.D. : **Corrosion below Discontinuous Oxide Coatings, with Special Reference to Magnesium.**

Sutton, H., M.Sc., and L. F. Le Brocq, B.Sc. : **The Protection of Magnesium Alloys Against Corrosion.**

### North-East Coast Section.

**The Manufacture of Zinc.** By Stanley Robson, M.Sc. (*November* 12.)

The paper will deal with the general characteristics of the commercial metal and the ores from which it is extracted. It will summarize the uses to which the metal is put and the trend of its application to industry and the arts. Samples of the commercial metal in its various forms, its ores and alloys will be exhibited.

The processes for preparing the ores for distillation and wet extraction by electrolytic means will be described and a brief account given of the recovery of sulphuric acid from the roasting process. Various furnace processes for the recovery of zinc from its ores will be discussed and illustrated by diagrams and slides. Reference will be made to the electrolytic process of both the wet and fused electrolytic types.

### Sheffield Section.

**Rolled Gold and its Industrial Applications.** By Ernest A. Smith, A.R.S.M. (*November* 8.)

Rolled gold may be described as a veneer of alloyed gold overlaid on base metal. Formerly known as plated metal, the name was subsequently changed to rolled gold to distinguish it from electro-gilded metal. Its chief industrial applications are in the imitation jewellery and optical trades. After a brief historical survey of its beginnings and active development in the nineteenth century, an account will be given of the methods of manufacture, both past and present, together with its mechanical properties and the technique employed in its fabrication in modern works' practice. Its varied uses for imitation jewellery manufacture, and in the optical and other industries, will be fully dealt with, with the aid of suitable lantern slides.

### Scottish Section.

On November 11, Dr. J. W. Donaldson will deliver his Address as Chairman of the Section. He will deal with "Research and the Non-Ferrous Industry."

### Swansea Section.

Mr. Roosevelt Griffiths, M.Sc., Chairman of the Section, will give his Inaugural Address on November 12, on the subject of the aims and objects of the Local Section of the Institute of Metals; this will be followed by an informal reception.

# THE TRANSFORMATION IN THE COPPER–GOLD ALLOY $Cu_3Au$.*

By C. SYKES,† Ph.D., and H. EVANS,‡ Assoc.Met.

## SYNOPSIS.

The effect of the transformation in the alloy $Cu_3Au$ on the electrical resistance, X-ray structure, and specific heat has been investigated experimentally, and it is shown that the general character of the transformation is satisfactorily predicted by the Bragg–Williams theory of the formation of super-lattices by atomic rearrangement.

The atomic rearrangement process involves first the formation of small nuclei having a relatively high degree of order. These nuclei then grow to a size approximating to that of the individual crystals, if a constant temperature is maintained. If, however, the alloy is continuously cooled before it attains equilibrium, two processes proceed simultaneously, then nuclei tend to grow, and at the same time the degree of order in the nuclei increases owing to the reduction in the temperature.

The existence of such nuclei is not considered in the statical theory of super-lattices, so that it is not surprising to find that the theoretical predictions regarding the rate of relaxation into the equilibrium state are not in agreement with experiment.

THE alloys of copper and gold exhibit certain interesting solid transformations at compositions approximating to $Cu_3Au$ and CuAu. Since the discovery of these transformations in 1916,[1] a large number of investigations have been carried out regarding them, and the experimental work prior to 1931 is adequately described in two papers [2, 3] published in this *Journal* in that year. At temperatures above 400° C. the alloys, through the whole range, form an uninterrupted series of solid solutions up to the melting point, the lattice is face-centred, and the gold atoms are distributed at random amongst the copper atoms. On cooling below 400° C., alloys around the compositions CuAu and $Cu_3Au$ exhibit certain discontinuities in physical properties such as electrical resistance and heat content. In the case of the alloy range $Cu_3Au$, the face-centred lattice persists, whilst in the alloy range CuAu the lattice becomes tetragonal.[4] In both cases the random distribution of atoms

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* Manuscript received July 18, 1935.

† Physicist, Research Department, Metropolitan Vickers Electrical Company, Ltd., Trafford Park.

‡ Metallurgist, Research Department, Metropolitan Vickers Electrical Company, Ltd., Trafford Park.

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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. LVIII, 1936. Reference should accordingly be as follows: *J. Inst. Metals*, 1936, 58 (Advance copy).

amongst the atomic sites is replaced by a more or less regular arrangement, and X-ray photographs exhibit super-lattice lines.

The transformation, as depicted by electrical resistance measurements, is affected very considerably by the cooling and heating rates used, and there are considerable hysteresis effects at the critical temperature of the transformations; *i.e.* the temperature at which the transformation starts on cooling, being in general appreciably lower than the temperature at which it ends on heating. Quenching from 400° C. suppresses the transformation in both ranges of alloys. Even at very slow rates of cooling (1° C. per hr.) the transformations persist over a considerable temperature interval.

The behaviour of these alloys appeared to be quite different from that usually associated with a phase-change, and the lack of any such change in $Cu_3Au$ indicated that a new type of transformation had been discovered. Recently a number of theoretical papers,[5, 6, 7] have appeared which purport to explain the phenomena in a quantitative manner. These various theories are in general agreement, so that the authors propose to quote particularly from the work of Bragg and Williams.[5]

"Differences between the atoms of metals forming an alloy tend to cause atoms of the one kind to segregate into certain particular sites forming an orderly arrangement because such an arrangement has a lower potential energy than that of disorder. Thermal agitation has the opposite effect of creating a random arrangement. The actual state of dynamical equilibrium of an alloy is one in which the two processes balance."

The face-centred lattice of the alloy $Cu_3Au$ may be regarded as four interpenetrating cubic lattices; in the perfectly ordered state all the gold atoms are on one of these lattices, the remaining three lattices being occupied by copper atoms. In general, the lattice is not perfectly ordered, and Bragg and Williams define the degree of order $s$ by the equation:

$$s = \frac{p - r}{1 - r} \qquad . \quad . \quad . \quad . \quad . \quad (1)$$

where $r$ is a fraction which in the case of $Cu_3Au$ equals $\frac{1}{4}$ and gives the proportion of ordered positions in the lattice, and $p$ is the probability that an ordered position is occupied by a gold atom. When an atomic exchange takes place so that a gold atom replaces a copper atom and thereby increases the degree of order, energy is released. If it be assumed that the amount of energy given up is proportional to the degree of order existing at the time, then relations between the degree of order and temperature can be established. From such relations it appears that although order sets in rapidly just below the critical temperature there is no real lower limit to the transformation, *i.e.* perfect order is theoretically possible only at absolute zero of temperature.

The actual degree of order existing in any alloy at a given temperature depends on a variety of factors, in particular the thermal history of the specimen, and is only equal to the equilibrium degree of order in special circumstances. The rate of approach to the equilibrium state has also been treated theoretically by Bragg and Williams, who have considered an alloy at a temperature $T$ whose degree of order is slightly different from that corresponding to dynamic equilibrium at temperature $T$ and corresponds to the equilibrium degree of order at a different temperature $\theta$. They assume that the rate of approach to equilibrium is given by

$$\frac{d\theta}{dt} = -\frac{\theta - T}{\tau} \quad . \quad . \quad . \quad . \quad (2)$$

where $\tau$, the time of relaxation, is the time taken for the departure from equilibrium to be reduced to $\frac{1}{e}$th of its original value. The time of relaxation obeys a relation $\tau = Ae^{\frac{W}{KT}}$ where $A$ is effectively a constant having a computed value of $10^{-12 \pm 3}$ and $W$ is the activation energy required for the interchange of atomic positions.

Most of the experimental work hitherto carried out on order–disorder transformations has given results unsuitable for direct comparison with the theoretical work, and it seemed desirable to carry out further experiments specifically to check the theoretical predictions.

The transformation in $Cu_3Au$ was chosen since the previous results indicated that the magnitude of the changes in physical properties produced by the transformation were large, and further they were not complicated by any change in lattice type.

Publications by other investigators subsequent to 1931 on $Cu_3Au$ will be described at appropriate points in this paper.

As a result of the present authors' experiments, it is shown that the general character of the transformation is predicted satisfactorily by theory and that alloys relaxing into equilibrium at constant temperature obey a relation of the type

$$\tau = Ae^{\frac{W}{KT}} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

A considerable amount of information has also been obtained about the rearrangement process itself.

The theory considers the degree of order in a crystal and makes the tacit assumption that this is the same as the degree of order over short distances. Such an assumption is, of course, correct when the alloy is in equilibrium, but it appears that only in special circumstances is the degree of order uniform over the whole crystal if the alloy is not in equilibrium. The first stage in the transition from disorder to order involves the production of nuclei, *i.e.* small volumes which have a degree of order corresponding to the equilibrium degree of order at the temperature of the specimen. If the temperature is held constant these nuclei grow until they become of the same order of size as the crystals themselves. In such conditions a formula of the type $\tau = Ae^{\frac{W}{KT}}$ holds for the relaxation. If, however, the alloy is continuously cooled before it attains equilibrium, two processes proceed simultaneously; the nuclei tend to grow, and at the same time the degree of order in the nuclei increases owing to lowering of the temperature. The latter effect involves changes in structure over very small distances, and so persists to a lower temperature than the former. In these conditions the value of $\tau$ and its dependence on temperature is different from that predicted by theory. Once the alloy has become thoroughly ordered throughout it is no longer possible to produce nuclei in it unless it is again disordered; the structure changes as a whole. A variety of interesting experimental results can be explained by the presence of these nuclei.

## I. EXPERIMENTAL ARRANGEMENTS.

### *Materials.*

Two alloys were used, one in the form of wire for resistance and X-ray measurements, and the other in the form of a cylinder for specific heat measurements. The first alloy in the form of 1 mm. diam. wire was obtained from Johnson Matthey & Co., Ltd., and according to them had a composition 50·92 per cent. gold and 49·08 per cent. copper. The authors' check analysis gave 50·88 per cent. gold and 49·10 per cent. copper; the mean is almost 25·05 atomic per cent. gold. Haughton and Payne[2] showed that variations in the transformation temperature can be produced by the presence of small amounts of oxygen. In the alloy in question the total impurity is certainly less than the analytical error ± 0·05 per cent., so that the results are not likely to be in error for this reason.

The 1 mm. wire was annealed at 825° C. *in vacuo* for 4 hrs. to remove coring and the effects of cold-work. X-ray specimens in the form of wire 0·4 mm. diam. were drawn from the 1 mm. wire and then annealed *in vacuo* at 670° C. for 2 hrs. In this latter case it was desired to remove lattice distortion without producing excessive crystal growth. In view of the fact that the atomic transformation persists at temperatures as low as 250° C., it is interesting and rather remarkable that such a high temperature, *viz.* 670° C., is necessary to remove lattice distortion.

The specimen used for specific heat measurements was a cylinder whose overall dimensions were 1½ in. diam. and 1¾ in. long. It was made by Mr. A. R. Raper, of the Mond Nickel Refinery, Acton, who kindly loaned us the alloy. The specimen after machining was heated to 825° C. and soaked for 20 minutes to remove coring. The analysis was 24·91 atomic per cent. gold.

### *Resistivity–Temperature Curves. Experimental Procedure.*

As has been stated, the change from the disordered to the ordered structure produces a considerable change in electrical resistance, and measurements of this very convenient parameter have been used to follow the transformation. In the course of the investigation it was necessary to determine the resistance in the following conditions:

(*a*) as a function of the temperature at a constant rate of cooling,
(*b*) as a function of the time at constant temperature, and
(*c*) as a function of temperature during quenching.

With regard to (*a*) and (*b*) the specimen in the form of a 1 mm. wire about 12 cm. long was spot-welded to two leads of a 3-electrode valve pinch. Thin nickel wires (0·4 mm.) were spot-welded at points on the specimen approximately 10 cm. apart and welded to the other two leads passing through the pinch.

For experiments of the type (*a*) this electrode arrangement was sealed into a glass tube containing two small tubes which extended outside the furnace used for heating the specimen. By this means a thermocouple could be used, the junction of which was in close proximity (2 mm.) to the specimen, and further, hydrogen could be circulated round the specimen to ensure a reducing atmosphere and also to minimize temperature differences between specimen and thermocouple.

In experiments of the type (*b*) the duration of the test was in certain cases as long as 600 hrs., and hydrogen circulation was not convenient. In such cases the specimens were sealed into a glass tube evacuated and sealed off. The thermocouple was placed outside the tube, but this introduced no errors since the temperature was kept constant.

Specimens of both types (*a*) and (*b*) were heated in a Nichrome-wound furnace. Between the furnace and the specimen were three copper tubes thermally insulated from one another, the furnace, and the specimen. They acted as radiation screens and eliminated temperature gradients over the length of the specimen; measurement showed that from one end of the specimen to the other the gradient was less than ⅛° C. under steady conditions. In order to control the temperature of the furnace a platinum resistance thermometer was used in the manner * described by Cooke and Swallow.[8] This was placed between the outer copper cylinder and the furnace tube, and short-time fluctuations in temperature thus eliminated by the radiation screens. Over intervals of 1 day the *maximum* temperature variation was not more than ± ⅛° C. whilst over periods of a week it was ± ⅜° C.

Resistance measurements were made by passing a known current through the specimen and measuring the potential difference decrease across a known length by means of a potentiometer. Readings could be repeated to ± 0·1 per cent. The residual thermal e.m.f. across the specimen due to temperature gradient, inhomogeneity in the leads, and stray thermal junctions was never greater than 0·05 mv. and was about 0·25 per cent. of the total e.m.f. measured. It could be measured directly and a correction made. The determination of the absolute value of the resistivity requires an accurate knowledge of the length of specimen. With the type of specimen used, involving welded potential leads, the absolute accuracy is limited to about 0·5 per cent.

The specimens used for the determination of resistance–temperature curves during quenching were straight wires sealed into close-fitting glass tubes. Resistance measurements were made after quenching, using a knife-edge arrangement for the potential determinations.

## II. RESISTIVITY–TEMPERATURE CURVES.

### (a) *General.*

Fig. 1, curve (*a*), gives the change in resistivity produced by cooling at 30° C. per hr. from 500° C. to room temperature. Two sets of experimental determinations on different specimens are shown to demonstrate the exact reproducibility of this type of curve.

Fig. 1, curve (*b*), shows results obtained by cooling from 500° to 390° C. at 30° C. per hr., then the cooling rate was reduced to 1° C. per hr. until the transformation started at 381° C. The specimen was then cooled at small temperature intervals with suitable soaking periods to 350° C. in 100 hrs. From 350° to 175° C. the cooling time was 100 hrs. and from 175° C. to room temperature about 6 hrs.

Fig. 1, curve (*c*), shows the probable curve of resistivity against temperature for an alloy during quenching from 425° C., the resistivity at 20° C. being $11{\cdot}5 \times 10^{-6}$ ohms/c.c.

It is clear from the three curves that the *slower the rate of cooling* the

---

* This is a very satisfactory device.

*lower the final resistivity.* At temperatures above 385° C. (*D–C*), where the alloy is in the disordered state, all three curves coincide. The temperature at which the resistivity begins to decrease rapidly, at the point *C*, depends to a certain extent on the cooling rate and will be dealt with in detail in Section II (*b*) of this paper. Referring to Fig. 1 (*a*), the temperature coefficient is constant from *B–A*, the position of *B* cannot be fixed exactly, but it occurs at about 250° C. for a cooling rate of 30° C. per hr. It does not correspond to the *completion* of the process, since the final resistivity is lower if the cooling rate is reduced below 30° C. per hr., cf. Fig. 1 (*b*). On the other hand, so far as the result of the experiment depicted in Fig. 1 (*a*) is concerned, the transformation *ends* at *B*. This can be seen from Fig. 2, which gives the relation between the resistivity at room temperature of the alloy as quenched plotted against the quenching temperature. The specimens were cooled from 450° C. to the quenching temperature at 30° C. per hr.

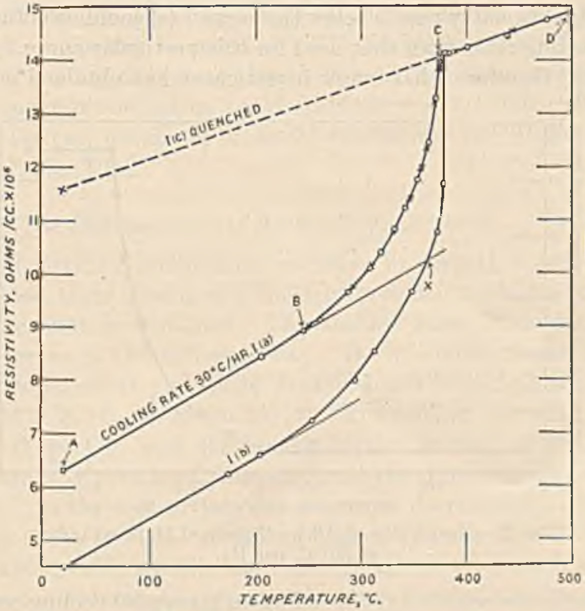

FIG. 1.—Resistivity–Temperature Curves.

*B* must correspond to that point at which the rate of atomic interchange becomes so small that the alloy is effectively frozen and further ordering of the structure cannot proceed. The position of *B* will vary, depending on the cooling rate; at high rates of cooling, for example, *B* will coincide with *C*. For rates slower than 30° C. per hr., *B* should, and does, move to the left, cf. Fig. 1 (*b*). The authors have elaborated this point, since various previous investigators [2, 10] have considered that *B* denoted the completion of the transformation. At temperatures between *C* and *B* they have postulated two phases, below *B*, a single phase. So far as the *equilibrium diagram* is *concerned*, the *point* B has *no particular significance.*

By suitable choice of heat-treatment the alloy can be prepared in a condition corresponding to any point between the curves 1 (*b*) and 1 (*c*), and presumably points below the curve 1 (*c*) could be obtained with slower cooling rates than that used for this particular curve. It is not surprising, therefore, that every investigator has obtained a different end value for the resistivity, depending on his special cooling conditions. For example, Haughton and Payne [2] found $7 \times 10^{-6}$ ohms/c.c. for the slowly-cooled alloy; presumably the cooling rate must have been faster than 30° C. per hr. Results which can be directly compared with this work have been published by Sachs and Weerts [9] and by Grube, Schönmann, Vaupel, and Weber.[10] Sachs and Weerts, after annealing an alloy at 325° C. for 10 days found a resistivity at room temperature of $4{\cdot}7 \times 10^{-6}$ ohms/c.c., whilst Grube and his co-workers who cooled their alloy in 60 days from 440° to 40° C. found $4{\cdot}15 \times 10^{-6}$ ohms/c.c., which so far as the present authors can ascertain is the lowest value published. Again, these variations are due to the heat-treatment, since the present authors' results on the disordered alloy are in good agreement with those of both the above-mentioned investigators. Sachs and Weerts found $11{\cdot}4 \times 10^{-6}$ ohms/c.c. for the disordered alloy at room temperature, cf. the authors'

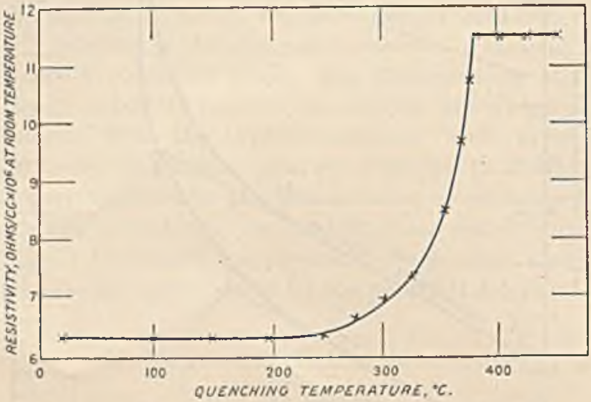

FIG. 2.—Resistivity of Alloys Quenched During Cooling at 30° C. per Hr.

value of 11·5; whilst Grube and his co-workers gave $14{\cdot}35 \times 10^{-6}$ ohms/c.c. for the resistivity at 400° C., cf. the authors' value of $14{\cdot}2 \times 10^{-6}$. Grube's curves were taken on heating (10° C. in 25 minutes—approximately 30° C. per hr.), and he found the point $B$ at 250° C., also in excellent agreement.

No previous investigators show the small flattening on the resistivity–temperature curve just above the critical temperature, but it is doubtful whether they made observations sufficiently close together.

In transformations of the $Cu_3Au$ type, where the time of relaxation is appreciable, heating and cooling curves are almost useless unless the rate of heating or cooling is specified. The authors suggest that a constant rate of cooling or heating should be used in such experiments so that subsequent investigators could then carry out reliable check experiments. Curves obtained in such conditions are accurately reproducible, cf. Fig. 1 (*a*).

### (b) *The Determination of the Equilibrium Curve.*

Whilst the resistivity–temperature curve is, in general, a function of the cooling rate, there should be a limiting curve below which experimental points cannot be obtained. The authors have attempted to determine the curve in the following way: the specimen mounted in an evacuated container as previously described was heated to 500° C. and then cooled at 30° C. per hr. to 390° C. The cooling rate was then reduced to 1° C. per hr. and the transformation started at 381° C. The temperature was then kept constant until the resistance attained a steady value; in the first 47 hrs. the resistance decreased by about 20 per cent; in the next 24 hrs. it did not change by more than 0·1 per cent., *i.e.* the alloy was in equilibrium. The specimen was then heated to 382·5° C., and it did not pass into the disordered state, but attained a value after 1 hr. which remained steady for the next 15 hrs. It was necessary to heat the alloy to 386° C. before it changed completely into the disordered state. Further points were obtained on the curve, some taken after heating, others after cooling to the new equilibrium temperature. By taking points in this way, any slight errors due to departure from equilibrium are in opposite directions, *i.e.* the former gives a resistance slightly too high, and the latter values slightly too low. Use has been made of this fact in drawing Fig. 3 through the experimental points. The time taken to determine the curve from 386°–350° C. was 600 hrs., and it was then checked at various points using two different specimens. It is unlikely that the curve is in error by more than 1 per cent. The points plotted on the equilibrium curve correspond to temperatures involving a fraction of a degree. The absolute value of the temperature is not known to this accuracy, and the readings were obtained in the following way : calibration of the thermocouple showed that at 16 mv. the temperature was 385° C. with an accuracy of about ± 1° C. For the equilibrium curve it was assumed that 16 mv. corresponded to 385·0° C., and other temperatures down to 350° C. were determined by difference.

From 385° to 350° C. the curve is well below the curves obtained in any previous investigation. Since Fig. 3 is not a straight line below

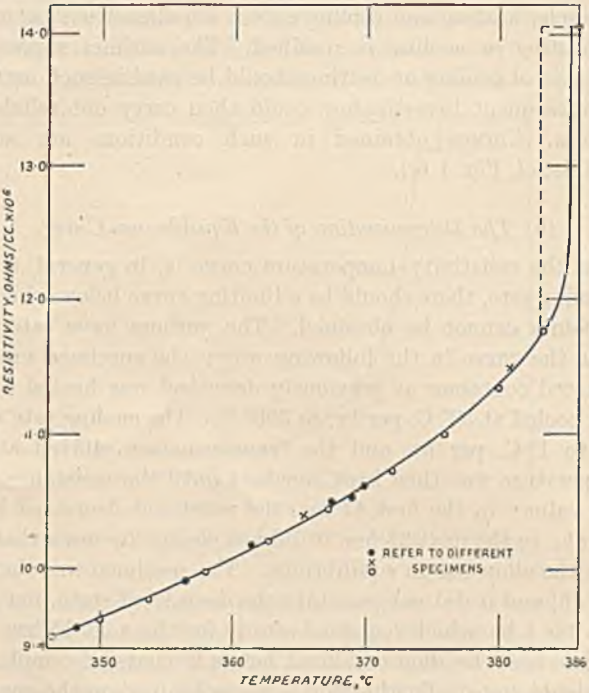

FIG. 3.—Equilibrium Curve : Resistivity–Temperature.

the critical temperature, it was anticipated by comparison with Fig. 1 (*a*) that the transformation proceeded as the temperature was reduced, *i.e.* the equilibrium was a dynamic one. Three alloys quenched from points on the equilibrium curve had the following resistivity at room temperature :

Quenched from 384° C. Resistivity at 24° C. $8{\cdot}36 \times 10^{-6}$ ohms/c.c.
" " 380° C. " " $7{\cdot}81 \times 10^{-6}$ ohms/c.c.
" " 369° C. " " $7{\cdot}06 \times 10^{-6}$ ohms/c.c.

*These results prove the point that the transformation proceeds as the temperature is lowered, although at any particular temperature a steady state can be achieved.* (It may be argued that the authors' alloy was never in equilibrium, but this is unlikely as the following statement shows: in 47 hrs. at 381° C. the resistance decreased by 20 per cent.; in the next 24 hrs. it did not change by more than 0·1 per cent. The temperature was then decreased to 367° C. in 2 hrs., and at the end of this time the resistance decreased by 11 per cent. If the alloy was not in equilibrium at 381° C. the authors had increased the speed of the transformation over 1000 times by *reducing* the temperature.)

There is a very large decrease in resistivity at the critical temperature, which is in qualitative agreement with the prediction of Bragg and Williams who showed that for $Cu_3Au$ the degree of order should increase from zero just above the critical temperature to about 30 per cent. just below. This discontinuity in the degree of order is typical of a transformation in which the number of positions of order is one quarter that of the total number of atomic sites. In CuZn where the ratio is one half there is no such discontinuity either in theory or from experiment.

Various previous investigators have noticed hysteresis effects at the critical temperature, in some cases the critical temperature on heating was given as 20° C. higher than that on cooling. Haughton and Payne studied this question and concluded that the true hysteresis, if any existed, was very small, and they obtained results varying from 9° to 1° C. As previously mentioned, the transformation starts at 377° C. for a cooling rate of 30° C. per hr., whereas at 1° C. per hr. it starts at 381° C. On heating, the transformation is completed at 390° and 387° C., respectively. Since it takes about 40 hrs. for the alloy to attain equilibrium just below the critical temperature, it is not surprising that the apparent critical temperature is affected by the cooling rate. It seemed desirable, however, to determine if there was any true hysteresis at the critical temperature.

As the 30° C. per hr. curve indicates, a few minutes starts the transformation at 377° C. After 4 hrs. the transformation occurred at 383° C., whilst after 24 hrs. at 384° C. it had not commenced. On the other hand, if the transformation had once been started, soaking at 385° C. for 24 hrs. would not change the alloy back to the disordered state. Increasing the temperature to 386° C. invariably produced the completely disordered state in about 1 hr. On the basis of tests having a duration of 24 hrs. each, it is not possible to say with certainty that any true hysteresis exists; nevertheless, there is definitely a region of about 2° C. from 383° to 385° C. in which the transformation proceeds more sluggishly than on either side. Expressed in another way, there is a discontinuity in the value of $\tau$ at the critical temperature.

The large increase in order at the critical temperature produces an appreciable change in lattice constant, and Bragg has suggested that this effect is probably responsible for the lag at the critical temperature. The ordered nuclei, when formed, have a lattice constant so different from that of the main crystal that a considerable strain must occur in the disordered lattice when the nuclei form. This strain will tend to prevent the formation of nuclei. Calculation indicates that this effect should produce a lag of the order of 2° C., which is in agreement with the authors' experimental result.

The actual temperature of the transformation (385° C.) is lower than that given by Haughton and Payne (392° C.), but equal to the mean value given by Borelius, Johansson, and Linde[4] (390° C. on heating, and 380° C. on cooling).

The upper portion of the curve from 390° to 500° C. was identical with that shown in Fig. 1 (*c*). It was determined at the beginning of the experiment, and again at the end; within the limits of experimental error of ± 0·1 per cent. there was no change, indicating that no deterioration had taken place in the specimen.

### (c) *Resistivity–Temperature Curves During Quenching.*

As demonstrated in Section II (*a*) of this paper, once the alloy is frozen the resistivity–temperature curve is a straight line, cf. part *AB* of Fig. 1 (*a*). Since the transformation is sluggish, quenching in water could be expected to retain the structure at the moment of quenching. Consequently it was thought that, provided the resistivity before quenching and also the final value at room temperature were known, the resistivity–temperature curve during quenching would be given by assuming that the resistivity varied linearly with temperature between these two values. It was realised that if this deduction were correct then a satisfactory method of investigating equations (2) and (3) was available, which was independent of any assumptions regarding the relation between resistivity and degree of order. (See next section.)

To prove the above deduction experimentally in a really satisfactory manner it would be necessary to record oscillographically the resistance and temperature of a specimen during the actual quenching process. The authors used a method which whilst probably quite satisfactory, is not so sound: a specimen of the type (*a*) was placed inside a furnace together with an additional wire of the same diameter sealed into a thin close-fitting glass tube. The furnace was then heated to 450° C.

so that both wires became completely disordered; then the furnace was cooled below the critical temperature until the specimen of the type (*b*) indicated that the transformation had proceeded to a definite extent. It was assumed that the other wire had the same resistivity as the specimen of the type (*b*). The additional wire was then quenched in water, and its resistivity measured at 20° C. and at some convenient temperature between 100° and 200° C. where no relaxation takes place. A number of specimens were examined in this way; some were quenched after they had attained equilibrium at the quenching temperature, others before they had reached equilibrium. The results are shown in Fig. 4: the three points corresponding to each quench fall on a straight line, and prove that the temperature coefficient of the alloy having a definite structure throughout is independent of temperature. The agreement also indicates that different specimens behave in an identical manner under the same experimental conditions.

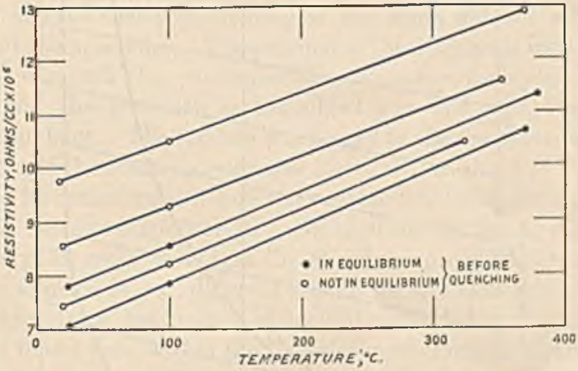

Fig. 4.—Resistivity–Temperature Curves During Quenching.

The experimental method of enclosing the specimens inside thin glass tubing prior to quenching will probably be regarded with a certain amount of apprehension for a type of test in which very quick quenching is desired. The glass tube shatters on making contact with the water, and direct experiment proves that the quench produces values of resistivity as high as those obtained by the Rosenhain method for this particular alloy. The method described has the great advantage that more than one specimen can be loaded into the furnace at once. Each specimen is sealed on to a long glass tube one end of which protrudes outside the furnace and can be used to withdraw the specimen quickly for quenching. A number of quenching experiments can then be made during one run of the furnace, and this leads to an appreciable saving of time.

By suitable choice of the initial treatment prior to quenching a family of lines was obtained covering the alloy from the disordered state to the state corresponding to equilibrium degree of order at 350° C. which is probably about 70 per cent. The slope of the lines increases only slightly as the degree of order increases, so that intermediate stages could be interpolated.

## III. Rate of Approach to the Equilibrium State.

### (a) *Relaxation at Constant Temperature.*

Fig. 5 shows the equilibrium curve together with a number of lines relating resistivity with temperature for a constant structure. Consider an alloy having a resistivity and temperature characterized by the point *A*. Its actual temperature *T* is 350° C., whereas its characteristic temperature θ is 380·5° C.; consequently if it is held at 350° C. its resistivity will gradually decrease with time along the line *X–X′* until it reaches the equilibrium curve.

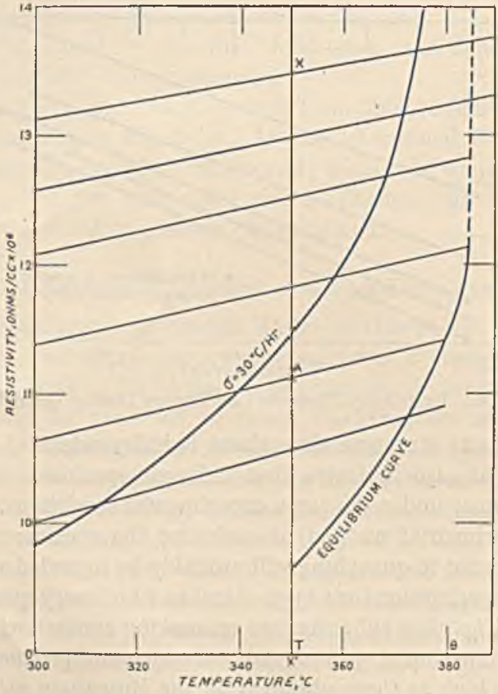

Fig. 5.—Equilibrium Curve. Cooling Curve at 30° C. per Hr. Resistivity–Temperature Lines for Constant Structure.

If, therefore, an alloy characterized by the point $X$ be obtained and the resistivity–time curve ($\rho . t$ curve) for it determined at constant temperature $T$, then the graphical method as described above enables a $\theta . t$ curve to be derived. This curve together with the relation

$$\frac{d\theta}{dt} = -\frac{\theta - T}{\tau}$$

gives $\tau$ at the temperature $T$.

### (b) *Experimental Method and Results.*

A number of wires about 12 cm. long were quenched in water from 450° C. and thus converted into the disordered state. They were then assembled into evacuated containers as previously described. Direct experiment showed that spot-welding of the leads did not affect the resistance of the specimen. The position of the glass seals with respect to the wire was such that no appreciable relaxation took place during sealing-in, and the specimen as assembled was thus completely disordered throughout. The furnace was heated to the temperature of the experiment, and then the specimen was inserted. In this way measurements could be commenced before appreciable relaxation took place.

Since all the experiments could not be made on one specimen, it was necessary, in order to obtain the $\theta t$ curve, to compare resistivity measurements made on two different specimens, and thus introduce the relatively large error due to lack of accurate knowledge of the length. It had been found that, within the limits of measurement, all the alloys in the disordered state, *i.e.* from 400° to 500° C. gave identical results for resistivity. In order to eliminate errors so far as possible in the graphical evaluation of $\tau$ it has been assumed that the length of the specimen used for the equilibrium curve was correct, and the length of the relaxation specimen was determined by comparison of resistance at 450° C. with that of the specimen used for the equilibrium curve. In cases where relaxation proceeded right down to the equilibrium curve an excellent check was always obtained, indicating that the various specimens had identical properties.

Fig. 6 (*a*) is the relaxation curve of electrical resistivity obtained at 350° C. Fig. 6 (*b*) is the $(\theta - T)\ t$ curve obtained graphically. If $\tau$ is a constant independent of $T$ then log $(\theta - T)$ plotted againt $t$ should give a straight line. Actually (see Fig. 6 (*c*)), log $(\theta - T)$ is not a linear function of $t$, and it appears that $\tau$ increases as the alloy approaches equilibrium. This is not particularly surprising since $W$, the activation energy, will increase as the degree of order increases; nevertheless this change in $\tau$ with $s$ raises a slight difficulty if it is desired to investigate the relation between the time of relaxation and the temperature.

If, as Bragg and Williams assume, the lattice changes uniformly throughout the whole crystal during the ordering process, we can compare values of $\tau$, obtained during relaxation at different temperatures ($T$), corresponding to the same characteristic temperature ($\theta$), since all the specimens will then have the same atomic arrangement although at different temperatures. The values of $\tau$ obtained at four different temperatures are given in Table I, the characteristic temperature in each case being 380° C.

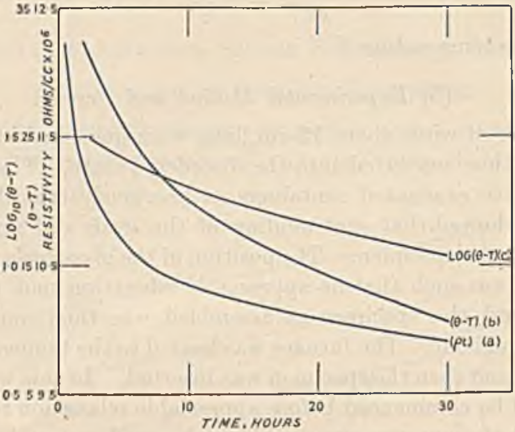

FIG. 6.—Relaxation at 350° C.

TABLE I.

| Temperature, °C. | $\tau$, in Hrs. |
|---|---|
| 361 | 8·7 |
| 350 | 14·4 |
| 321 | 64·0 |
| 300 | 212·0 |

The increase in $\tau$ as the temperature is decreased is very rapid, and it is clear that to get a disordered alloy into equilibrium at 250° C. will require an annealing period of about a year. If log $\tau$ is plotted against $\frac{1}{T}$, $T$ being expressed in degrees absolute, a very reasonable straight line results, see Fig. 7. It follows, therefore, that $\tau$ obeys a relation of the type

$$\tau = Ae^{\frac{W}{KT}}.$$

Extrapolation of the experimental results gives ($\tau$ in seconds)

$$A = 10^{-8\cdot 5} \text{ and } W = 1\cdot 65 \text{ electron volts.}$$

In view of the experimental difficulties associated with the determination of these constants and the relatively large extrapolation necessary, the authors do not stress the accuracy of the results. They are of the order computed by Bragg and Williams.

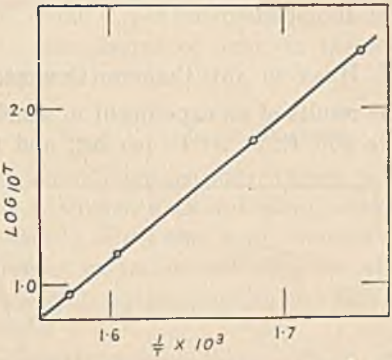

FIG. 7.—Relation Between $\tau$ and $\frac{1}{T}$.

(c) *Cooling Curves.*

Equation (2) can be written as follows :

$$\frac{d\theta}{dt} \times \frac{dT}{dt} = -\frac{\theta - T}{\tau} \quad . \quad . \quad . \quad . \quad (4)$$

If an alloy is cooled at a constant rate $\sigma = \frac{dT}{dt}$ a curve is obtained such as is shown in Fig. 5, cooling rate $\sigma = 30°$ C. per hr. By a graphical construction similar to that previously described, a $\theta T$ curve can be evaluated. Tangents at suitable points give values of $\frac{d\theta}{dT}$ for different values of $T$, which together with the $(\theta - T)$ results enable $\tau$ to be determined over the whole range of temperature using equation (4). In Table II the results of such a determination are shown.

TABLE II.

| Temperature, ° C. . . | 350 | 340 | 330 | 320 | 310 | 300 | 290 | 280 | 270 | 260 | 250 | 240 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\tau$, in hrs. . | ... | 5 | 6·9 | 8·3 | 9·9 | 12·9 | 16·7 | 19 | 23 | 35 | 55 | ... |

These results are quite different from those obtained by the previous method both as regards absolute magnitude and the dependence of

$\tau$ on temperature. For example, $\tau$ as determined at constant temperature varies from 12·4 hrs. at 350° C. to 210 hrs. at 300° C., whilst by the cooling curve method the values are about 3·4 hrs. and 12·9 hrs.: if due allowance for the variation of $\tau$ with $\theta$ be made on the results by the first method the agreement is even worse. The difference appeared to us to be much larger than could be accounted for by experimental error, and further experiments were then carried out in an attempt to explain the apparent discrepancy.

## IV. Heating and Cooling Curves.

Fig. 8 shows the results of an experiment in which a specimen was cooled from 450° to 250° C. at 30° C. per hr., and then reheated at 40° C. per hr. to 450° C. The interesting point is that the slopes of the heating and cooling curves are identical from 250° to 330° C. although as Fig. 2 proves conclusively atomic rearrangement takes place in this range.

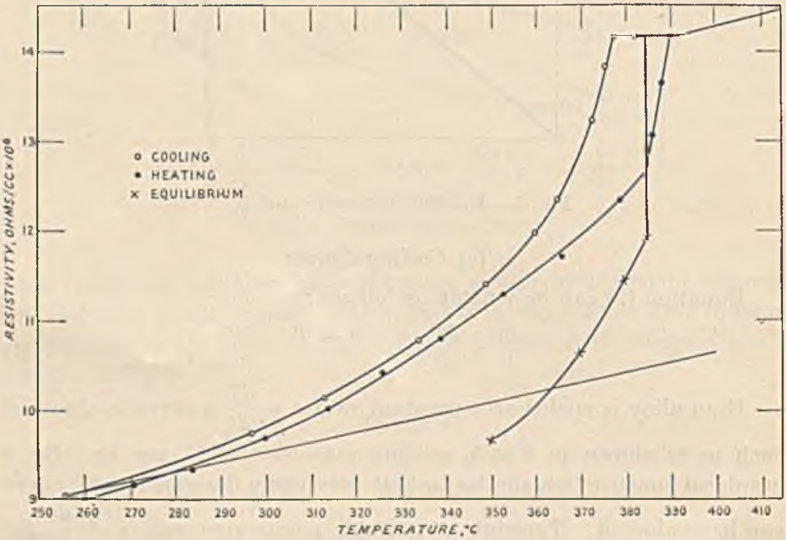

Fig. 8.—Resistance–Temperature Curves at 30° C. per Hr.

The alloy freezes at 250° C. on cooling, and its resistivity decreases with temperature along the thin straight line (produced to lower values of temperature). Since the alloy as cooled at 30° C. per hr. is still a long way from equilibrium, it would be expected that the heating curve would fall *below* the straight line as it relaxed towards equilibrium. Actually the slope of the heating curve only begins to differ from that of the cooling curve at about 330° C. and never becomes less than that of the dotted line. This means that the specimen on the whole is disordering throughout the whole of the heating cycle although it is out of equilibrium in the opposite sense. (Heating curves obtained by other investigators show this anomaly, but it had remained unnoticed.)

The authors concluded that the supposition that the lattice throughout the crystal was uniformly ordered was incorrect, and that in fact, the alloy as cooled at 30° C. per hr. consisted of small nuclei within the individual crystals, the degree of order in the nuclei following the temperature within close limits.

## V. X-Ray Investigation.

In order to test and develop the above theory an X-ray examination was carried out of specimens heat-treated in a variety of ways. The specimens, short lengths of 0·4 mm. wire, were sealed into close-fitting glass tubes to prevent oxidation and were heat-treated in a furnace accompanied in general by a pilot specimen on which resistivity measurements could be made.

The X-ray photographs were taken in a circular camera 9 cm. diam. using the $K$ radiation of copper.

### (a) *Ordering Process at Constant Temperature.*

Fig. 11 (Plate I) is an X-ray powder photograph of a wire which had been heated to 425° C. and quenched in water. The lines, which are those associated with a face-centred lattice, are quite sharp, showing that the individual crystals are free from strains, coring, &c.

Fig. 12 (Plate I) refers to a similar specimen which had an additional heat-treatment in which it was rapidly heated to 375° C. and then quenched in water. Very diffuse super-lattice lines appear, the end doublet being almost invisible.

Reheating to 375° C. for 1 hr. followed by subsequent quenching produces a structure characterized by Fig. 13 (Plate I). The super-lattice lines are much less diffuse.

After soaking for 21 hrs., Fig. 14 (Plate I), the super-lattice lines are well resolved. (The alloy is then, according to resistance measurements, almost in equilibrium.)

In Figs. 11–14 (Plate I) the main lattice lines are perfectly sharp, whereas the super-lattice lines become sharp only when the alloy approaches equilibrium. The ordering process is also accompanied by a decrease in lattice parameter.

Dehlinger and Graf [11], in an X-ray investigation of a single-crystal of $Cu_3Au$, found that the extra X-ray reflections (spots) produced by the atomic rearrangement were diffuse unless the crystal had been annealed for a long period before quenching. They deduced that the diffuse character of the reflections was due to the fact that the degree of order was only uniform throughout small volumes and that the reflections from such volumes were not in phase (*i.e.* the small volumes had not all chosen the same cubic lattice, of which there are four, as the one on which the gold atoms should segregate).

Since the width of the super-lattice lines in Figs. 11–14 (Plate I) is inversely proportional to the size of the nuclei contributing to them, the relaxation process at constant temperature can be described as follows : when the disordered alloy is heated to 375° C. there will be, purely on probability considerations, certain very small volumes throughout which the degree of order is equal to the equilibrium degree of order at 375° C. As the alloy relaxes, these nuclei will grow until they touch. Provided adjacent nuclei are in phase they will coalesce, if not in phase, then by a process similar to grain-growth, the larger nuclei will absorb the smaller, until finally the crystal is uniformly ordered throughout.

As the temperature is decreased the rate at which the nuclei grow decreases, whilst the equilibrium degree of order increases. Fig 15 (Plate II) shows the super-lattice lines developed in an alloy held at 350° C. for 50 hrs. The super-lattice lines are sharp as this treatment according to resistance measurement brings the alloy almost to equilibrium. There is a further contraction in lattice parameter indicating that the degree of order is higher at 350° C. than at 375° C. Figs. 16 and 17 (Plate II) refer to relaxation at 320° C., one taken after 18 hrs. and the other after 66 hrs. By comparison with Figs. 13 and 14 (Plate I) they demonstrate the slowing up in the ordering process produced by lowering the temperature. After 66 hrs. at 320° C. the super-lattice lines are comparable in diffuseness with the photograph taken after 2 hrs. at 375° C. As the resistance measurements indicate, an annealing time of at least 250 hrs. would be required at 320° C. to give sharp super-lattice lines.

### (b) *Ordering Process During Cooling from the Disordered State.*

When the alloy is continuously cooled from the disordered state through the critical temperature to room temperature at 30° C. per hr. the structure produced is given in Fig. 18 (Plate II). The super-lattice lines are still diffuse, but not as diffuse as those in Figs. 12 (Plate I) and 16 (Plate II).

The effect of the various heat-treatments, producing the structures shown in Figs. 11–18, on the electrical resistivity is given in Fig. 9.

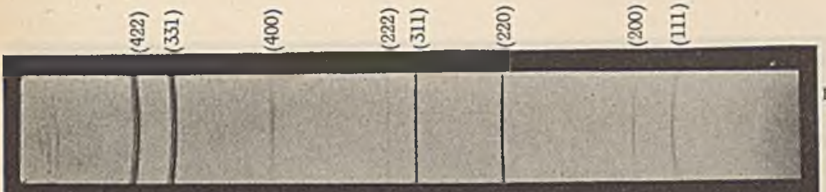

FIG. 11

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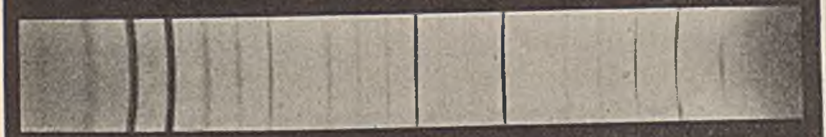

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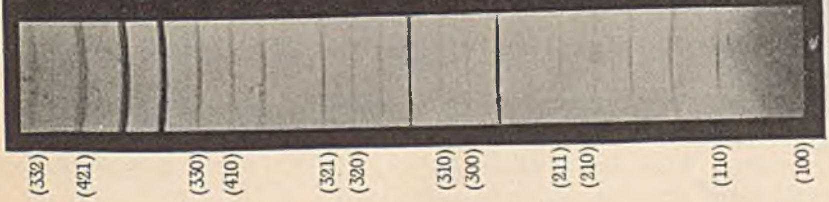
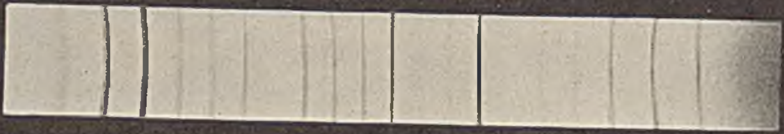


14

# PLATE II.

FIG. 15



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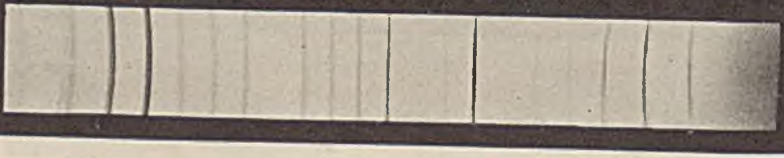

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PLATE III.

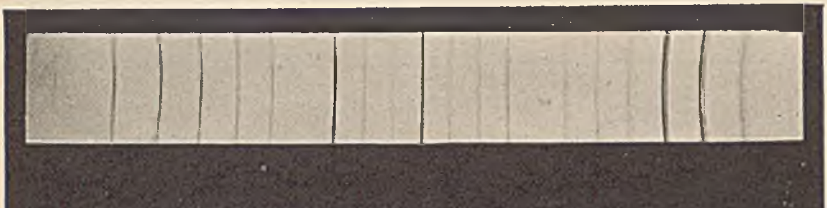
FIG. 19


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21


22

It seems reasonable to suppose that the nuclei formed just below the critical temperature are affected by the subsequent heat-treatment in two ways. In the first place they can grow and in the second the degree of order in the nuclei will increase as the temperature is reduced. As will be shown later, the effect of both these processes can be seen on the specific heat and resistivity curves.

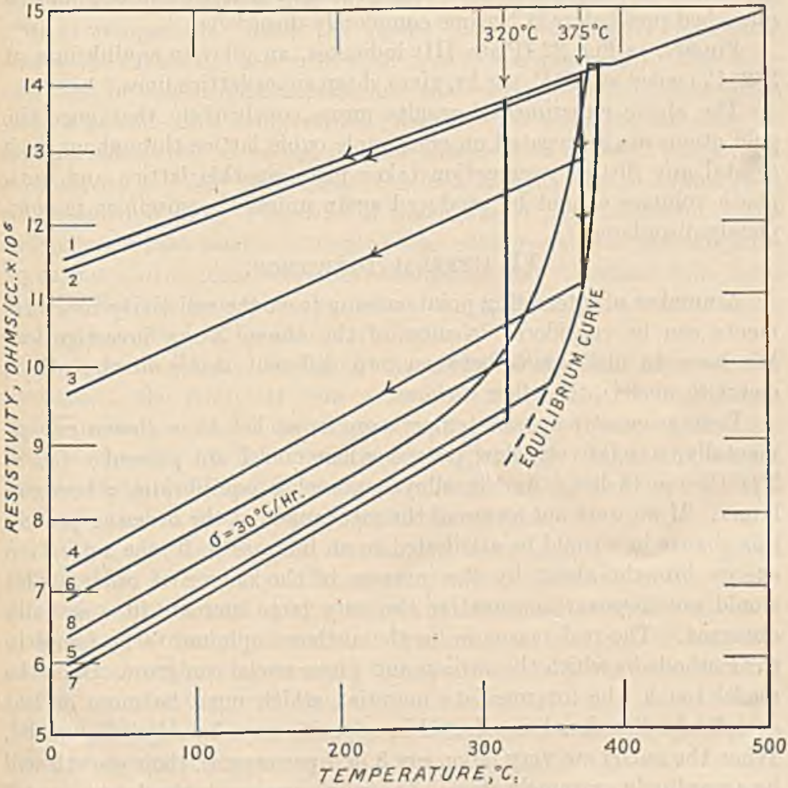

FIG. 9.—Resistivity of $Cu_3Au$.

Having produced a uniformly ordered alloy in equilibrium at one particular temperature, it is of interest to determine how this structure changes into another equilibrium state either at a higher or a lower temperature.

An alloy in equilibrium at 375° C. was quenched in water, reheated to 350° C. for 1 hr., and then quenched. Fig. 19 (Plate III) gives the X-ray structure, which shows that the crystals are still ordered on the same simple cubic lattice throughout, *i.e.* no new anti-phase nuclei have been formed. The same specimen was then reheated to 300° C., soaked for 50 hrs., and again quenched in water. The resulting structure shows sharp super-lattice lines, Fig. 20 (Plate III). Relaxation had taken place since the lattice constant had changed appreciably. Similarly, on heating the lattice disorders uniformly from an equilibrium position. Fig. 21 (Plate III) was obtained on a specimen heat-treated to bring it into equilibrium at 382° C. and then heated to 386° C. and quenched just before it became completely disordered.

Finally, as Fig. 22 (Plate III) indicates, an alloy in equilibrium at 382° C. cooled at 30° C. per hr. gives sharp super-lattice lines.

The above experimental results prove conclusively that once the gold atoms are segregated on one simple cubic lattice throughout each crystal any further segregation takes place on this lattice and anti-phase volumes cannot be produced again unless the specimen is completely disordered.

## VI. General Discussion.

A number of interesting points arising from the resistivity measurements can be considered in view of the above X-ray investigation. We have to distinguish between two different states of the alloy : one with nuclei—the other without.

Relaxation at constant temperature is, as has been shown experimentally, a relatively slow process when nuclei are present; *i.e.* at 350° C. $\tau = 14$ hrs. As the alloy approaches equilibrium $\tau$ becomes larger. If we were not aware of the mechanism of the ordering process this change in $\tau$ could be attributed to an increase in $W$, the activation energy brought about by the increase in the degree of order. This would not however account for the very large increase in $\tau$ actually observed. The real reason is, in the authors' opinion, to be found in the methods by which the various anti-phase nuclei can grow. Once the nuclei touch, the intermediate material, which must be more or less completely disordered, is affected in opposite ways by adjoining nuclei. When the nuclei are very large, say 3 or 4 per crystal, their growth will be accordingly extremely slow. The whole process is similar to crystal growth in a polycrystalline material. The analogy is not complete since the gaps in the lattice produced due to grain boundaries are not present in the ordering crystal.

On the other hand, inside any particular nucleus the degree of order can follow the temperature relatively quickly since there are no opposing forces due to anti-phase material. This is well demonstrated by the experimental fact that an alloy once in equilibrium at 382° C., if cooled at 30° C. per hr., follows the equilibrium curve down to 350° C. If it be assumed that $(\theta - T) = 2°$ C. *i.e.* that the authors' equilibrium curve is in error by 1 per cent. at 350° C., then $\tau$ is about 4 minutes at 350° C. It seems reasonable to assume that $\tau$ for the nucleus is about $10^{-3}$ times the initial $\tau$ for the growth of the nuclei at constant temperature.

Apart from its theoretical significance, this is, of course, a very important experimental result, since it suggests that the quickest way to obtain an equilibrium curve of any physical property for this type of transformation, consists first in soaking the specimen just below the critical temperature until the nuclei are approximately the same size as the crystals (where $\tau$ for their growth is a minimum). The alloy can then be cooled quite rapidly and still follow the equilibrium curve over a considerable temperature interval. For example, an alloy in equilibrium at 382° C. cooled to room temperature at 30° C. per hr. has a resistivity of $4{\cdot}5 \times 10^{-6}$ ohms/c.c. which is about the same value (4·6) as obtained on Fig. 1 (*b*) with a much longer heat-treatment. The difference in heat-treatment times becomes appreciable at low temperatures, *e.g.* a disordered alloy heat-treated at 250° C. would take from 4 to 10,000 hrs. to attain equilibrium, whereas the same result can be obtained in 100 hrs. by the above method.

Relaxation during cooling in the presence of nuclei involves two processes: the relatively slow growth of nuclei and the increase in order inside the nuclei consequent on the change in the equilibrium degree of order by the lowering of temperature. Since the second process is relatively fast it is not surprising that the two experimental methods used to determine $\tau$ give different results.

Alloys can be produced having the same resistivity at a given temperature with widely different structures. Referring to Fig. 5, the point $A$ can be arrived at by a variety of different heat-treatments each producing its own characteristic structure. At the one extreme we may quench to the temperature $T$ from equilibrium at the corresponding higher temperature, and thus obtain a structure which is uniformly ordered throughout. At the other, we can allow a disordered alloy to relax at constant temperature $T$ down to $A$, and in this way obtain a specimen containing a large number of small nuclei having a relatively high degree of order. This type of structure was not contemplated by Bragg and Williams, and our experimental values of $\tau$ (all of which refer to structures involving nuclei) cannot be expected to agree with their predicted values. Further experimental work on the relaxation of alloys uniformly ordered throughout will be necessary to obtain a reliable check on this aspect of the theory.

There is no precise meaning to the term "characteristic temperature" as applied to a structure containing nuclei.

Some of the experimental curves will now be considered in detail.

Referring to Fig. 8. The cooling curve will become straight when the time of relaxation *inside* the *nuclei* is so long that they are substantially "frozen." The actual degree of order *in the nuclei* at 250° C. will be very nearly the *equilibrium degree of order* at that temperature. On reheating, there will be a slight relaxation up to 250° C., but thereafter the degree of order in the nuclei will keep slightly above the equilibrium degree of order, and the resistance will increase. Since the time of relaxation inside the nuclei is very small, the slope of the two curves is identical. At the higher temperatures, 330° C. and upwards, the time of relaxation for the growth of the nuclei is decreasing rapidly. Growth produces a diminution in the amount of disordered material and tends to reduce the effect on the resistance produced by the decrease in degree of order in the nuclei. Once the temperature is above the critical temperature effects due to growth are absent and the heating curve has a sharp upward trend.

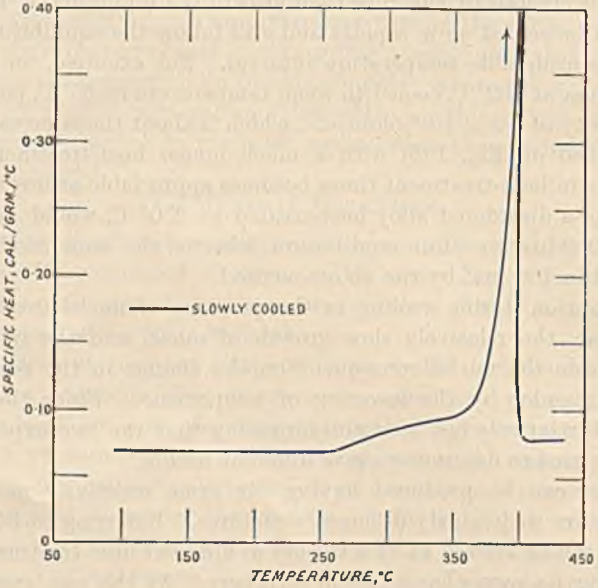

FIG. 10.—Specific Heat–Temperature Curve, $Cu_3Au$.

That this is the correct explanation of Fig. 8 is substantiated by the specific heat curve in Fig. 10.* [12] The specific heat was determined on heating, the heating rate being about 2° C. per minute, and the initial condition was as cooled at 30° C. per hr. from 450° C.

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* The experimental method for determining these curves is described in detail elsewhere.

At 250° C. the specific heat begins to increase, which means that the alloy is disordering, in spite of the fact that its average degree of order is well below the equilibrium degree of order. At about 320° C. the rate of increase in specific heat decreases, owing to the release of energy produced by the growth of nuclei.

Whilst the curve substantiates the authors' theory of the ordering process, at the same time it follows that the curve itself bears no simple relation to the equilibrium specific heat–temperature curve, and, in fact, just as for the resistivity curves, it seems reasonable to suppose that there are an infinite number of possible specific heat curves. The experimental data described in this paper suggests a simple way to obtain the equilibrium specific heat curve at any rate from 350° C. upwards. An alloy containing no anti-phase nuclei when cooled fairly rapidly (30° C. per hr) from 382° C. follows the equilibrium curve down to 350° C. and possibly much lower. Such an alloy on heating should possess a similar property and thus enable a reliable specific heat curve to be obtained.

Once the alloy is ordered throughout it is not possible to produce anti-phase nuclei in it unless it is first completely disordered. When such an alloy is displaced from an equilibrium condition we have not been able as yet to distinguish whether small nuclei are first formed having the equilibrium degree of order at the new temperature or whether the lattice orders as a whole. It seems reasonable, however, to assume that ordering inside nuclei proceeds around other nuclei in view of the definite evidence that such a process exists in the initial stages of the transition from the disordered state. The only essential difference will lie in the fact that all the nuclei are similarly oriented and can easily coalesce.

## VII. SUMMARY AND CONCLUSIONS.

It has been shown that the general character of the transformation in $Cu_3Au$ is very similar to that predicted by Bragg and Williams. In particular, the transformation takes place continuously from the critical temperature to very low temperatures and the equilibrium condition when produced after long annealing is displaced by a change in temperature, *i.e.* the equilibrium is a dynamic one. The authors have found a large change in resistivity at the critical temperature, not previously established, which is in agreement with theory.

The simple hypothesis put forward in order to describe the relaxation to the equilibrium state is inadequate, and it is not yet possible to state whether a formula of the type

$$\frac{d0}{dt} = \frac{0 - T}{\tau}$$

is an accurate representation of the experimental facts, even if applied to a uniformly ordered structure. Further relaxation experiments on alloys ordered throughout on the same simple cubic lattice are desirable. We should expect a formula of the type

$$\tau = Ae^{\frac{W}{KT}}$$

to hold in any case for relaxation at constant temperature, so that measurements of $\tau$ by both methods, *i.e.* at constant temperature and during cooling are desirable.

The marked difference in properties of the alloy containing nuclei as distinct from those ordered throughout on the same simple cubic lattice is of considerable interest, and previous work on transformations of this type should be reconsidered in view of these results.

The performance of different samples of the same alloy is accurately reproducible. This is perhaps remarkable in view of the large range of properties which can be obtained by heat-treatment, and must be attributed to the fact that the transformation is an intracrystalline phenomenon almost independent of grain boundary effects.

## ACKNOWLEDGMENTS.

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The authors thank Professor W. L. Bragg, F.R.S., for his kind and continued interest.

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# THE EFFECT OF MOLTEN SOLDER ON SOME STRESSED MATERIALS.*

By G. WESLEY AUSTIN,† O.B.E., M.Sc., MEMBER.

## SYNOPSIS.

Breakages of steel and non-ferrous parts during assembly by soldering whilst subjected to stress, led to this investigation on the effect of molten solder on stressed tensile test-pieces of many of the metals and alloys used in engineering. Although the phenomenon was found to be very general, certain materials proved less susceptible than others; a selection of materials which will offer resistance to the simultaneous action of stress and solder is thus possible.

## I.

THE rapid penetration and weakening of various tension-stressed materials by molten solder and other metals and alloys has often been observed in engineering workshops.

The failure of an alternator end-plate owing to penetration by mercury has been described by Dickenson.[1] Genders [2] stated that hot-shortness occurs in steel if the tension side of a heated bender be covered with molten brass, copper, or zinc. Shottky, Schichtel, and Stolle [3] investigated the effect of molten metals and alloys on steel under tension, also by means of bend tests, and concluded that if a minimum tension is present in the steel, and at least partial contact between steel and molten alloy, then shortness and failure result by intergranular penetration, if the alloy or its principal constituent is soluble in iron, or iron in the alloy. Schuster [4] stated that liquid brass will enter the grain boundaries of highly-stressed steel at a high temperature. Van Ewijk [5] has investigated the effect of various low melting point molten alloys on stressed heat-treated alloy steels.

The author's attention was directed to the phenomenon in 1928 by frequent breakages of high-tensile brass fittings whilst being soldered and screwed into position, and by the unexpected fracture of a high-tensile alloy steel cylindrical shell. Solder was subsequently found on the fracture face of the latter.

The operation of soldering is carried out so extensively in engineering

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* Manuscript received February 6, 1935.

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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. LVIII, 1936. Reference should accordingly be as follows: *J. Inst. Metals*, 1936, 58 (Advance copy).

practice, that it was decided to investigate, quantitatively if possible, the susceptibility of the commoner metals and alloys to the combined effects of stress and molten solder.

## II.

The investigators referred to above had used bend-test specimens. The tensile test-piece appeared to the present author to offer many advantages, particularly as a complete autographic load–extension diagram could be taken on the 50-ton machine available for the tests. It was thus possible to determine at which stage of the load–extension curve (elastic, general stretching to maximum load, or necking) the effect, if any, occurred, and whether the normal tensile flow curve was interrupted only, or modified. It also appeared probable that a numerical value could be obtained for the mean axial stress at which active penetration took place.

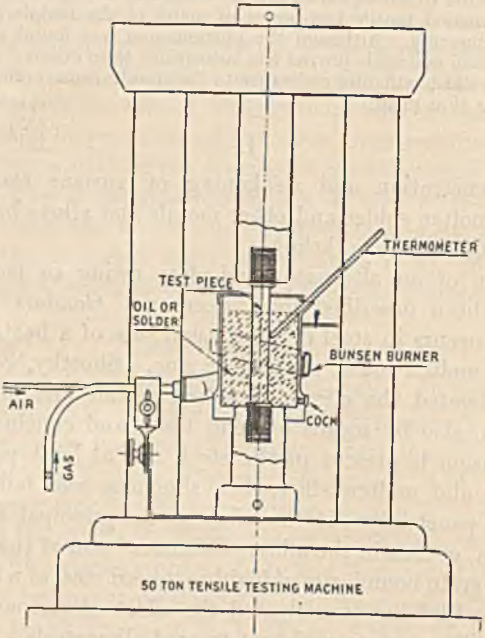

**Fig. 1.—Diagrammatic Arrangement of Apparatus used for Testing the Materials in Oil or Solder at Various Temperatures.**

The diagrammatic arrangement of the testing machine, test-piece, liquid bath, burner, and thermometer are shown in Fig. 1, and the forms of test-piece used in Fig. 2. Form (A) was soon found unsuitable on account of frequent fracture at the shoulder. Form (B) proved more satisfactory, although it was often found necessary to protect the lower part of the test-piece by an oxidized and greased copper film, and to repeat the test till a test-piece fractured within the acting length. The lower reaction screwed grip in the testing machine was originally made of heat-treated spring steel. Failure by cracking from the upper threads led to the replacement of this material, first by mild steel, and next by Monel metal which did not crack, but showed a tendency to seize on to the threads of the test-piece.

Tests were carried out on pairs of specimens at the temperature selected. One specimen was tested under oil, and one specimen under solder. The specimens were immersed for three-quarters of their length. An experiment under oil was carried out in the following way: the test-piece was screwed into the grips of the testing machine and warm oil poured into the bath. The temperature of the oil was then increased to the desired figure, before any load was applied. After the temperature had been maintained for 10 minutes, the piece was slowly broken and an autographic diagram obtained. The piece to be tested under solder was coated with saturated zinc chloride solution, prepared from the salt. The procedure till the desired temperature had been reached was as above. After the temperature had been attained, proof loads corresponding to about $\frac{1}{3}$ and $\frac{2}{3}$ the yield-load (previously determined at the same temperature in oil) were applied for 15 minutes each; unless fracture had occurred the load was then slowly increased till the piece broke.

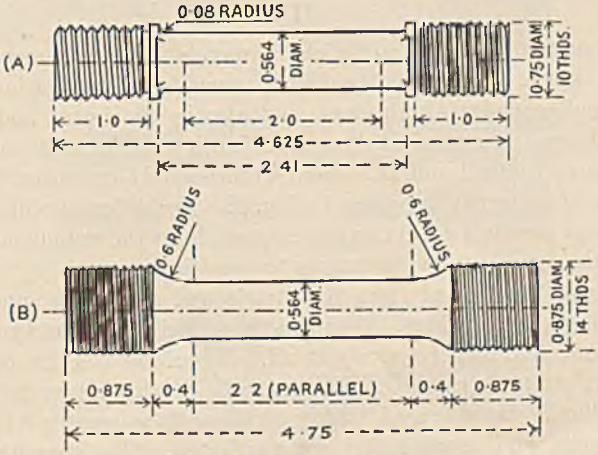

Fig. 2.—Tensile Test-Piece Forms. (Dimensions in Inches.)

General contraction was measured 0·5 in. from the acting length gauge-mark, on the longer half tensile, and was taken as an indication of the general stretching of the test-piece. This measurement also enabled the stress at maximum load to be calculated. The load at fracture was also determined, and from this the mean stress intensity across the least section at fracture, calculated. This has been called the "tearing strength."

Photographs of representative pairs of broken tensile pieces are given in Fig. 3 (Plate I), the piece tested in solder being to the right in each case.

## III.

The materials tested comprised 6 metals, 10 non-ferrous alloys and 16 steels. Some of the latter were tested at various hardnesses and secondary grain-sizes, and also in the burnt and temper brittle states. Chemical analyses and density of the materials tested are given in Tables I and II. Representative load–extension diagrams for pairs of materials are given in Fig. 5. The different slopes of the elastic lines are due to differing elastic moduli for the various materials, and for the same material at various temperatures.

The results obtained from the metals and alloys are summarized in the curves given in Figs. 4 (*a*) and 4 (*b*). Iron, nickel, and copper are slightly affected, nickel scarcely at all. Silver and zinc are dissolved, and their strength reduced. The strength of aluminium is reduced, but its ductility is increased, largely consequent on greater "necking." Monel metal and cupro-nickel are unaffected. The strength of the other alloys, silicon–zinc–bronze excepted, is reduced to a greater or less degree. The ductility of the two light alloys is increased, as in the case of aluminium.

The results obtained from the steels are given in Table III. The group of mild, mild cold-rolled, and medium carbon steels shows only slight reduction in maximum load if in contact with molten solder. The stress at fracture and the ductility are reduced. The results from the group of pearlitic and austenitic rust- and heat-resisting steels tested at 600° F. (316° C.) (Nos. 21–29) show a reduction in the strength of each steel in oil at this temperature. Molten tin did not seriously affect the two pearlitic steels. The seven austenitic steels were affected, the two with lowest carbon apparently least. The test-pieces of the last four ceased to deform in tin at about half the extension which occurred in oil.

Four constructional alloy steels were more fully tested (Nos. 30–33). No. 30 is the steel which showed susceptibility to penetration as a

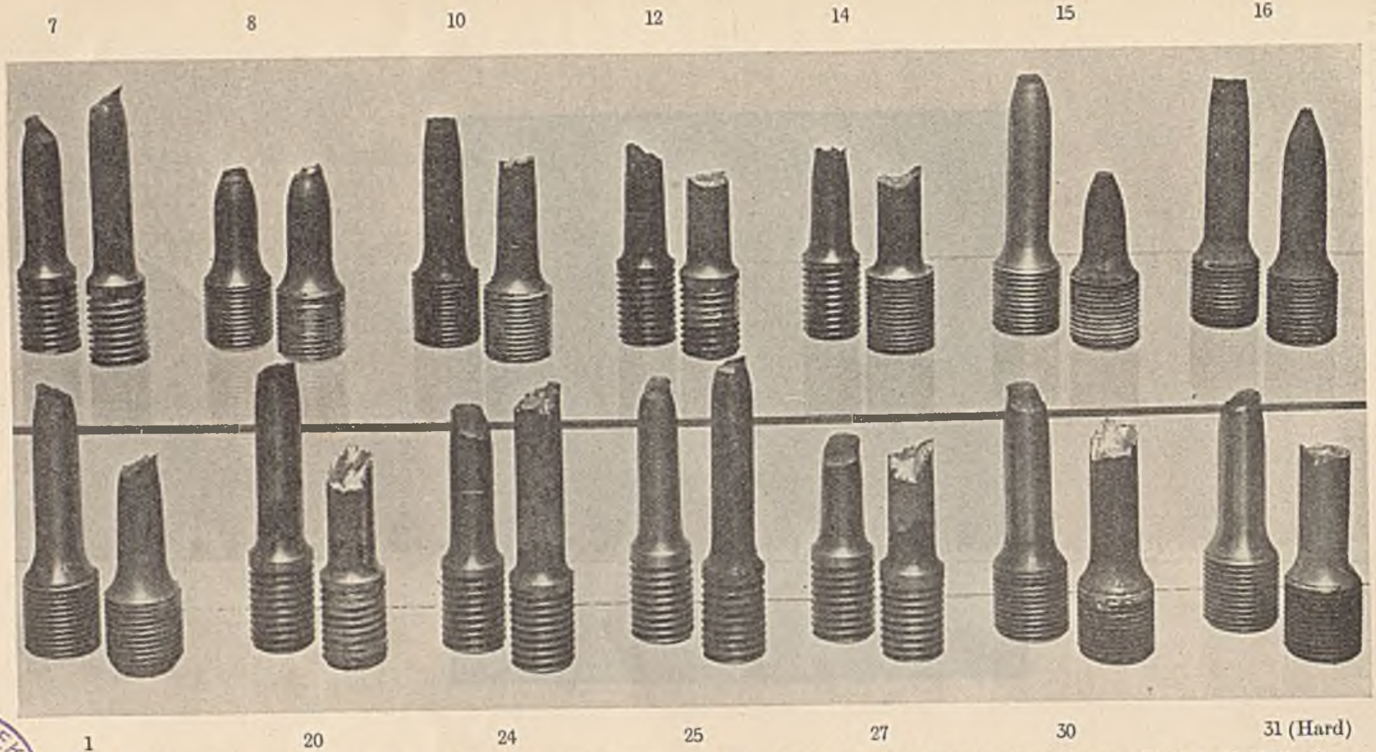

FIG. 3.—Representative Pairs of Broken Tensile Pieces Tested under Oil and Solder (Piece Tested under Solder to Right in Each Case).

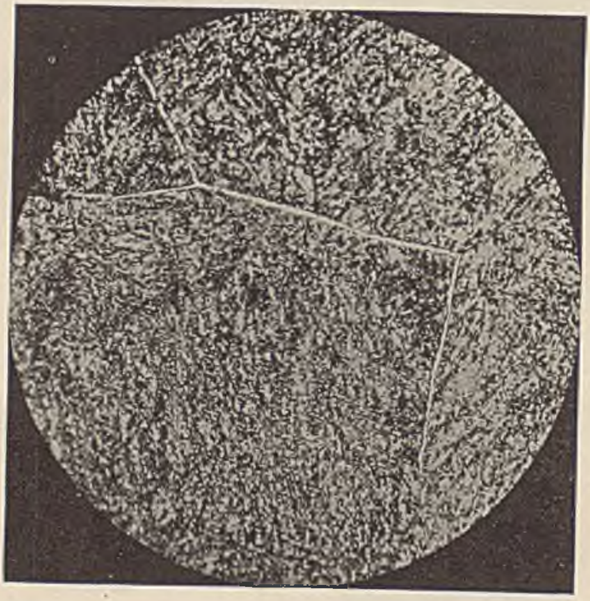

FIG. 6.—Penetrable Steel No. 30. × 500.

TABLE I.—*Density and Chemical Analysis of the 6 Metals and 10 Alloys Tested and of the Solder Used.*

| No. | Material. | Density. | Chemical Analysis. | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fe. | Ni. | Cu. | Ag. | Al. | Zn. | Mn. | Co. | Pb. | Sn. | Mg. | Si. | Sb. | As. | C. | P. | S. | Cd. |
| 1 | Armco iron | 7·85 | 99·88 | ... | ... | ... | ... | ... | 0·02 | ... | ... | ... | ... | <0·01 | ... | ... | 0·03 | 0·008 | 0·047 | ... |
| 2 | Nickel | 8·85 | 0·13 | △ | 0·006 | ... | ... | ... | ... | ... | ... | ... | ... | 0·03 | ... | ... | 0·06 | ... | ... | ... |
| 3 | Copper | 8·81 | <0·02 | 0·08 | 99·54 | ... | <0·02 | <0·02 | <0·02 | ... | <0·02 | <0·02 | ... | ... | ... | 0·34 | ... | ... | ... | ... |
| 4 | Silver | 10·49 | ... | ... | ... | 99·9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 5 | Aluminium | 2·71 | 0·60 | ... | 0·03 | ... | 99·2 | ... | ... | ... | ... | ... | ... | 0·17 | ... | ... | ... | ... | ... | ... |
| 6 | Zinc | 7·14 | 0·01 | ... | 0·005 | ... | ... | 99·92 | ... | ... | 0·005 | 0·01 | ... | ... | ... | ... | ... | ... | ... | 0·052 |
| 7 | Monel metal | 8·78 | 2·50 | 65·75 | 29·68 | ... | ... | <0·02 | 1·92 | 0·02 | <0·02 | <0·02 | ... | ... | ... | <0·02 | ... | ... | ... | ... |
| 8 | Cupro-nickel | 8·90 | 0·04 | 19·80 | 79·44 | ... | ... | 0·58 | ... | ... | ... | ... | ... | 0·11 | ... | ... | 0·03 | ... | ... | ... |
| 9 | Cast tin-bronze | 8·67 | <0·02 | <0·02 | 88·24 | ... | <0·02 | 1·68 | <0·02 | ... | <0·02 | 10·06 | ... | ... | ... | <0·02 | ... | 0·02 | ... | ... |
| 10 | Wrought tin-bronze | 8·89 | <0·02 | <0·02 | 94·20 | ... | <0·02 | 0·15 | <0·02 | ... | <0·02 | 5·53 | ... | ... | ... | <0·02 | ... | 0·25 | ... | ... |
| 11 | Aluminium-bronze | 7·63 | 0·28 | ... | 89·56 | ... | 9·42 | 0·16 | 0·50 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 12 | Silicon-zinc-bronze | 8·42 | 1·82 | ... | 91·56 | ... | 0·18 | 2·24 | 0·47 | ... | ... | ... | ... | 3·57 | ... | ... | ... | 0·08 | ... | ... |
| 13 | 70–30 brass | 8·52 | 0·01 | 0·02 | 70·84 | ... | ... | △ | ... | ... | <0·02 | <0·02 | ... | ... | ... | <0·02 | ... | ... | ... | ... |
| 14 | 60–40 high tensile brass | 8·38 | 0·41 | <0·02 | 58·32 | ... | 0·02 | 38·81 | 0·41 | ... | 0·84 | 1·18 | ... | <0·02 | ... | ... | ... | ... | ... | ... |
| 15 | Duralumin | 2·81 | 0·57 | 0·03 | 4·64 | ... | △ | ... | 0·62 | ... | ... | ... | 0·46 | 0·30 | ... | ... | ... | ... | ... | ... |
| 16 | Elektron | 1·82 | 0·07 | ... | ... | ... | 10·29 | ... | 0·19 | ... | ... | ... | 89·36 | 0·09 | ... | ... | ... | ... | ... | ... |
| 17 | Eutectic (3 : 2) tin-lead solder | 8·53 | 0·07 | ... | 0·05 | ... | ... | ... | ... | ... | 39·89 | 59·89 | ... | ... | 0·12 | ... | ... | ... | ... | ... |

TABLE II.—*Chemical Analysis of the 16 Steels Used in the Penetration Experiments.*

| No. | Steel. | Density. | Chemical Analysis. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C. | Si. | Mn. | P. | S. | Ni. | Cr. | Mo. | V. | W. |
| | *Carbon.* | | | | | | | | | | | |
| 18 | Mild, hot-rolled . . . | 7·838 | 0·17 | 0·09 | 0·64 | 0·013 | 0·018 | ... | ... | ... | ... | ... |
| 19 | Mild, cold-rolled . . . | 7·836 | 0·20 | 0·08 | 0·76 | 0·032 | 0·036 | ... | ... | ... | ... | ... |
| 20 | Medium, hot-rolled, treated . | 7·826 | 0·40 | 0·20 | 0·64 | 0·030 | 0·026 | 0·03 | 0·03 | ... | ... | ... |
| | *Rustless and Heat-Resisting.* | | | | | | | | | | | |
| 21 | Rustless, pearlitic . . | 7·686 | 0·29 | 0·79 | 0·51 | 0·027 | 0·012 | 0·28 | 12·5 | nil | nil | nil |
| 22 | Rustless, pearlitic . . | 7·715 | 0·27 | 0·18 | 0·23 | 0·032 | 0·030 | 0·41 | 13·2 | nil | nil | nil |
| 23 | Rustless, austenitic . . | 7·935 | 0·16 | 0·33 | 0·18 | 0·017 | 0·029 | 10·0 | 15·4 | nil | nil | nil |
| 24 | Rustless, austenitic . . | 7·897 | 0·18 | 0·38 | 0·24 | 0·027 | 0·016 | 8·20 | 17·9 | nil | nil | nil |
| 25 | Heat-resisting austenitic . | 8·037 | 0·16 | 0·67 | 0·30 | 0·025 | 0·011 | 9·10 | 18·0 | nil | nil | nil |
| 26 | Heat-resisting austenitic . | 7·816 | 0·42 | 2·46 | 0·84 | 0·026 | 0·042 | 24·5 | 16·2 | nil | nil | 0·67 |
| 27 | Heat-resisting austenitic . | 7·922 | 0·44 | 0·79 | 0·78 | 0·028 | 0·019 | 8·80 | 13·4 | nil | nil | nil |
| 28 | Heat-resisting austenitic . | 7·963 | 0·37 | 1·50 | 0·74 | 0·022 | 0·018 | 14·1 | 14·1 | 0·34 | nil | 3·04 |
| 29 | Heat-resisting austenitic . | 8·078 | 0·33 | 1·34 | 1·34 | 0·021 | 0·010 | 27·6 | 15·1 | nil | nil | 2·15 |
| | | | | | | | | | | | | 3·35 |
| | *Alloy Steel Hollow Forgings.* | | | | | | | | | | | |
| 30 | Ni–Cr–Mo. Penetrable . | 7·835 | 0·31 | 0·22 | 0·31 | 0·028 | 0·022 | 3·49 | 0·68 | 0·26 | ... | ... |
| 31 | Ni–Cr–Mo. Varied hardness and secondary grain-size . | 7·831 | 0·31 | 0·23 | 0·58 | 0·022 | 0·025 | 3·48 | 0·84 | 0·37 | ... | ... |
| 32 | Ni–Cr–V. Burnt . . | 7·822 | 0·36 | 0·22 | 0·31 | 0·022 | 0·032 | 4·42 | 1·19 | ... | 0·165 | ... |
| 33 | Ni–Cr. Temper brittle . | 7·818 | 0·29 | 0·25 | 0·54 | 0·025 | 0·035 | 3·77 | 0.78 | ... | ... | ... |

cylindrical shell. The susceptibility is confirmed in the test-piece, for the general extension is almost suppressed. The steel was hard. Slight softening by tempering gave a small average increase in resistance; on fully tempering, the average resistance again improved. The results from the first series of tests on steel 31, in which the hardness was varied, show that the effect of molten solder is greater in the harder state. The general and local reduction in area were entirely suppressed in the two hardest states, but reappeared on further tempering and softening. The second series of tests on steel 31 was carried out after three sets of test-pieces of different secondary grain-size had been prepared. All the test-pieces were of approximately the same hardness, and all the test-pieces in each set were of the same grain-size. The heat-treatment and test results are given in Table III. Each tensile test-piece broken under oil or solder was subjected to loads of 40 and of 50 tons/in.$^2$ for 5 minutes. The stress was then slowly increased until fracture occurred. The test-piece which broke at 40 tons/in.$^2$ broke after this load had been applied for 4 minutes, and those which broke at 50 tons/in.$^2$, each broke after 1 minute. In general, the effect of solder was more marked on the steel with the largest secondary grain-size, especially in suppressing the general extension.

Results from tests on the " burnt " and unburnt portions of a nickel–chromium–vanadium forging are given under 32. It appears that this steel is not very subject to penetration, and the burnt portion only slightly more so than the unburnt. This steel is not very hard.

A series of tests was also carried out on a temper brittle nickel–chromium steel, No. 33. This material was slightly affected by both molten solder and tin.

Experiments on three heat-treated alloy steels, using solder, tin, cadmium, bismuth, or lead as the molten surrounding liquid, showed that the ductility of all the steels was affected by each of the molten metals; most powerfully by solder and tin, and then by cadmium, bismuth, and lead in the order given. The tearing strength, or stress at fracture, was also definitely reduced by each of the above metals.

## IV.

Examination of the tensile test-pieces broken under solder showed that, with the exception of aluminium and the light alloys, and some of the rustless steels, the surface of each test-piece and its fracture had been definitely " wetted " by the solder, although in exceptional cases only in patches. Recently published work by Daniels [6] on the hot-tinning of metal surfaces suggests that if the metal pairs form neither

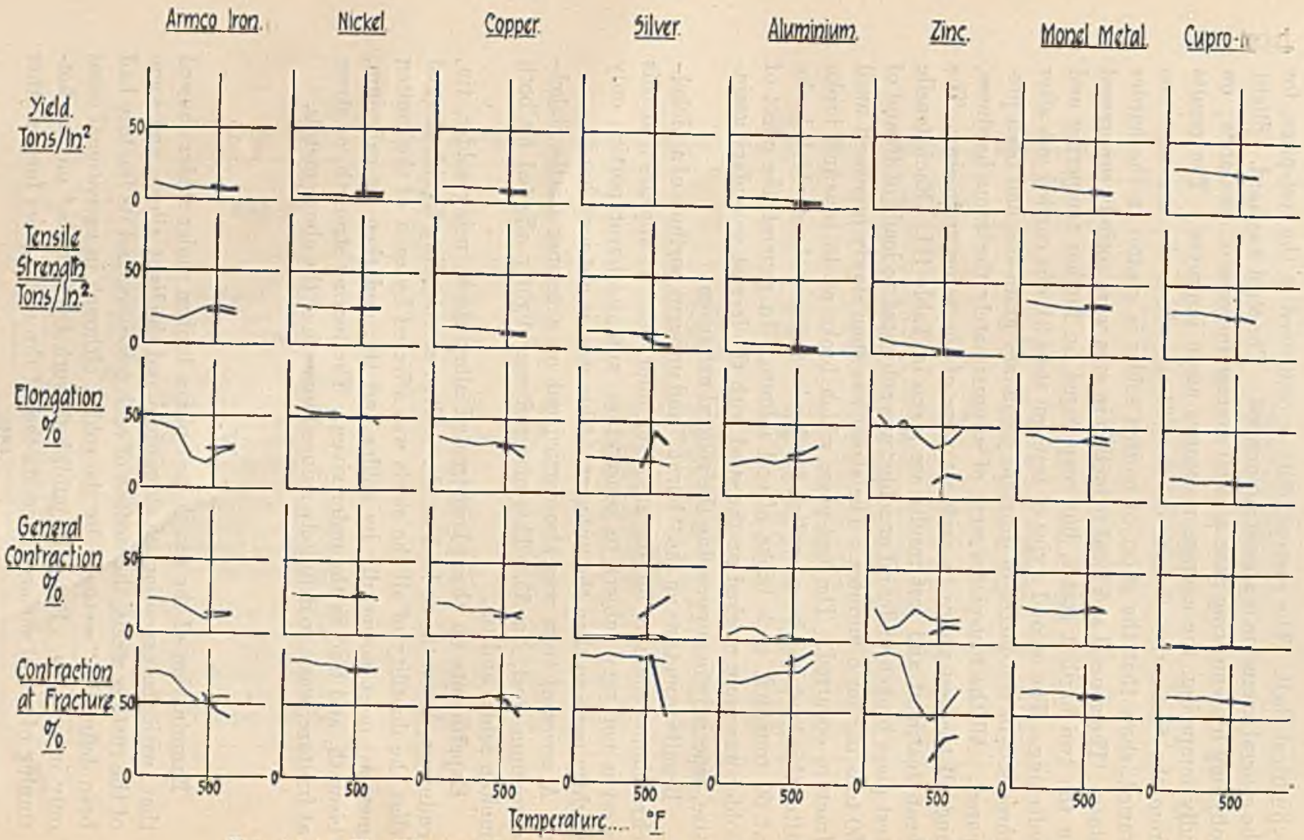

FIG. 4 (*a*).—The Effect of Molten Solder on the Properties of Some Metals and Alloys.
—— Properties in Oil. —— Properties in Solder.

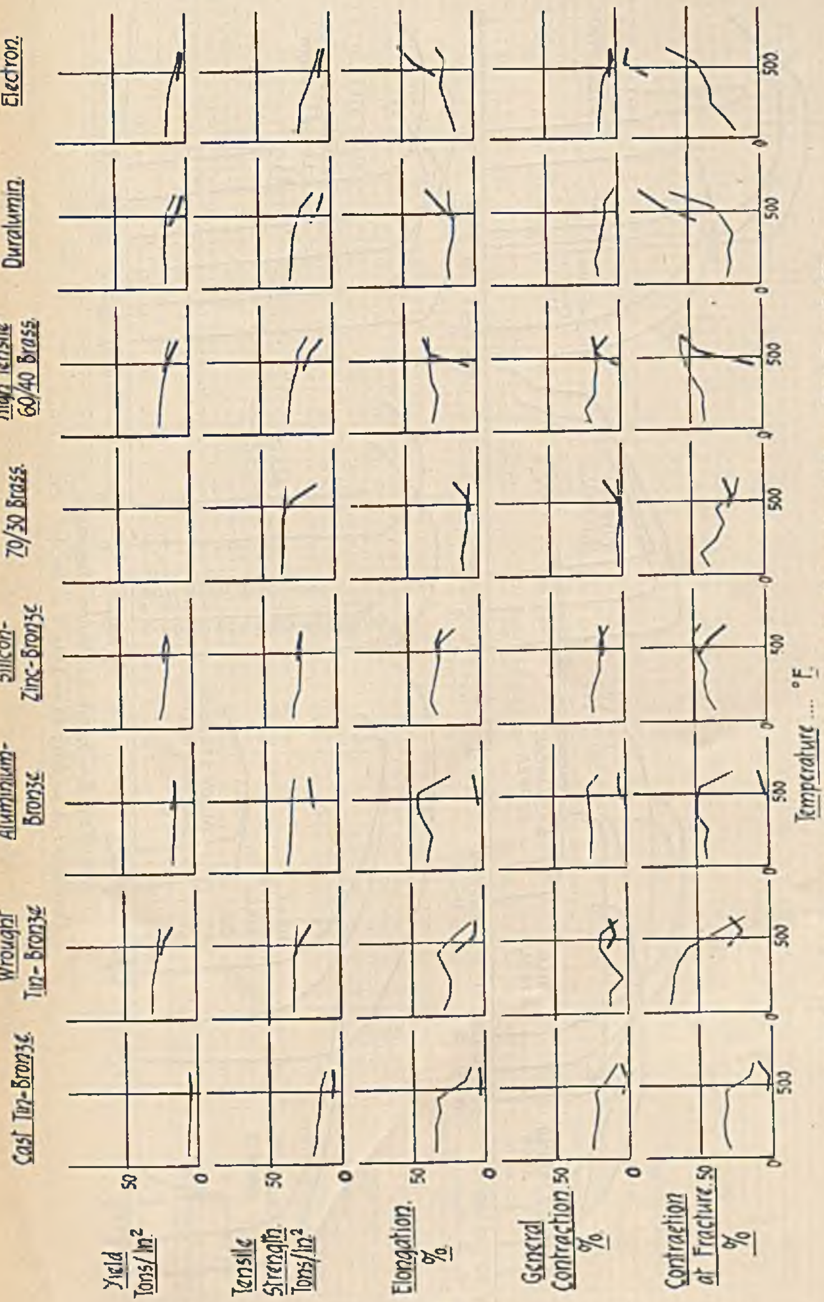

FIG. 4 (*b*).—The Effect of Molten Solder on the Properties of Some Metals and Alloys.
—— Properties in Oil. —— Properties in Solder.

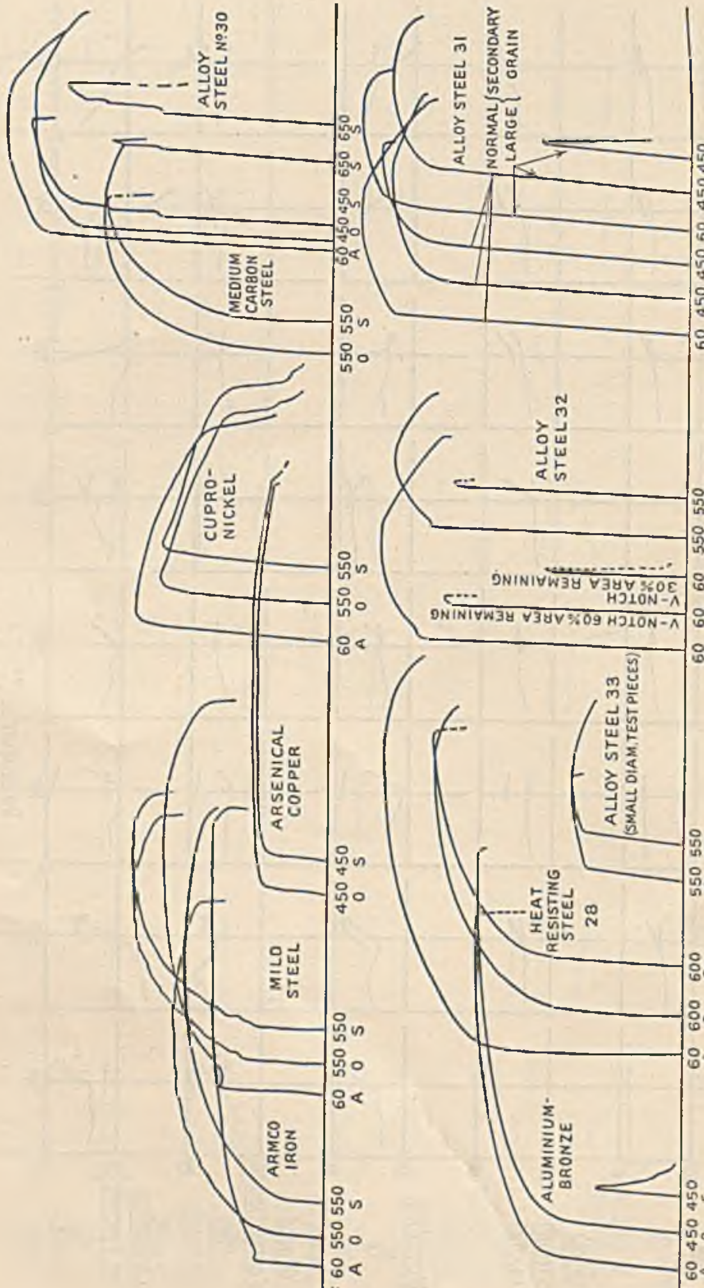

Fig. 5.—Load-Extension Diagrams.

Contacts: A = Air; O = Oil; S = Solder; Sn = Tin.

TABLE III.—*Solder Penetration Tests—Results Obtained from 16 Steels.*

TENSILE TESTS.

SYMBOLS USED  Y = YIELD, TONS IN²  B = MAX. LOAD, TONS IN²  Sδ = AXIAL STRESS INTENSITY AT FRACTURE, TONS IN²  E = ELONGATION % ON 2"
R = REDUCTION IN AREA %  G = GENERAL REDUCTION  H = TOTAL LOCAL REDUCTION  H = BRINELL HARDNESS
L = LONGITUDINAL  T = TRANSVERSE  650°F = 343°C, 600°F = 316°C, 550°F = 288°C, 450°F = 232°C  NO = NOT OBSERVED

| Nº | STEEL | | H | IZOD | COLD – AIR CONTACT | | | | | | | HOT – OIL CONTACT | | | | | | | HOT – MOLTEN SOLDER (S) OR TIN (T) CONTACT | | | | | | | % DECREASE IN PROPERTY, DUE TO MOLTEN SOLDER (S) OR TIN (T) CONTACT. (▭ = % INCREASE IN PROPERTY) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | °C | Y | B | Sδ | E | R G | R H | °C | Y | B | Sδ | E | R G | R H | °C | Y | B | Sδ | E | R G | R H | °C | Y | B | Sδ | E | R G | R H |
| | CARBON STEELS (BAR) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | MILD, HOT ROLLED | L | 121 | 81·3 | 15 | 19·0 | 30·0 | 66·7 | 38·0 | 18·3 | 67·0 | 232 | 19·0 | 29·0 | 61·3 | 22·3 | 11·7 | 54·3 | 232 S | 17·0 | 29·4 | 47·3 | 15·0 | 6·3 | 42·0 | 232 S | 10·5 | 2·9 | 4·2 | 11·6 | 27·4 | 8·8 |
| | | L | | | | | | | | | | 288 | 17·0 | 35·5 | 61·3 | 21·3 | 10·5 | 52·0 | 288 S | 17·5 | 36·0 | 47·6 | 21·0 | 15·0 | 28·4 | 288 S | 2·3 | 1·9 | 30·7 | 2·1 | 42·6 | 43·1 |
| 19 | MILD, COLD ROLLED | L | 143 | 15·8 | 15 | 36·0 | 44·0 | 66·3 | 16·0 | 2·5 | 57·3 | 232 | 34·0 | 40·3 | 56·3 | 11·0 | 1·5 | 45·0 | 232 S | 36·0 | 42·7 | 45·2 | 11·5 | 1·5 | 45·0 | 232 S | 5·9 | 5·4 | 18·5 | 4·2 | NIL | 2·2 |
| | | L | | | | | | | | | | 288 | 32·0 | 42·0 | 63·6 | 12·0 | 2·4 | 45·0 | 288 S | 35·0 | 42·3 | 47·2 | 11·0 | 7·0 | 10·5 | 288 S | NIL | 1·2 | 25·8 | 8·3 | 191·7 | 58·9 |
| 20 | MEDIUM, HOT ROLLED | L | 187 | 3·3 | 15 | 24·3 | 40·0 | 72·5 | 23·5 | 16·3 | 34·2 | 232 | 21·0 | 40·0 | 77·7 | 16·0 | 3·0 | 27·0 | 232 S | 20·3 | 43·0 | 53·4 | 18·0 | 27·0 | 26·0 | 232 S | 2·9 | 7·5 | 28·7 | 12·5 | 11·6 | 44·7 |
| | | L | | | | | | | | | | 288 | 30·5 | 65·1 | 67·8 | 17·0 | 11·7 | 41·0 | 288 S | 15·5 | 62·0 | 66·0 | 11·4 | 3·5 | 6·5 | 288 S | 8·3 | ·7 | 31·5 | 33·5 | 16·8 | 80·2 |
| | " HEAT TREATED | L | 255 | — | 15 | 27·5 | 55·0 | 87·0 | 23·3 | 12·2 | 39·0 | 232 | 33·5 | 50·8 | 83·3 | 4·3 | 4·6 | 45·0 | 232 S | 33·5 | 50·3 | 66·1 | 11·8 | 3·5 | 23·5 | 232 S | NIL | 1·0 | 18·2 | 30·3 | 34·5 | 39·4 |
| | | L | | | | | | | | | | 288 | 38·0 | 52·5 | 72·8 | 11·3 | 8·3 | 31·0 | 288 S | 33·5 | 50·8 | 54·5 | 7·0 | 4·0 | 8·0 | 288 S | 12·5 | 3·2 | 28·3 | 33·1 | 52·9 | 74·2 |
| | RUSTLESS & HEAT RESISTING (BAR) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | RUSTLESS PEARLITIC | L | 269 | 57·0 | 16 | 43·3 | 58·0 | 90·3 | 22·5 | 3·0 | 36·0 | 316 | 40·0 | 43·0 | 68·7 | 17·1 | 3·9 | 57·0 | 316 T | 38·0 | 46·1 | 78·3 | 17·0 | 6·1 | 42·0 | 316 T | 5·5 | 1·0 | 14·8 | 2·9 | 66·7 | 14·0 |
| 22 | " " | L | 207 | 17·3 | 16 | 30·0 | 47·0 | 80·3 | 24·0 | 13·0 | 55·3 | 316 | 33·0 | 33·6 | 64·7 | 24·0 | 11·3 | 57·0 | 316 T | 33·0 | 34·6 | 61·6 | 25·0 | 12·0 | 56·5 | 316 T | NIL | 3·0 | 4·8 | 4·2 | 9·4 | ·3 |
| 23 | " AUSTENITIC | L | 147 | 96·1 | 16 | 16·1 | 40·2 | 139·0 | 61·0 | 29·0 | 64·1 | 316 | 11·5 | 33·3 | 96·8 | 46·0 | 28·5 | 65·5 | 316 T | 11·5 | 34·0 | 97·1 | 47·0 | 27·3 | 65·0 | 316 T | NIL | 1·5 | ·3 | 2·1 | 3·5 | ·8 |
| 24 | " " | L | 163 | 105·0 | 16 | 17·4 | 44·4 | 144·3 | 64·0 | 33·0 | 63·0 | 316 | 11·4 | 34·5 | 117·3 | 65·0 | 30·0 | 63·0 | 316 T | 11·3 | 33·5 | 61·3 | 40·0 | 25·0 | 45·5 | 316 T | NIL | 2·9 | 49·9 | 27·3 | 16·7 | 30·1 |
| 25 | HEAT RESISTING AUSTENITIC | L | 132 | 100·0 | 16 | 16·0 | 41·3 | 150·2 | 63·0 | 29·5 | 72·3 | 316 | 11·3 | 35·6 | 101·2 | 47·3 | 25·0 | 67·0 | 316 T | 11·3 | 33·0 | 104·7 | 47·0 | 25·0 | 68·5 | 316 T | NIL | 1·3 | 3·2 | 1·1 | NIL | 2·2 |
| 26 | " " | L | 209 | 35·0 | 16 | 25·0 | 46·4 | 77·3 | 31·0 | 18·3 | 93·3 | 316 | 39·0 | 44·0 | 63·6 | 25·5 | 18·6 | 35·5 | 316 T | 39·0 | 35·0 | 37·7 | 6·0 | 3·3 | 11·3 | 316 T | NIL | 20·5 | 40·7 | 66·6 | 76·3 | 67·4 |
| 27 | " " | L | 229 | 44·0 | 16 | 29·0 | 61·2 | 108·3 | 36·5 | 22·5 | 43·1 | 316 | 33·0 | 46·5 | 65·3 | 34·5 | 23·3 | 41·5 | 316 T | 33·0 | 41·0 | 33·8 | 16·0 | 13·0 | 20·0 | 316 T | NIL | 7·3 | 38·3 | 56·2 | 44·7 | 36·0 |
| 28 | " " | L | 281 | 31·0 | 16 | 33·6 | 46·0 | 47·3 | 30·0 | 19·5 | 46·0 | 316 | 11·0 | 46·0 | 73·7 | 26·0 | 16·0 | 43·0 | 316 T | 33·0 | 46·0 | 60·3 | 10·0 | 12·0 | 38·0 | 316 T | NIL | NIL | 17·6 | 76·5 | 12·5 | 88·7 |
| 29 | " " | L | 187 | 83·1 | 16 | 21·0 | 57·5 | 79·6 | 35·0 | 55·0 | 64·6 | 316 | 11·0 | 43·5 | 80·6 | 39·0 | 22·3 | 46·0 | 316 T | 33·0 | 40·0 | 47·3 | 13·0 | 13·0 | 15·5 | 316 T | NIL | 4·0 | 41·3 | 61·6 | 42·2 | 66·3 |
| | ALLOY STEEL HOLLOW FORGINGS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | NI-CR-MO PENETRABLE | T | 341 | 28·0 | 16 | 62·0 | 70·4 | 105·0 | 16·0 | 7·5 | 42·5 | 232 | 56·0 | 64·6 | 97·4 | 16·0 | 7·0 | 42·5 | 232 S | 55·2 | 65·2 | 71·4 | 6·7 | 4·4 | 8·7 | 232 S | 1·8 | ·5 | 26·7 | 58·1 | 37·1 | 79·5 |
| | | T | | | | | | | | | | 193 | 51·0 | 65·6 | 101·3 | 20·0 | 6·0 | 33·0 | 193 S | N.O. | 59·0 | 54·2 | 2·2 | ·3 | 1·7 | 193 S | N.O. | 17·7 | 45·2 | 87·5 | 55·0 | 94·8 |
| | " TEMPERED 600°C | T | 321 | — | 16 | 56·0 | 67·2 | 100·2 | 17·0 | 7·0 | 66·1 | 232 | 56·0 | 64·9 | 97·7 | 15·0 | 9·5 | 43·6 | 232 S | 55·7 | 65·6 | 42·7 | 10·2 | 4·5 | 20·0 | 232 S | ·3 | 1·2 | 55·4 | 32·0 | NIL | 54·0 |
| | | T | | | | | | | | | | 193 | 63·5 | 65·6 | 97·7 | 17·0 | 5·0 | 43·7 | 193 S | 55·0 | 53·4 | 60·3 | 3·3 | ·7 | 3·3 | 193 S | ·9 | 8·4 | 38·3 | 81·1 | 56·0 | 95·4 |
| | " TEMPERED 650°C | T | 288 | — | 16 | 59·0 | 62·9 | 105·2 | 18·5 | 7·0 | 53·5 | 232 | 53·8 | 56·2 | 102·0 | 19·5 | 7·0 | 51·3 | 232 S | 54·5 | 56·0 | 65·4 | 17·2 | 7·3 | 45·0 | 232 S | 1·9 | 1·7 | 17·7 | 11·8 | 7·2 | 12·6 |
| | | T | | | | | | | | | | 193 | 54·7 | 57·2 | 100·6 | 17·0 | 7·1 | 49·4 | 193 S | N.O. | 50·0 | 65·7 | 4·0 | 2·5 | 5·0 | 193 S | N.O. | 11·0 | 47·4 | 76·5 | 64·7 | 89·7 |
| 31 | NI-CR-MO VARIED HARDNESS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | OIL HARDENED 850°C | T | 477 | 7·3 | 16 | N.O. | 125·4 | 192·4 | 2·0 | 3·3 | 10·4 | 232 | N.O. | 116·4 | 163·3 | 14·0 | 3·3 | 32·3 | 232 S | N.O. | 30·0 | 30·0 | 1·0 | NIL | NIL | 232 S | N.O. | 37·2 | 70·5 | 92·3 | 100·0 | 100·0 |
| | | T | | | | | | | | | | 343 | N.O. | 92·8 | 157·3 | 13·0 | 3·2 | 41·0 | 343 S | N.O. | 33·0 | 38·0 | NIL | NIL | NIL | 343 S | N.O. | 58·0 | 75·2 | 100·0 | 100·0 | 100·0 |
| | " TEMPERED 450°C | T | 388 | 7·3 | 16 | 76·0 | 87·5 | 130·3 | 10·0 | 3·5 | 30·0 | 232 | 65·0 | 89·4 | 116·7 | 10·5 | 3·7 | 23·5 | 232 S | N.O. | 30·0 | 30·0 | NIL | NIL | NIL | 232 S | N.O. | 66·4 | 57·2 | 100·0 | 100·0 | 100·0 |
| | | T | | | | | | | | | | 343 | N.O. | 83·4 | 119·5 | 10·0 | 3·2 | 23·5 | 343 S | N.O. | 60·0 | 60·0 | 1·0 | NIL | NIL | 343 S | N.O. | 28·2 | 49·8 | 90·0 | 100·0 | 100·0 |
| | " TEMPERED 550°C | T | 321 | 24·0 | 16 | 66·8 | 72·4 | 102·2 | 16·0 | 8·1 | 40·2 | 232 | 58·0 | 67·3 | 91·3 | 14·0 | 8·3 | 32·5 | 232 S | 57·3 | 66·8 | 80·0 | 2·0 | 6·3 | 15·0 | 232 S | ·7 | 2·4 | 12·4 | 85·7 | 23·3 | 53·8 |
| | | T | | | | | | | | | | 193 | 55·0 | 67·8 | 88·1 | 16·0 | 3·5 | 38·3 | 193 S | 53·2 | 58·8 | 61·7 | 2·3 | 1·1 | 6·0 | 193 S | 3·3 | 12·8 | 27·7 | 85·1 | 68·6 | 84·4 |
| | " TEMPERED 650°C | T | 283 | 32·4 | 16 | 56·7 | 64·4 | 103·3 | 18·0 | 10·0 | 42·3 | 234 | 55·5 | 63·2 | 101·1 | 15·0 | 3·5 | 37·5 | 234 S | 53·0 | 63·6 | 90·2 | 14·0 | 10·5 | 29·3 | 234 S | ·9 | ·6 | 10·8 | 4·7 | 40·0 | 21·1 |
| | | T | | | | | | | | | | 193 | 56·5 | 63·7 | 106·6 | 16·0 | 8·0 | 37·5 | 193 S | 55·0 | 56·8 | 67·4 | 4·5 | 2·4 | 4·7 | 193 S | ·3 | 7·0 | 36·1 | 71·9 | 65·0 | 88·0 |
| " | VARIED SECONDARY GRAIN SIZE<br>OIL HARDENED 1150°C, TEMPERED 650°C | T | 302 | 23·8 | 16 | 67·2 | 79·0 | 86·6 | 11·0 | 8·0 | 21·3 | 232 | 56·0 | 68·4 | 63·4 | 12·0 | 7·5 | 27·5 | 232 S | 57·0 | 68·0 | 21·4 | 8·0 | 5·0 | 16·3 | 232 S | 1·8 | 1·2 | 6·3 | 33·3 | 33·3 | 40·0 |
| | | T | | | | | | | | | | 193 | 56·5 | 68·6 | 72·2 | 8·0 | 7·0 | 13·0 | 193 S | N.O. | 50·0 | 51·3 | 1·3 | NIL | 6·4 | 193 S | N.O. | 27·3 | 32·6 | 81·2 | 100·0 | 50·8 |
| | " 1050°C " 650°C | T | 302 | 23·3 | 16 | 66·6 | 73·6 | 96·1 | 12·0 | 6·0 | 31·0 | 232 | 57·0 | 67·2 | 68·3 | 11·0 | 6·0 | 26·5 | 232 S | 56·3 | 67·6 | 79·0 | 7·6 | 5·1 | 19·6 | 232 S | ·9 | ·6 | 10·3 | 31·6 | 14·3 | 91·1 |
| | | T | | | | | | | | | | 193 | 56·0 | 68·0 | 67·7 | 14·0 | 6·0 | 29·0 | 193 S | 56·7 | 62·4 | 63·6 | 3·7 | ·9 | 5·0 | 193 S | 1·3 | 8·2 | 25·0 | 80·7 | 84·4 | 82·8 |
| | " 850°C " 650°C | T | 371 | 29·0 | 16 | 66·8 | 72·4 | 102·2 | 16·0 | 8·3 | 40·3 | 232 | 58·0 | 67·2 | 91·3 | 14·0 | 8·3 | 32·3 | 232 S | 57·3 | 55·8 | 80·0 | 2·0 | 6·5 | 15·0 | 232 S | ·9 | 2·4 | 12·4 | 85·7 | 23·3 | 53·8 |
| | | T | | | | | | | | | | 193 | 65·5 | 67·2 | 88·1 | 16·0 | 3·3 | 38·5 | 193 S | 63·2 | 56·8 | 63·7 | 2·7 | 1·1 | 6·0 | 193 S | 4·1 | 15·9 | 27·7 | 83·1 | 66·4 | 84·4 |
| 32 | NI-CR-V<br>UNBURNT | T | 331 | 33·6 | 16 | 56·3 | 69·4 | 98·6 | 17·2 | 8·9 | 43·7 | 288 | 55·0 | 61·6 | 87·3 | 14·5 | 6·5 | 33·0 | 288 T | 53·0 | 61·3 | 70·4 | 8·0 | 5·0 | 16·0 | 288 T | NIL | ·6 | 19·8 | 44·8 | 22·1 | 53·0 |
| | | T | | | | | | | | | | 343 | 55·0 | 60·5 | 76·4 | 13·0 | 4·0 | 27·5 | 343 S | 55·0 | 57·8 | 66·1 | 6·0 | 3·9 | 16·5 | 343 S | NIL | 4·5 | 13·5 | 58·5 | 51·9 | 40·0 |
| | BURNT | T | 321 | 77·9 | 16 | 59·7 | 63·3 | 88·4 | 13·7 | 6·6 | 31·6 | 288 | 55·0 | 60·5 | 82·4 | 16·0 | 7·5 | 35·3 | 288 T | 55·0 | 60·0 | 67·6 | 8·5 | 6·5 | 11·5 | 288 T | NIL | ·8 | 18·1 | 46·9 | 13·3 | 67·5 |
| | | T | | | | | | | | | | 343 | 53·0 | 58·3 | 87·3 | 15·5 | 6·5 | 39·5 | 343 S | 44·0 | 58·0 | 65·7 | 7·5 | 3·9 | 11·7 | 343 S | 12·7 | ·5 | 20·2 | 51·6 | 40·0 | 70·4 |
| 33 | NI-CR TEMPER BRITTLE | T | 262 | 2·3 | 16 | 32·0 | 60·7 | 111·6 | 21·2 | 10·3 | 60·0 | 288 | 49·0 | 55·3 | 100·4 | 14·0 | 6·0 | 53·0 | 288 S | 49·2 | 56·2 | 63·5 | 8·5 | 7·0 | 10·2 | 288 S | ·6 | ·9 | 37·7 | 39·3 | 16·7 | 81·5 |
| | | T | | | | | | | | | | 288 | 49·0 | 55·6 | 108·5 | 15·0 | 6·5 | 55·0 | 288 T | 49·0 | 55·3 | 61·1 | 6·0 | 5·8 | 2·5 | 288 T | 7·1 | ·5 | 44·2 | 60·0 | 10·8 | 82·7 |

solid solutions nor compounds, the tendency to wetting should be relatively small.

The fracture of the affected test-pieces was " short," and of the type associated with brittleness or the presence of discontinuities.

The load–extension diagrams for a pair of materials, broken at a given temperature, but in oil and solder respectively, were similar, and generally superimposable, except that the diagram from the piece tested under solder stopped earlier. The presence of the molten solder does not thus apparently affect the general resistance of the material to deformation, but interrupts the normal tensile deformation curve, probably by diminishing the technical cohesion at the grain boundaries. The plane penetrated by solder no longer resists the normal force and separation occurs.

Microexamination has been carried out on some of the specimens broken under solder. Solder was observed round the grain boundaries of steel No. 30 (Fig. 6, Plate II) and in the vicinity of the fracture in many other cases. The indication of intergranular penetration given by the load–extension diagrams has thus been confirmed in several cases. Recrystallization was observed in some of the materials, especially those of low melting point, after tests at the higher temperatures.

## V.

The following conclusions are drawn from the results obtained :

(1) Almost all the usual metals, alloys, and steels, employed in general engineering, if tensile stressed and in contact with molten solder, are susceptible to penetration and weakening to a greater or less degree. Nickel, Monel metal, and cupro–nickel are, however, but slightly affected.

(2) The plain low-carbon steels, and the lower carbon pearlitic and austenitic heat- and rust-resisting steels do not appear as subject to penetration as similar steels with higher carbon. The liability to penetration in the heat-treated alloy steels tested becomes greater with increasing hardness and secondary grain-size, especially the former. Neither the temper brittle nor the burnt state appears of itself to increase greatly the susceptibility to penetration of the alloy steel tested.

(3) The phenomenon has been shown to be an interruption of the normal tensile deformation curve at a point depending on the material and conditions of the test. The shape of the curve thereto appears unaltered. The action is thus not dissimilar to that of discontinuities, notches, certain types of chemical attack, or the brittle state, and is probably due to intergranular penetration. The cohesion is reduced, whilst the resistance to deformation persists.

These conclusions could be applied as follows:

A. It appears advisable when soldering parts, especially if screwed, or of shape liable to stress concentration, to avoid the application of any load or temperature gradient which may give rise to tensile stresses at the surface in contact with the molten solder.

B. The phenomenon may have application for the technological parting off, or destruction of such materials and parts as are readily surface-stressed and penetrable by molten solder.

C. The increased deformability shown by aluminium, Duralumin, and Elektron, in the presence of molten solder, may present a possible means of facilitating the hot-forming of these materials.

D. The method of investigation, if pursued, may throw light on the nature of technical cohesion and grain boundaries.

## ACKNOWLEDGMENTS.

The author wishes to thank the Admiralty for permission to publish an account of this work, and all who have assisted in carrying it out. Several Admiralty Departments have given encouragement. Engineer Rear-Admiral H. E. Hoare, the late Superintendent of the Royal Naval Torpedo Factory, where most of the work was carried out, took a personal interest in its progress. Mr. G. A. Keay, B.Sc., constantly advised and assisted. Finally, the author desires to record his thanks to the personnel of the test-room for their active co-operation and assistance with the foregoing tests.

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# MEETINGS OF OTHER SOCIETIES

### *SATURDAY*, October 19.

Institute of British Foundrymen, East Midlands Branch, Lincolnshire Section.—L. W. Bolton: "Recent Developments in Foundry Practice." (Technical College, Lincoln, at 7 p.m.)

Institute of British Foundrymen, Scottish Branch, Falkirk Section.—W. McArthur: "Moulding Shop Problems." (Temperance Café, Lint Riggs, Falkirk, at 6 p.m.)

### *SATURDAY*, October 26.

Institute of British Foundrymen, East Midlands Branch.—L. E. Benson: "Microscopy of Cast Metals." (Loughborough College, at 6 p.m.)

Institute of British Foundrymen, Wales and Monmouth Branch.—F. J. Cook: "Some Further Notes on Balancing the Elements." (University College, Newport Rd., Cardiff, at 6.30 p.m.)

### *WEDNESDAY*, October 30.

Electrodepositors' Technical Society.—C. Béchard: "Electrodeposition of Bronze." S. Baier: "Some Tests on Bronze Deposits." (Northampton Polytechnic Institute, St. John St., Clerkenwell, London, E.C.1, at 8.15 p.m.)

### *FRIDAY*, November 1.

Institute of British Foundrymen, Birmingham, Coventry and West Midlands Branch.—W. J. Rees: "Refractories for Foundry Use." (James Watt Memorial Institute, Gt. Charles St., Birmingham, 3, at 7.30 p.m.)

Institute of British Foundrymen, East Midlands Branch, Lincolnshire Section.—G. W. Brown: "Some Details of Modern Foundry Control." (Technical College, Lincoln, at 7 p.m.)

Junior Institution of Engineers.—Major H. J. Williams: "Metal Spraying." (The Institution, 39 Victoria Street, London, S.W.1, at 7.30 p.m.)

### *SATURDAY*, November 2.

Institute of British Foundrymen, Lancashire Branch.—A. H. Mundey: "Die-Castings." (Engineers' Club, Albert Sq., Manchester, at 4 p.m.)

### *TUESDAY*, November 5.

Electrodepositors' Technical Society.—L. Wright: "Exhibition of Lantern Slides Appertaining to Electrochemistry." (James Watt Memorial Institute, Gt. Charles St., Birmingham, 3, at 7.30 p.m.)

### *WEDNESDAY*, November 6.

Institute of British Foundrymen, London Branch.—R. R. Hyde: "Welfare Work in Relation to Foundries." (Charing Cross Hotel, London, W.C.2, at 8 p.m.)

### *SATURDAY*, November 9.

Institute of British Foundrymen, Scottish Branch.—W. Y. Buchanan: "The Balanced Blast Cupola." (Royal Technical College, George St., Glasgow, at 4 p.m.)

### *TUESDAY*, November 12.

Institute of British Foundrymen, Lancashire Branch, Burnley Section.—J. Jackson: "Castings Viewed from the Machine Shop *re* Machinability." (Municipal College, Ormerod Rd., Burnley, at 7.15 p.m.)

### *FRIDAY*, November 15.

Institute of British Foundrymen, Sheffield and District Branch.—W. J. Rees: "Refractories in the Foundry." (Grand Hotel, Sheffield, at 7.30 p.m.)

### *SATURDAY*, November 16.

Institute of British Foundrymen, Wales and Monmouth Branch.—H. Stead: "Patternmaking—The Craftsman and His Craft." (Technical College, Newport, at 6.30 p.m.)

# AUTHOR INDEX TO ABSTRACTS

# *Author Index to Abstracts*

# METALLURGICAL ABSTRACTS

## (GENERAL AND NON-FERROUS)

Volume 2 OCTOBER 1935 Part 10

## I.—PROPERTIES OF METALS

(Continued from pp. 413–417.)

*__The Longitudinal Thermoelectric Effect. (3) Aluminium; (4) A Further Study of Aluminium; (5) Silver.__ (3) M. K. Li and William Band; (4) William Band; (5) J. L. Ch'en and William Band (*Proc. Phys. Soc.* (*Lond.*), 1935, **47**, 859–861, 862–872, 904–909).—(3) The thermoelectric e.m.f. developed in aluminium wire by asymmetrical heating to temperatures below 180° C. have been measured, using a Paschen galvanometer. They were found to be in the same direction as those previously found in copper, and were less than 0·3 μv. Asymmetrical temperature distribution does not appear to be the controlling factor in the production of the e.m.f.; it is suggested that there may exist an allotropic form of aluminium having a transition temperature below 180° C. (4) The experimental results obtained in (3) are discussed and the existence of a critical transition temperature at 79° C. is deduced and confirmed by cooling-curve determinations. (5) A critical temperature at about 200° C. for silver, under zero tension, is found at which the thermoelectric "constants" of the metal change abruptly. It is suggested that there is an intimate connection between this temperature and the ordinary elastic limit of the wire.—J. S. G. T.

*__A Modification of Carpenter and Elam's Method of Producing Single Crystals of Aluminium by Deformation and Annealing.__ Vaughan H. Stott (*Trans. Faraday Soc.*, 1935, **31**, 998–1000).—Single crystals of pure aluminium (99·9%) are readily obtained from hard-rolled cylindrical bars by annealing at 560° C. for 6 hrs., stretching the bar by 10–15%, again annealing at 560° C. for several hours, extending the rod a further 1·7% and annealing at 450°–640° C. for several days raising the temperature by 10° C. per day, then at 640°–645° C. for a few more days. In this way specimens of ¾ in. diam. and 7 in. long are generally obtained. The above procedure gives a better yield of single crystals than the method of Carpenter and Elam, since the second 560° anneal after the 10–15% extension removes inequalities in the internal stresses produced by the original round rolling.—A. R. P.

*__The Recrystallization of Pure Aluminium.__ Jean Calvet, Jean J. Trillat, and Miloslav Paič (*Compt. rend.*, 1935, **201**, 426–428; and (abstract) *J. Four élect.*, 1935, **44**, 282).—Continuing the work of Calvet (*Met. Abs.*, this vol., pp. 137, 273), the recrystallization of the purest aluminium hitherto prepared in France has been studied by X-ray spectroscopy. Strip, 99·9986% pure, and containing approximately iron 0·0002, silicon 0·0009, and copper 0·0003%, was rolled down to 1·08 mm. from cast ingots 22·9 mm. thick, and subjected to various annealings. At 0° C., no sign of recrystallization was observed after 6 hrs., slight traces after 12 hrs., more after 24 hrs., and it had definitely began after 38 hrs.; it was not complete after 336 hrs. or even 48 days. At 25° C., there was a trace after 30 minutes, it was distinct after 1 hr., but was not completely finished after 336 hrs. (another experiment showed it to be complete after 48 days). At 40° C., there were traces after 1 minute, more distinct after 30 minutes, very advanced after 16 hrs., and probably complete after 32–48 hrs. At 60° C., complete after 6 hrs. At 100° C., already com-

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* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

plete after 1 minute. At higher temperatures, recrystallization is practically instantaneous, *e.g.* at 150° C. after 5 seconds. An examination of the plates did not confirm the results of Trillat and Paić (*Met. Abs.*, this vol., p. 256), owing to the presence of large crystalline formations in the rest of the worked structure. Very pure metal recrystallizes normally without the formation of appreciable crystals before the disappearance of the laminated structure. —J. H. W.

***Recrystallization of Cast Aluminium.** H. Röhrig and E. Köpernick (*Aluminium*, 1935, 17, 411–415).—When very pure aluminium (99·95%) castings are annealed at 580° C. for 20 hrs. the coarse casting structure disappears and is replaced by irregular polygonal crystals; at 610° C. complete recrystallization occurs. Addition of 2% copper or 0·15% silicon has no effect on the recrystallization, but even 0·1% of iron prevents it by segregating along the grain boundaries and thus restraining crystal growth.—A. R. P.

***A Study of the Passivity of Iron and Aluminium.** W. H. Cone and H. V. Tartar (*J. Amer. Chem. Soc.*, 1934, 56, 48–52).—Experimental results obtained on the passivity of iron and aluminium in nitric acid and of iron in chromic acid and in silver nitrate solutions are described. In nitric acid, the presence of phosphate or sulphate makes the metal more electronegative with respect to the solution and accelerates solution.—R. G.

***Amorphous Antimony.** J. A. Prins (*Nature*, 1935, 136, 299).—"Explosive" antimony, prepared by electrodeposition, is shown by electron-diffraction analysis to be identical with the amorphous films of antimony produced by distillation in a high vacuum. When such an amorphous film is heated at 120°–150° C. crystallization occurs. The amorphous form is considered to be in the supercooled liquid state.—E. S. H.

***The Allotropy of Beryllium.** F. M. Jaeger and J. E. Zanstra (*Proc. K. Akad. Wet. Amsterdam*, 1933, 36, 636–644).—[In English.] X-ray examination of a single crystal of very pure beryllium showed, in addition to lines due to the well-known hexagonal lattice, $a = 2{\cdot}283$ A., $c = 3{\cdot}61$ A., traces of further lines which could be attributed only to an allotropic modification. After heating the metal *in vacuo* for some hours at 680°–800° C. these lines became pronounced, and corresponded with a hexagonal lattice with $a = 7{\cdot}1$ and $c = 10{\cdot}8$ A.; about 10% of the metal appeared to remain in this $\beta$-form on cooling to room temperature.—A. R. P.

***Determination of the Melting Point of Calcium, Strontium, and Barium.** F. Hoffmann and A. Schulze (*Z. Metallkunde*, 1935, 27, 155–158).—Determinations made in an argon atmosphere on vacuum-distilled metals gave the following values for the melting points (± 1° C. in each case): calcium 851° C., strontium 771° C., barium 704° C. Hence the melting points of the alkaline earth metals follow the rule that an increase in atomic volume is accompanied by a decrease in melting point. The results of determinations made on several grades of the commercial metals are also given.—A. R. P.

***The Vacuum Distillation of Metals [Chromium, Aluminium, Silicon, Beryllium].** W. Kroll (*Light Metals Res.*, 1935, 4, 48–50).—Translation, in summary, of a paper in *Metallwirtschaft*, 1934, 13, 725–731, 789. See *Met. Abs.*, this vol., p. 2.—L. A. O.

***Investigations on the Heat Effects in the Transformations of Cobalt.** H. von Steinwehr and A. Schulze (*Z. Metallkunde*, 1935, 27, 90–92).—The determinations were made on a 20 kg. block of 98·1% cobalt (containing copper 0·24, iron 1·60, carbon 0·006%, nickel trace). The change from $\alpha$ to $\beta$ is accompanied by a heat evolution of 0·1 grm.-cal./grm. and the magnetic transformation by a heat evolution of 1·2 grm.-cal./grm. The first transformation occurs over the range 380°–420° C. and the second over the range 1070°–1125° C.—A. R. P.

***Abnormal Magnetic Behaviour of Treated Cobalt Wire.** T. F. Wall (*Nature*, 1935, **136**, 397).—After heating at about 1200° C. for some hours in hydrogen by a.c. at 50 cycles, the saturation value of the intensity of magnetization of a cobalt wire was only about 60% of that for normal cobalt.—E. S. H.

**Mechanical Moment of the Cobalt Nucleus.** Hans Kopfermann and Ebbe Rasmussen (*Z. Physik*, 1935, **94**, 58–67).—The mechanical moment of the cobalt nucleus is found, from spectroscopic evidence, to have the value 7/2. —J. S. G. T.

***The Effect of Sulphur on the Properties of Copper.** Witold Broniewski and W. Lewandowski (*Compt. rend.*, 1935, **201**, 273–275).—The following determinations were made on copper containing up to 0·75% of sulphur, made by melting the 2 constituents together in a high-frequency furnace: proportion of sulphur (by analysis); electrical conductivity; temperature coeff. of electrical resistance between 0° and 100° C.; thermal e.m.f. at 0° C. compared with that of lead, and its variation between − 80° and + 100° C.; resistance to drawing; limit of proportionality; total elongation to rupture ($l = 10d$); percentage elongation; percentage contraction of area; Brinell hardness; and resilience. These properties, except the thermo-electric properties, varied but little with the sulphur content, the curves having no apices. The shape of the curves, characteristic of mixtures, was confirmed by micrographic examination, which showed crystallites of $Cu_2S$, even at as low a sulphur content as 0·03%. These crystallites, round in shape, increase in number and size with the sulphur content. The limit of solubility of sulphur in copper appears to be very low, less than 0·03%. The harmful effect of sulphur in copper appears to be less than that of oxygen (cf. *Met. Abs.* (*J. Inst. Metals*), 1933, **53**, 226).—J. H. W.

***Preparation and Properties of Gallium and Gallium Trichloride.** William M. Craig and G. Wilson Drake (*J. Amer. Chem. Soc.*, 1934, **56**, 584–585).—An easy and rapid method for the separation of traces of gallium from lead dross by means of fused lead chloride is described. The melting point of metallic gallium was found to be 29·755° C., the density 5·903 grm./c.c. at 25° C., and the atomic volume 11·81. Pure gallium shows little tendency to super-cooling.—L. A. O.

***On the Change of the Resistance of Single Crystals of Gallium in a Magnetic Field.—I–II.** W. J. de Haas and J. W. Blom (*Comm. K. Onnes Lab. Univ. Leiden*, 1934, (**229b**), pp. 11; 1934, (**231b**), pp. 10).—[In English.] See *Met. Abs.*, 1934, **1**, 285, 546.—L. A. O.

**†Investigations on the Transformation of Pure Manganese.** A. Schulze (*Z. Metallkunde*, 1935, **27**, 66).—The properties of the three forms of manganese are as follows:

| Form. | Lattice Parameter, A. | Atoms in Unit Cell. | d. | Temp. Coeff. of Conductivity, × $10^{-3}$. | Sp. Electrical Conductivity, $Ohm^{-1}$. $cm.^{-1}$. |
|---|---|---|---|---|---|
| α | $a = 8{\cdot}901$ | 58 | 7·4 | 0·17 | 0·14 × $10^4$ |
| β | $a = 6{\cdot}367$ | 20 | 7·29 | 1·36 | 1·1 × $10^4$ |
| γ | $a = 3{\cdot}767$<br>$c/a = 0{\cdot}934$ | 4 | 7·20 | 5·3 | 4·4 × $10^4$ |

These figures indicate that the γ-form behaves as a pure metal, whereas the α- and β-forms appear to be solid solutions of another form in γ.—A. R. P.

***On the Orientation of the Crystallites in a Nickel Casting and the Changes Produced by Rolling and Recrystallization.** G. Tammann and F. Laass (*Z. Metallkunde*, 1935, **27**, 86–88).—In cast nickel, octahedral planes lie on the cooling surface and after working and annealing at just below the melting point the new crystals formed in nickel sheet are so oriented that octahedral planes lie in the rolling plane. Nickel thus behaves like aluminium and not like copper in which cube planes lie on the cooling surface and in the rolling plane of recrystallized sheet.—A. R. P.

***Thermomagnetic Hysteresis in Nickel Wire.** Y. K. Hsü and William Band (*Proc. Phys. Soc.* (*Lond.*), 1935, **47**, 910–922).—The dependence of the thermomagnetic hysteresis of nickel wire on magnetization and tension, is investigated. The results corresponding to zero tension agree with those of Broili, but there is still a measurable increase in e.m.f., not detected by Broili, when the maximum temperature is raised above the Curie point. This is attributed to the Benedicks' e.m.f. The effect is still greater for a stretched wire. The e.m.f. reverses sign in 2 quadrants of the hysteresis curve. The change in Thomson potential gradient produced by various magnetizing fields at different tensions is shown graphically as a function of temperature, the Benedicks' e.m.f. being neglected.—J. S. G. T.

**The Dispersion of X-Rays by Nickel.** J. Oumanski and W. Wexler (*Physikal. Z. Sowjetunion*, 1934, **6**, 258–267).—[In French.] The "atomic factor" $F(\theta)$ enters into the expression for the intensity of the X-rays diffracted by a crystal at angle $\theta$. $F(\theta)$ has been determined experimentally for nickel and its values for various values of $\theta$ compared with theoretical values derived by application of Fermi's theory. The slight discrepancy between the respective results is attributable partly to experimental error and partly to deficiency of the theory.—J. S. G. T.

**Preparation, Properties, and Technical Uses of Palladium.** E. T. Richards (*Metallbörse*, 1935, **25**, 819, 850–851, 882–883, 914–915).—A review, with especial reference to the use of the metal in dental alloys and for plating.
—A. R. P.

***The Rôle of Intragranular Fissures in the Occlusion and Evolution of Hydrogen by Palladium.** Donald P. Smith and G. J. Derge (*J. Amer. Chem. Soc.*, 1934, **56**, 2513–2525).—See also *Met. Abs.*, 1934, **1**, 549. In view of previous work showing that the primary distribution of hydrogen in palladium is along fissures in certain crystallographic planes, experimental work was carried out to determine the connection between the absorption and release of hydrogen by palladium and the effects of deformation. The effects of annealing on decay of avidity and of grain-size were also studied. The measurement of electrical resistance was used. It was found that the avidity of palladium in the most active state inducible by heat-treatment alone (*i.e.* heated at 450° C. slightly above the recrystallization temperature), is increased by fairly severe cold-work (stretching or rolling). After annealing at 860° C. stretching gave no increase in avidity; rolling, however, gave a considerable increase. The evidence generally indicated that gaseous hydrogen, as well as electrolytic hydrogen, disseminates in palladium through minute fissures from the planes of slip which originate during crystallization and which are enlarged by cold-working.—R. G.

***Platinum Isotopes and Their Nuclear Spin.** B. Venkatesachar and L. Sibaiya (*Proc. Indian Acad. Sci.*, 1935, Sect. A, **1**, 955–960).—The masses of the isotopes of platinum and their respective relative abundances have been determined as follows from spectroscopic data: 196, 18; 195, 9; 194, 7; 192, 1. The abundance values are provisional only. The nuclear spin of the odd isotope 195 is $(h/2\pi)/2$.—J. S. G. T.

***Measurements of the Thermoelectric Force of Solid and Liquid Alkali Metals Towards Platinum.** E. Heiber (*Ann. Physik*, 1935, [v], **23**, 111–136).—The alkali metals used were very carefully purified by vacuum distillation. Lithium and cæsium are positive and rubidium, potassium, and sodium negative towards platinum. The curves in all cases show an inflection at the melting point of the alkali metal.—v. G.

***On the Recrystallization of Silver of Different Degrees of Purity.** E. Osswald (*Z. Metallkunde*, 1935, 27, 101–104).—The temperature of recovery of properties of cold-worked silver, determined from curves showing the change of mechanical properties with increase of annealing temperature, is the same as the temperature at which recrystallization commences as determined by X-rays, and hence the recrystallization temperature can be defined as that temperature at which the rate of recrystallization suddenly increases from an almost imperceptible, to a very high, value. Small quantities of impurities have an extraordinary influence on the recrystallization temperature of silver; the very pure metal recrystallizes spontaneously at room temperature, the process beginning 24 hrs. after rolling, and being complete in 3 weeks. Silver containing 0·1% of iron recrystallizes at 80° C. when annealed immediately after rolling, but starts to recrystallize at room temperature in 14 days.—A. R. P.

***The Exact Measurement of Specific Heats at Higher Temperatures. XL—On the Variability of the Specific Heats of Fused and Solidified Silver under Different Circumstances.** F. M. Jaeger, E. Rosenbohm, and W. A. Veenstra (*Proc. K. Akad. Wet. Amsterdam*, 1933, 36, 291–298).—[In English.] Deviations in measurements of the sp. heat of silver at high temperatures previously found are attributed to the presence of dissolved oxygen. Apparently not all the oxygen absorbed during fusion is liberated on solidification, but the amount retained slowly diffuses out of the metal over a period of some months. Again, when oxygen-free silver is maintained at above 650° C. for some time a slow diffusion of oxygen into the metal takes place and the sp. heat rises. For oxygen-free silver the true sp. heat ($c_p$) between 0 and 800° C. is given by the expression $c_p = 0{\cdot}055401 + 0{\cdot}14414 \,.\, 10^{-4}t - 0{\cdot}16216 \,.\, 10^{-8}t$.—A. R. P.

***The Effect of Adsorbed Oxygen on the Photoelectric Emissivity of Silver.** A. Keith Brewer (*J. Amer. Chem. Soc.*, 1934, 56, 1909–1913).—Oxygen has 3 distinct effects on the work-function of clean silver as determined by photoelectric emission: (1) at room temperature the presence of oxygen slightly enhances the emissivity, the effect disappearing with its removal; (2) after heating in oxygen the silver, on heating *in vacuo*, has abnormally large emissive properties, the effect only disappearing after long exposure; (3) heating in oxygen or exposure to ozone destroys the emissivity. (1) and (2) have been associated, respectively, with "physical" and "activated" adsorption and (3) is due to the presence of "surface" silver oxide.—L. A. O.

**Preparation of Thin Single Crystals of Silver and Their Examination by Electron Diffraction Methods.** L. Royer. H. Lassen and L. Brueck (*Ann. Physik*, 1935, [v], 23, 16–17, 18–20).—A discussion of L. and B.'s paper (see *Met. Abs.*, this vol., p. 140).—v. G.

***Diamagnetism of Thallium Single Crystals.** S. Ramachandra Rao and K. C. Subramaniam (*Nature*, 1935, 136, 336–337).—The magnetic susceptibilities of single crystals of thallium parallel and perpendicular to the hexagonal axis, and their variation with temperature as the crystal changes to cubic symmetry, have been investigated. It is suggested that the hexagonal structure is due to the 3 valency electrons of thallium, whilst only the single valency electron is active in the cubic structure.—E. S. H.

***Specific Heat of Thallium at Liquid Helium Temperatures.** W. H. Keesom and J. A. Kok (*Comm. K. Onnes Lab. Univ. Leiden*, 1934, (230c), pp. 7).—[In English.] See *Met. Abs.*, 1934, 1, 287.—L. A. O.

***Sputtering of Thorium and Barium from Tungsten.** L. R. Koller (*Phys. Rev.*, 1935, [ii], 47, 806).—Abstract of a paper read before the American Physical Society. Measurements have been made of the sputtering of thorium from tungsten in neon, argon, and mercury at pressures of the order of 1 mm. Thoriated filaments were bombarded with ions of known velocity, and surface conditions were determined by thermionic emission measurements. Values were obtained for the number of ions required to remove an atom of thorium from the surface of cold tungsten, at ion velocities between 25 and 70 v. For 40 v. ions the values were: $6 \times 10^2$ ions per atom for neon, $1 \times 10^1$ ions per atom for mercury, $2 \times 10^1$ ions per atom for argon. Measurements were also made of the sputtering of barium from tungsten. Sputtering was observed for ions of as low velocity as 12 v. At 18 v. in neon the value was $3 \times 10^2$ ions per atom. Relative values for sputtering, as a function of voltage, were also determined for an oxide-coated cathode. A method is suggested for determining the cathode fall by means of the rate of sputtering.—S. G.

***A New Phenomenon in the Superconducting Transition of Tin and Tantalum.** F. B. Silsbee, F. G. Brickwedde, and R. B. Scott (*Phys. Rev.*, 1935, [ii], 47, 794).—Abstract of a paper read before the American Physical Society. The effect of combinations of the variables, temperature, transverse magnetic field, and specimen current, on the resistance in the transition range was investigated. The most characteristic effect, noted when the current is large (several thousand amp./cm.$^2$), is that the passage from the superconducting to the normal resisting condition is accompanied by a spontaneous increase in resistance, occupying several seconds, followed by a slower return. This transient resistance is sometimes 75% of the normal. After such an effect has occurred, it will not occur again when the same conditions are re-established, after a short interval. The combination of variables at which this effect occurs is, however, definite if the time interval is long enough or if the specimen has been cooled to a low temperature. The effect occurs in 2 tantalum specimens at approximately the same (apparent) current density. The tin wire requires about 50% greater current density. For tin $H = 2I/r$ connects, approximately, with specimen radius the currents and fields which acting alone (1) restore a given fraction of the normal resistance and (2) initiate the spontaneous rise. For tantalum the currents required were only 3–4% of the calculated values.—S. G.

***The Establishment and Destruction of Superconductivity at Radiofrequency [Tin].** R. B. Scott, F. B. Silsbee, and F. G. Brickwedde (*Phys. Rev.*, 1935, [ii], 47, 794).—Abstract of a paper read before the American Physical Society. A tin wire 0·022 cm. in diam. was supplied simultaneously with d.c. and with a.c. of 200 kilocycles/second and of such value that the circular magnetic field in the outer layers exceeded the critical value at one crest of each cycle but was less than critical at the other crest. If the resistance of the material followed these pulsations it would be expected that the flow of the a.c. would produce between the ends of the specimen a drop of potential of distorted wave form containing a strong component of double frequency. Such a double-frequency component of the expected value was found. It varied with the temperature and the magnitudes of the components of current in the manner to be expected. It may be concluded that the mechanism of superconduction can come into action or be destroyed within a few microseconds, by a sufficiently large magnetic field.—S. G.

***Thermionic Emission from Tungsten with Weak Accelerating Fields.** W. B. Nottingham (*Phys. Rev.*, 1935, [ii], 47, 806).—Abstract of a paper read before the American Physical Society. The thermionic emission from a well-aged 3 mil tungsten filament of the G.E. 218 type has been studied as a function of the temperature, over the range 1218°–1973° K., and the surface field for values between zero and 64,000 v./cm. For fields greater than 2000 v./cm. the observed currents when plotted as log $I$ *vs.* $V^{\frac{1}{2}}/T$ (where $V$ = voltage and $T$ = temperature) are accurately represented by the straight line given by the Schottky mirror image theory. A "zero field" Richardson plot obtained by extrapolating the mirror image lines to zero, yielded an $A = 60$ amp./cm.$^2$/degree$^2$ and $b_0 = 52{,}400°$ in exact agreement with Dushman's values. The true values of emission current at zero field were less than those obtained by extrapolation by 53% at 1218° K. and 34% at 1848° K. Space charge effects definitely distort the results at zero field for temperatures above 1840° K. The surface excess theory of Tonks would suggest that a decrease of 25–30% should be expected, but this theory cannot account for the above temperature effect. Bien's work on the crystal structure of tungsten shows promise of explaining this if there is a difference in work function of 0·5–1·0 v. between the 110 and 211 facets giving rise to local contact potential fields between facets.—S. G.

***Dependence on Applied Field of Thermionic Constants for Thoriated Tungsten.** A. Rose (*Phys. Rev.*, 1935, [ii], **47**, 806).—Abstract of a paper read before the American Physical Society. Data are presented for the variation of slope of Richardson plot with applied field, for stages of activation ranging from a flashed surface to maximum activity. An analysis is made of the variation of slope of Richardson plot in terms of a square array patch theory. The size of patch remains roughly constant at $3 \times 10^{-4}$ cm. during activation. The contact potential between patches increases from 0·8 v. for low activity to 1·4 v. near 0·5 monatomic layer and decreases to 0·4 v. for maximum activity. Analysis of data for a thoriated tungsten surface, bombarded and contaminated with alkali atoms, shows an increase in contact potential difference between patches to 2·4 v. In so far as the log of the intercept may be related to the change in slope, it is proportional, the constant of proportionality not changing seriously with state of activation. —S. G.

***Embrittlement of Uranium by Small Amounts of Aluminium and Iron.** H. W. Highriter and W. C. Lilliendahl (*Metals Technology*, **1935**, (June), A.I.M.M.E. Tech. Publ. No. 630, 1–5).—The cause of the embrittlement of electrolytically-prepared uranium is investigated. Serious embrittlement is caused by the presence of 0·2% of aluminium, whilst 0·5% of iron produces moderate embrittlement. Small amounts of carbide do not affect the ductility. The source of the impurities was the graphite crucible used for the electrolysis.—W. H.-R.

***The Spectra of Zinc, Cadmium, and Mercury in the Extreme Ultra-Violet.** Léon and Eugène Bloch (*Compt. rend.*, 1935, **201**, 137–139).—The investigations followed those carried out on copper, gold, and silver (cf. *J. Phys. et Radium*, 1932, **3**, 437). The measurements in the case of mercury confirmed those of Carroll (*J. Inst. Metals*, 1926, **35**, 630), and are not reproduced. The spectrum of zinc was measured between 1333 and 227 A., and that of cadmium between 1337 and 212 A., and is markedly similar. The lines between 478·92 and 425·45 A. for zinc and between 546·54 and 493·02 A. for cadmium are tabulated.—J. H. W.

**†Recent Researches on Zinc with Especial Reference to Electrolytic Zinc.** O. Bauer (*Z.V.d.I.*, 1935, **79**, 681–683).—A report of the work of the zinc committee of the Deutscher Gesellschaft für Metallkunde.—K. S.

***On the Superconductivity of Zinc.** W. H. Keesom (*Comm. K. Onnes Lab. Univ. Leiden*, 1934, (**230a**), pp. 6).—[In English.] See *Met. Abs.*, 1934, **1**, 287.—L. A. O.

***Rolling and Drawing Texture of Zirconium.** W. G. Burgers (with F. M. Jacobs) (*Metallwirtschaft*, 1935, **14**, 285–287).—In rolled zirconium sheet the basal plane of the crystallites is parallel to the rolling plane, and a digonal axis of type I is parallel to the direction of rolling. Drawn zirconium wire has a ring fibre structure with the basal plane parallel to the axis of the wire. The presence of a digonal axis of type I parallel to this direction can be detected only in certain cases in annealed wires. The structure is similar to that of magnesium.—v. G.

***Free Path and Thermoelectric Effects.** L. W. Nordheim (*Phys. Rev.*, 1934, [ii], **47**, 794).—Abstract of a paper read before the American Physical Society.

A general expression for the mean free path of electrons in metals is derived. This expression is valid for high temperatures and for any spherically symmetrical but otherwise arbitrary distribution of eigen values. The formulæ for the resistance and the thermoelectric phenomena can be obtained in a simple manner for any model of the interaction between the electrons and the ionic lattice. The method is applied to derive relations between changes in the resistance and thermoforce produced by foreign atoms or by distortions. The agreement with the experimental material is fairly good.—S. G.

***Establishment of an Absolute Scale for the Thermoelectric Force.** G. Borelius, W. H. Keesom, C. H. Johansson, and J. O. Linde (*Proc. K. Akad. Wet. Amsterdam*, 1932, **35**, 10; and *Comm. K. Onnes Lab. Univ. Leiden*, 1932, Supplement **70a**, 1–6).—[In English.] The results obtained for the thermoelectric forces of lead and tin at liquid helium temperatures and higher (see *Proc. K. Akad. Wet. Amsterdam*, 1931, **34**, 1365) together with the assumption made probable by those results, that the Thompson heat $\sigma$ is zero in the superconducting state, make possible the establishment of an absolute scale for the thermoelectric force. The expression $e_{\text{abs.}} = \int_0^T \frac{\sigma}{T} dT$ is suggested and used to calculate this quantity for tin, lead, and a special silver alloy wire. —L. A. O.

***On the Demagnetizing Factor of Cylindrical Rods.** Tamotu Nishina (*Sci. Rep. Tôhoku Imp. Univ.*, 1935, [i], **24**, 254–263 [In English]; and *Kinzoku no Kenkyu*, 1935, **12**, 315–321).—[In Japanese.] The demagnetizing factor of cylindrical rods of ferromagnetic substances was determined by the magnetometric and the ballistic methods in a very weak magnetic field. The demagnetizing factor was found to depend on permeability, dimension ratio, diameter, and also on the magnetic properties of the materials.—S. G.

***Change of Magnetic Susceptibility of Metals During Melting and Allotropic Transformation.** Kotarô Honda and Yosomatsu Shimizu (*Nature*, 1935, **136**, 393).—New measurements, in vacuum, of the change of magnetic susceptibility of tin, copper, silver, and gold during melting or allotropic transformation are recorded.—E. S. H.

***Magnetic Hysteresis at Low Flux Densities.** W. B. Ellwood (*Physics*, 1935, **6**, 215–226).—The energy loss per cycle in a ferromagnetic material subjected to small alternating fields is sometimes separated into 3 parts: the first due to eddy current loss, the second due to hysteresis, and the third, of unknown origin, is the subject of much controversy; it has been termed "magnetic viscosity," "after effect," and square law hysteresis. Energy losses in a ring of compressed iron dust are investigated within a range of fluxes between 2 and 100 gauss, by a new method in which the relative error in the determination of $B_m$ is as low as 0·01%. The results are discussed. —J. S. G. T.

***Magnetic After-Effect.** F. Preisach (*Z. Physik*, 1935, **94**, 277–302).—The significance of the phenomenon of magnetic after-effect (*Nachwirkung*), *i.e.* the possible existence of a true time-lag between the creation of a magnetic field and the production of magnetization in ferromagnetic material subjected to the field, is investigated in considerable detail. Inconclusive results are obtained: two sets support the deduction based on classical theory; one set is not in accordance with such anticipations.—J. S. G. T.

**The Effect of Temperature on Electrical Resistance.** W. J. de Haas and J. Voogd (*Comm. K. Onnes Lab. Univ. Leiden*, 1932, Supplement **73b**, 22–34).—[In French.] Summary of Report No. 10 of the 6th Congrès International d'Électricité, Paris, 1932. See *Met. Abs.*, 1934, **1**, 166.—L. A. O.

***New Aspects of Ferromagnetic Phenomena.** J. L. Snoek (*Nederlandsch Tijdschrift Natuurk.*, 1935, **2**, 180–189).—[In Dutch.] The forces determining the position of elementary magnets in pure unstrained ferromagnetic substances are simply related to the crystal axes. Thus in iron, the crystal axes represent the directions of minimum magnetic energy, whilst in nickel they represent the direction of maximum energy. In the nickel–iron range, a gradual transition takes place so that a nickel–iron alloy with 70% nickel is isotropic while a 50% alloy is nearly so. If, however, these crystals are exposed to an elastic strain, the symmetry type changes to that of cobalt which shows magnetic symmetry, round one axis. By special treatment, the internal strain in a 50 : 50 nickel–iron alloy can be so modified that the magnetic behaviour of the metal shows a close resemblance to that of cobalt. When magnetized in a direction perpendicular to the axis of easiest magnetization the material shows a remarkable freedom from hysteresis losses, while perfect linearity and stability are obtained.—L. A. O.

***Deformation Resulting from the Heat-Treatment of Worked Metals.** Maurice Bonzel (*Compt. rend.*, 1935, **201**, 394–396).—The deformation of cylindrical specimens heated after cold torsion has been studied. The specimens consisted of pure metals (copper and nickel), solid solutions (chromium–iron, nickel–chromium, or manganese austenitic steels) and two-phase alloys (aluminium–copper and various carbon steels). The deformations obtained were solely connected with the specific characters of the alloys, the graphs being very complicated, indicating the effects of a number of factors. There exists a first temperature zone in which the deformation is subordinated to the displacement of equilibrium of internal couples, owing to the viscosity of surface films and the recovery of the elastic limit (ageing) in the less worked central portion. Secondly, in the zone of recrystallization, the deformations have a direction and amplitude dependent on the nature of the alloy, its physico-chemical state, and the amount of cold-work caused by the initial torsion. These results were confirmed by experiments on specimens subjected to bending.—J. H. W.

**†Contribution to the Knowledge of the Vapour Pressure–Temperature Relations in Metals.** W. Leitgebel (*Metallwirtschaft*, 1935, **14**, 267–270).—The information previously given (*Met. Abs.* (*J. Inst. Metals*), 1932, **50**, 736) is amplified by a review of the information published since that date. Vapour pressure–temperature diagrams are given for 20 of the most important metals.
—v. G.

## II.—PROPERTIES OF ALLOYS

(Continued from pp. 417–422.)

***X-Ray Examination of the Alloy System Aluminium–Barium.** K. R. Andress and E. Alberti (*Z. Metallkunde*, 1935, **27**, 126–128).—The system has been examined up to 56% barium. There appears to be no range of solid solutions and only one compound $Al_4Ba$ with a body-centred tetragonal lattice, $a = 4{\cdot}53$, $c = 11{\cdot}14$ A.—A. R. P.

**On Binary Aluminium Alloys.** E. T. Richards (*Metallbörse*, 1935, **25**, 498–499, 530–531, 562–563, 721–722, 1041–1043).—A summary is given of the available information on binary systems of aluminium with the following metals: antimony, arsenic, beryllium, lead, boron, cadmium, cæsium, cerium, chromium, iron, gallium, germanium, gold, potassium, calcium, cobalt, manganese, molybdenum, sodium, nickel, niobium, palladium, phosphorus, platinum, selenium, silver, tantalum, tellurium, thallium, titanium, uranium, vanadium, bismuth, tungsten, and tin. The footnotes contain 94 references.
—A. R. P.

***Experimental Investigation of the Alloys of Aluminium and Carbon.** M. P. Slavinsky, I. A. Nazirov, and L. R. Edelson (*Metallurg* (*Metallurgist*), 1934, (9), 12–22).—[In Russian.] Chemical analysis has shown that aluminium does not take up carbon at 1000°–1100° C. from charcoal, graphite, or their oxidation products, nor does it absorb carbon in the solid state at 600°–630° C. The small particles of metallic aluminium found in technical aluminium carbide indicate that at high temperatures aluminium dissolves in the carbide and separates again on cooling. On fusion of aluminium carbide with aluminium at above 2000° C. the system separates in the liquid state into two layers, and on cooling, pure aluminium separates from the carbide layer and the carbide from the aluminium layer.—N. A.

***Contribution to the Study of the Alloys Formed by the Solid Solution Aluminium–Magnesium.** G. Chaudron and R. Dandres (*Light Metals Res.*, 1935, **4**, 45–47).—See *Met. Abs.*, this vol., p. 280.—L. A. O.

***Researches on the Solubility of Sodium in Aluminium.** E. Scheuer (*Z. Metallkunde*, 1935, **27**, 83–85).—Aluminium and some of its alloys were treated with sodium in a neutral atmosphere and the amount dissolved at various temperatures determined. In 99·7% aluminium (silicon 0·1, iron 0·2%) the solubility increases linearly from 0·10 at 700° C. to 0·12 at 800° C., whereas in Silumin (13% silicon) it increases parabolically from 0·08% at 600° C. to a maximum of 0·13% at 750° C., then falls slowly to 0·11% at 800° C. The 5% magnesium alloy dissolves 0·17% of sodium at 700° C. and 0·21% at 800° C., and the 8% copper alloy 0·15% at 700° C. and 0·18% at 800° C. In all cases the sodium appears as a new phase when the alloy solidifies, and no evidence could be obtained of solid solubility of sodium in aluminium. The results show that copper and magnesium increase the solubility of sodium in molten aluminium, whereas iron and silicon have little effect, if any, on the solubility.
—A. R. P.

***Measurements of the Heat Conductivity of Aluminium Alloys.** G. Euringer and H. Hanemann (*Metallwirtschaft*, 1935, **14**, 389–391; and (summary) *Light Metals Rev.*, 1935, **3**, 412–413).—The heat conductivity (in grm.-cal./second/cm./° C.) of sand-cast aluminium alloys is as follows:

| | As Cast. | After 24 Hrs. at 175° C. | After 24 Hrs. at 250° C. |
|---|---|---|---|
| Silumin-γ (modified) . . . . . | 0·360 | ... | ... |
| Silumin-γ with 1·2% copper (modified) . | 0·344 | 0·355 | 0·378 |
| R.R. 50 . . . . . . . | 0·372 | 0·368 | 0·390 |
| R.R. 53 . . . . . . . | 0·331 | 0·330 | 0·336 |

—v. G.

***Notch Stresses in Avional Rods.** K. Guler (*Z. Metallkunde*, 1935, **27**, 137–138).—The material tested was an alloy of aluminium with silicon 0·7, manganese 0·7, magnesium 0·7, and copper 4%, which had been quenched from 500° C. and aged at room temperature. Under tensile stresses rods 17 mm. in diam. had a yield-point of 30·6 and a breaking stress of 44·7 kg./mm.$^2$ with an elongation of 19·65% and a reduction in area of 18%; under compression stresses the yield-point was 19·5 and the load at failure 24·95 kg./mm.$^2$. The elastic modulus under tensile stresses was 7370 kg./mm.$^2$ and under compression stresses 7480 kg./mm.$^2$. The effect of various types of notches on these properties is shown graphically.—A. R. P.

**Duralumin and Related Alloys.** Harold Silman (*Met. Ind.* (*Lond.*), 1935, **47**, 199–201).—The properties and heat-treatment of alloys of the Duralumin type are described.—J. H. W.

***The Electrical Conductivity of Hydronalium.** H. Vosskühler (*Aluminium*, 1935, **17**, 415–418).—Curves and tables are given showing the electrical conductivity, specific resistance, and temperature coeff. of resistance for alloys of aluminium with 0–12% magnesium and 0·1–0·4% manganese, after slow cooling and after quenching from 420° C. For alloys with more than 3% magnesium quenching reduces the conductivity; cold-rolling up to 30% reduction in thickness has little effect on the conductivity.—A. R. P.

***Structure of the Intermetallic Compounds of Beryllium with Copper, Nickel, and Iron.** Lore Misch (*Z. physikal. Chem.*, 1935, [B], **29**, 42–58).—X-ray examination of the systems reveals the existence of the compounds CuBe, $CuBe_2$, NiBe, $Ni_5Be_2$, $FeBe_2$, $FeBe_5$, and another iron compound with a higher beryllium content, the exact nature of which has not been established.—K. S.

***Free Energy and Heat of Formation of the Intermetallic Compound CdSb.** Harry Seltz and J. C. de Haven (*Metals Technology*, **1935**, (June), A.I.M.M.E. Tech. Publ. No. 622, 1–7).—Molten cadmium and a mixture of solid antimony and the compound CdSb were made the electrodes of a cell containing molten lithium and potassium chlorides as electrolyte. The electromotive force was measured at temperatures between 393° and 436° C. For the reaction solid Cd + solid Sb = solid CdSb, the free energy change is $\Delta F = -3486 + 1{\cdot}067T$ where $T$ is the absolute temperature. The heat of reaction at 298° abs. is − 3486 cal. The entropy change in the reaction is small; $\Delta S_{298} = -1{\cdot}1$ cal. deg.$^{-1}$.—W. H.-R.

**Research Brings a New Bearing Metal.** Carl E. Swartz (*Inco*, 1935, **12**, 13).—A brief description of the alloy Asarcoloy No. 7, which is a cadmium-base alloy containing about 1·3% nickel. The microstructure consists of the eutectic of cadmium and $NiCd_7$ (containing 0·25% nickel) with cubes of $NiCd_7$. Variation may be made in nickel content (0·75–3%) to suit different purposes. —R. G.

**†Resistance Alloys for Heating Elements.** —— (*Metallurgist* (Suppt. to *Engineer*), 1935, **10**, 35–37).—A critical review of papers by A. Schulze (*Met. Abs.*, 1934, **1**, 571; this vol., p. 148) and others on the subject. It is pointed out that the aluminium–chromium–iron alloys are superior to nickel–chromium alloys in heat resistance at 1200° C., but have the disadvantage of susceptibility to corrosion. These conclusions may have to be modified for other temperatures and for varied compositions.—R. G.

***Metallic Cementation. V.—Cementation of Some Metals by Means of Chromium Powder [Nickel, Iron].** Tsutomu Kase (*Kinzoku no Kenkyu*, 1935, **12**, 357–370).—[In Japanese.] The cementation of iron and nickel by chromium powder between 800° and 1300° C. was investigated. The depth of penetration, chemical analysis, corrosion by acids, microstructure, and heat-resisting properties were noted with special reference to the surface layer of the cemented specimen, and the following facts were observed: the diffusion of chromium into iron and nickel begins at 700° C. and the rate of diffusion increases with rise of temperature, this being especially marked above the $A_3$ point of iron (906° C.). The relation between the increase in weight or depth of penetration and temperature is given by an exponential function, which breaks into 2 branches at the $A_3$ point in the case of iron. Similarly, the relation between the weight increase or the depth of penetration and the duration of cementation is given by an exponential function. The surface layer of nickel cemented with chromium resists oxidation at high temperatures, and is also resistant to corrosion by nitric acid.—S. G.

**Introduces New Copper Alloy with Great Conductivity [Mallory 3].** —— (*Amer. Metal Market*, 1935, **42**, (164), 2).—A brief note. A new copper alloy (composition not stated) with high electrical conductivity and great mechanical strength is described. It may be substituted, with few exceptions, for brass, copper, bronze, or even structural steel, and has already been used for spot-welding tips, flash-welding dies, and seam-welding wheels.—L. A. O.

***Segregation Phenomena in Cast Bolts and Bars of Brass.** Ch. Bernhoeft (*Z. Metallkunde*, 1935, **27**, 115–116).—The distribution of the copper in various parts of cast bolts (80 cm. long, 18 cm. diam.) of brass containing copper 58, zinc 40, and lead 2%, and of bars of 64 : 36 brass cast in water-cooled moulds, has been determined. In both cases the centre of the casting contained a greater proportion of copper than the outside layers.—A. R. P.

**The Preparation and Properties of Lead–Bronzes.** Richard Thews (*Metallbörse*, 1935, 25, 593–594, 626–627, 658–659, 690–691, 722–723).—A review.—A. R. P.

**Bearing Metals.** R. T. Rolfe (*Met. Ind.* (*Lond.*), 1935, 46, 691–694; 47, 33–36, 59–62, 85–88, 109–111, 135–138).—Abstract of a paper read before the Midland Metallurgical Societies (Birmingham Local Section of the Institute of Metals, Birmingham Metallurgical Society, and Staffordshire Iron and Steel Institute). The following are discussed: the mechanism of lubrication, bearing conditions in service, distribution of stress, requirements of bearing materials, alloys commonly used in practice, tin-base bearing alloys, comparison of tin-base and lead-base bearing alloys, rate of wear, practical procedure in lining, tinning, centrifugal lining, failure of bearings in service, lead–alkaline earth metal bearing alloys, copper–tin bearing alloys, phosphor-bronzes, and straight copper–lead alloys. These are compared with white metals and self-lubricating alloys.—J. H. W.

***Contribution to the Knowledge of the Binary System Iron–Tantalum.** Werner Jellinghaus (*Z. anorg. Chem.*, 1935, 223, 362–364).—The solubility of tantalum in iron does not exceed 10% at the eutectic temperature and decreases with fall in temperature, the excess tantalum being precipitated as fine needles of FeTa; this compound melts at about 1700° C. and forms a eutectic with iron at about 1400° C., containing about 25% tantalum. FeTa has a hexagonal lattice with $a = 4 \cdot 81$, $c/a = 1 \cdot 64$ and 8 atoms in the unit cell.
—A. R. P.

***The Surface Tension of Molten Metals and Alloys. V.—The Surface Tension of Iron–Carbon Alloys, $Hg_5Tl_2$, and $NaHg_2$, the Change in the Surface Tension of Thallium with Time, and the Surface Tension of Slags.** F. Sauerwald [with B. Schmidt and F. Pelka] (*Z. anorg. Chem.*, 1935, 223, 84–90).—The values for the surface tensions of $Hg_5Tl_2$ and $NaHg_2$ at 18°–260° C., and 270°–390° C., respectively, are very little different from those for the surface tension of the component metals, hence the molecular state of aggregation is similar. In a high vacuum the surface tension of thallium at 310°–320° C. remains constant unless impurities are introduced by reaction with the glass or other container.
—A. R. P.

***The Solubility of Lead in Mercury.** Herbert E. Thompson, Jr. (*J. Phys. Chem.*, 1935, 39, 655–664).—The solubility of lead in mercury between 20° and 70° C. is given by the equation $N_{Pb} = 0 \cdot 5893 - 0 \cdot 004115T + 0 \cdot 000007354T^2$, $N_{Pb}$ denoting the atomic fraction of lead dissolved at $T$° abs.
—J. S. G. T.

***The Structure of the Nickel–Cobalt Alloys.** Witold Broniewski and W. Pietrek (*Compt. rend.*, 1935, 201, 206–208).—On the lines of similar researches on the iron–nickel alloys (cf. *J. Inst. Metals*, 1933, 53, 438), the following physical properties of the nickel–cobalt alloys have been measured and plotted graphically: electric conductivity; temperature coeff. of electrical resistance between 0 and 100° C.; thermo-electric force at 0° C. compared with lead, and its variation between − 80° and + 100° C.; temperatures of the Curie points in heating and cooling; coeff. of expansion, and its variation between 17° and 444° C.; Brinell hardness; loss in ergs/grm. for a hysteresis cycle in a field of 150 gauss; coeff. of sp. magnetization in fields of 5, 25, 50, 150, and 750 gauss. The alloys were annealed for 24 hrs. at 800° C. and cooled to room temperature in 24 hrs. They were with difficulty attacked by reagents, and microexamination appeared to reveal only one phase. Some of the curves seemed to indicate the existence of a compound, $NiCo_3$, but this was not generally confirmed. It is more probable that there is some connection between these indications and the allotriomorphic transformation of cobalt at 405° C. It is concluded, therefore, that no compound of these 2 metals exists, and that at room temperature the alloys appear to consist of a solid solution of γ-cobalt in α-nickel up to 75% of cobalt, and of a solid solution of α-nickel in CoH at higher cobalt contents.—J. H. W.

**K Monel Metal. A New Alloy.** C. A. Crawford and George F. Geiger (*Inco*, 1935, **12**, 8–9).—A description of properties and applications of the alloy.—R. G.

***On the Effect of Alternating Current on the Intensity of Magnetization of Some Ferromagnetic Substances [Permalloy].** Tamotu Nishina (*Kinzoku no Kenkyu*, 1935, **12**, 297–308).—[In Japanese.] The change of the intensity of magnetization in Permalloy and electrolytic iron on the passage of a.c., was measured. The intensity first increases and attains a maximum, and then decreases as the current increases. The observed values agree fairly well with those of theoretical calculation.—S. G.

**An Equilibrium Diagram for Quaternary Alloys.** V. Fischer (*Z. Metallkunde*, 1935, **27**, 88–89).—A method of representing the equilibria of polynary alloys on a plane orthogonal co-ordinate system is described and illustrated with reference to the manganese–copper–iron–nickel system. The original must be consulted for details.—A. R. P.

***The Activity of Sodium and Potassium Dissolved in Gallium.** E. S. Gilfillan, Jr., and H. E. Bent (*J. Amer. Chem. Soc.*, 1934, **56**, 1661–1663).—The solubility of sodium in gallium at 30° C. is about 0·001 weight-%. The activity of the sodium is given by an e.m.f. of 0·70 v. The solubility of potassium in gallium at 32° C. is about 4 × $10^{-6}$ weight-%. The e.m.f. from potassium to this alloy is 0·70 v. The insolubility of gallium in mercury indicates that gallium has a rather high internal pressure, probably about the same as that of tin.—L. A. O.

***The Influence of the Addition of Metals, Especially Silver, on the Hardening of Gold–Copper Alloys During Transformation.** J. Spanner and J. Leuser (*Metallwirtschaft*, 1935, **14**, 319–322).—The gold–copper transformation occurs in all ternary alloys containing up to 80% silver and such alloys may therefore be hardened by heat-treatment, the maximum Brinell hardness obtainable being about 250. Small additions of aluminium diminish the hardening effect, while platinum and nickel have no effect other than increasing the hardness in the soft state. The action of zinc is variable and has not yet been completely elucidated. The hardening properties of gold–silver–copper alloys are of value in dental work but not in jewellery.—v. G.

***Thermodynamic Properties of Solid Solutions of Gold and Silver.** A. Wachter (*J. Amer. Chem. Soc.*, 1932, **54**, 4609–4617).—The energy changes of solid silver on dilution with gold have been determined at mole fractions of silver varying from 1·000 to 0·150 between 200° and 400° C. The solid solution containing 0·500 mole of silver is shown to be the most stable. The thermodynamic properties of these solid solutions are considered compatible with the existence of a regular arrangement of gold atoms in the silver crystal lattice.—L. A. O.

***Equilibrium Diagram of the Silver–Indium System.** Friedrich Weibke and Hans Eggers (*Z. anorg. Chem.*, 1935, **222**, 145–160).—The solid solubility of indium in silver is 19·8% at 693° C., 19·5% at 600° C., and 19·4% at room temperature. In the region bounded by lines joining the points 693° C. 25·1% In, 667° C. 24·8% In, and 660° C. 25·9% In, the homogeneous phase β corresponding with $Ag_3In$ exists, but at lower temperatures it breaks up into γ or α + γ. The γ-phase is a range of solid solutions formed from β or from β + liquid by a peritectic reaction; it undergoes a transformation at 187° C. in alloys containing 19·5–25% indium and at gradually increasing temperatures up to 305° C., as the indium content increases from 25 to 33·1%. The δ-phase is hexagonal and exists over the range 26·8–33·1% indium; it apparently consists of solid solutions of silver or indium in $Ag_5In_2$ which has $a = 2{\cdot}983$, $c = 4{\cdot}789$, $c/a = 1{\cdot}608$. The ε-phase exists over the narrow range 33·1–33·5% indium at temperatures up to 305° C., and is formed by a peritectic reaction between $\gamma$ and liquid or by the transformation of $\gamma$; it appears to have rhombic symmetry or possible hexagonal symmetry with a simple superstructure. The $\phi$-phase corresponds with $AgIn_3$ and exists only over a small composition range about 75% indium; it forms a eutectic with indium at 97% indium and 141° C.—A. R. P.

†**Equilibrium Diagrams of Binary Alloys of Tin.** E. S. Hedges and C. E. Homer (*Tech. Publ. Internat. Tin Res. Development Council*, 1935, [B], (2), 1–90).—A compilation of 67 equilibrium diagrams covering the binary systems of tin with aluminium, antimony, arsenic, barium, bismuth, cadmium, calcium, cerium, chromium, cobalt, copper, gallium, gold, iodine, iron, lanthanum, lead, lithium, manganese, magnesium, mercury, nickel, phosphorus, platinum, potassium, selenium, silicon, silver, sodium, strontium, sulphur, tellurium, thallium, and zinc. Notes are given on the nature of the transformations indicated in each diagram, and an introduction discusses the interpretation of the diagrams. A *bibliography*, containing 119 references to the original literature, is appended.—E. S. H.

***The Diffusion of Titanium and the Dissociation of Titanium Compounds.** I. S. Gaeff (*Metallurg* (*Metallurgist*), **1934**, (10), 19–33).—[In Russian.] The diffusion of titanium (reduced from the tetrachloride with sodium) into iron commences at 1300° C. and proceeds according to the expression $x = Ae^{-a/T}$, where $x$ is the depth of diffusion at $T$° C. At the same time, the converse process of diffusion of iron into titanium takes place. The eutectic temperature of the system iron–$Fe_3Ti$ is 1340° ± 10° C.—N. A.

***Phenomena of Fracture of Two-Phase Alloys on Deformation.** D. G. Butomo, N. I. Zedin, and S. A. Kushakevitch (*Metallurg* (*Metallurgist*), **1934**, (9), 61–63).—[In Russian.] The mechanism of the deformation of zinc containing 0·14 and 1·15% iron and of $\alpha + \beta$-brass indicates that the less plastic phase is fractured first, fracture being preceded by the formation of lines of slip. The development of fractures is definitely connected with the proportion of the less plastic phase, the degree of deformation, and the ratio between the plasticities of the two phases. Fracture of the plastic phase is caused by the instantaneous increase in stress at the moment of fracture of the inclusions of the brittle phase.—N. A.

†**Report on the Superconductivity of Alloys and the Magnetic Anomaly.** W. J. de Haas and J. Voogd (*Comm. K. Onnes Lab. Univ. Leiden*, 1932, Suppt. No. **73a**, pp. 1–21).—[In French.] A critical review of published information on the superconductivity of alloys leads to the conclusion that the properties of the crystal lattice are of paramount importance for the establishment of a state of superconductivity. The threshold value for the magnetic anomaly of alloys increases more rapidly than for pure metal. Numerous references are included.—A. R. P.

**Non-Ferrous Metals in Relation to Prolonged Stress.** —— (*Met. Ind.* (*Lond.*), 1935, **47**, 223–227).—A review of recent researches, with 35 references. —J. H. W.

**The Significance of Equilibrium Diagrams.** J. S. Marsh (*Iron Age*, 1934, **133**, (10), 25–25B).—Abstract of a paper read before the New York Chapter of the American Society for Metals. The terminology used in connection with equilibrium diagrams is defined and the use of the phase rule for their interpretation is described. The 4 special cases of binary alloys are explained; these are: (1) complete intersolubility at temperatures above and below those of equilibrium; (2) complete intersolubility above and incomplete below those temperatures; (3) the reverse of (2); (4) incomplete intersolubility at temperatures above and below those of equilibrium.—J. H. W.

## III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

(Continued from pp. 423–426.)

***Sub-Boundaries in a Crystal Grown by the Bridgman Method.** W. H. George (*Nature*, 1935, 136, 392).—The etched surface of a single crystal of copper, grown by the Bridgman method, is similar in appearance to that of polycrystalline metals and suggests that the crystal has broken down into a large number of small ones. X-ray examination shows that their orientation is unchanged.—E. S. H.

***The Absorption Factor for the Powder and Rotating-Crystal Methods of X-Ray Crystal Analysis.** A. J. Bradley (*Proc. Phys. Soc.*, 1935, 47, 879–899).—A method for calculating the absorption factor, which influences the relative intensities of line in X-ray spectra taken by the powder and rotating-crystal methods of X-ray analysis, is discussed.—J. S. G. T.

***The Quantitative Measurement of the Intensity of X-Ray Reflections from Crystalline Powders.** J. C. M. Brentano (*Proc. Phys. Soc.*, 1935, 47, 932–947).—The absorption in a powder layer and the effect of size of crystallites on the intensities of X-ray spectral line are, *inter alia*, discussed.—J. S. G. T.

**New Models for Demonstrating the Correct Space-Filling [Characteristics] of Molecules.** H. A. Stuart (*Z. tech. Physik*, 1934, 15, 566–567).—From Vorträge u. Diskussionen auf dem 10 Deutschen Physiker- und Mathematikertages, 1934, Sept. Crystal models in which individual atoms are represented by truncated spheres of appropriate radius and which correctly represent the atomic distances and the space-packing of the atoms are described.—J. S. G. T.

***The Electronic Structure of Copper.** Harry M. Krutter (*Phys. Rev.*, 1935, [ii], 47, 810).—Abstract of a paper read before the American Physical Society. The method of Wigner, Seitz, and Slater has been applied to the calculation of the energy levels and wave functions of the electrons in the face-centred copper lattice, assuming a spherically symmetric field about each atom, and making the functions continuous at the midpoints between nearest neighbours. As a first approximation the $Cu^+$ potential field of Hartree was used for the *s*, *p*, and *f* states. A correction for the 4*s* electron was used in the study of the 3*d* electrons. Calculations of the energy bands on this basis show a strong overlapping of the 3*d* band with the 4*s* band. The minimum of the 4*s* energy band comes approximately at the correct interatomic distance for copper. Results of the calculation of energy as a function of momentum, which can only be solved simply in the 100, 110, and 111 directions, show that the 11 electrons $3d^{10}4s$ fall into 6 bands, 5 of which are filled, leaving 1 electron in the unfilled band, accounting for the conductivity of copper. This electron cannot be said to be either an *s* or *d* electron, but is built up of *s*, *p*, and *d* wave functions. In the 100 direction this electron behaves roughly as a free electron.—S. G.

***Investigations on Molecular Solid Solutions in the Copper–Gold System.** N. W. Ageew and D. N. Shoyket (*Ann. Physik*, 1935, [v], 23, 90–104).—The lattice structure of alloys containing 20–35 and 41–59 atomic-% gold (*i.e.* in the region of $Au_3Cu$ and AuCu) has been investigated. The degree of order for alloys with the stoichciometric composition is only 0·9 and decreases linearly towards the copper side and parabolically towards the gold side. This behaviour is confirmed by the changes in electrical conductivity and Brinell hardness.—v. G.

***The Copper Amalgam CuHg with the γ-Brass Structure.** Fritz Schlossberger (*Z. physikal. Chem.*, 1935, [B], 29, 65–78).—The cubic crystals of CuHg have a γ-structure with $a = 9{\cdot}406 \pm 0{\cdot}004$ A. In an attempt to produce an amalgam with a structure resembling that of $Cu_5Cd_8$ small deviations between the observed and calculated intensities similar to those already observed in copper–zinc and copper–cadmium alloys were found, as well as a few cases of too small atomic distances.—K. S.

***On the Crystal Structure of β-Manganese and Isomorphous Alloys.** Sven Fagerberg and A. Westgren (*Metallwirtschaft*, 1935, **14**, 265–267).—The cubic phases $Ag_3Al$, $Au_3Al$, and $Cu_5Si$ have a lattice of the β-manganese type with $a = 6{\cdot}920$, $6{\cdot}909$, and $6{\cdot}211$ A., respectively. The atomic distribution in all cases is random.—v. G.

***A Study of the Crystal Structure of Heat-Treated Tungsten Filaments.** R. P. Bien (*Phys. Rev.*, 1935, [ii], 47, 806).—Abstract of a paper read before the American Physical Society. Straight tungsten filaments have been examined after various heat-treatments. Microphotographs of the cross-sections and longitudinal sections were made showing the crystal sizes, while X-ray and goniometer measurements were made to show crystal orientation and surface facets. Well-aged tungsten filaments all showed very large crystals extending across the entire diameter of the filament. Their lengths varied from 2 or 3 cm. down to about 0·1 cm. This result applied to filaments flashed for a short time at 3100° K. and higher, or aged some hours at 2600° K. without higher temperature treatment. Optical reflections from well-aged 10 mil filaments showed distinct facets when viewed with light at normal incidence perpendicular to the axis of the filament. The predominant reflecting surfaces seem to be the (110) and (211) planes of a crystal oriented with a (110) plane normal to the filament axis. The fact that all Richardson plots so far reported on well-aged filaments are perfectly straight lines would indicate that either the work functions of these 2 surfaces in presence of a strong field are identical, or emission from the (110) planes is so much greater than that from the (211) planes that the latter contribution may be neglected over the observed temperature range.—S. G.

**The Structure of Metallic Coatings, Films, and Surfaces. Introductory Paper.** Cecil H. Desch (*Trans. Faraday Soc.*, 1935, **31**, 1045–1048).—See *Met. Abs.*, this vol., p. 284.—A. R. P.

**Electron Diffraction and Surface Structure.** G. I. Finch, A. G. Quarrell, and H. Wilman (*Trans. Faraday Soc.*, 1935, **31**, 1051–1080).—See *Met. Abs.*, this vol., p. 289.—A. R. P.

**Inner Potentials of Crystals and the Electron Diffraction.** W. E. Laschkarew (*Trans. Faraday Soc.*, 1935, **31**, 1081–1095).—See *Met. Abs.*, this vol., p. 289.—A. R. P.

***The Thickness of the Amorphous Layer on Polished Metals [Gold].** H. G. Hopkins (*Trans. Faraday Soc.*, 1935, **31**, 1095–1101).—See *Met. Abs.*, this vol., p. 288.—A. R. P.

***The Structure of Polished Metal Surfaces.** C. S. Lees (*Trans. Faraday Soc.*, 1935, **31**, 1102–1106).—See *Met. Abs.*, this vol., p. 288.—A. R. P.

**General Discussion on "The Structure of Metallic Coatings, Films, and Surfaces. I.—Electron Diffraction Methods."** —— (*Trans. Faraday Soc.*, 1935, **31**, 1107–1127).—See preceding abstracts.—A. R. P.

***Molecular Layers of Fatty Substances on Metals.** J. J. Trillat and H. Motz (*Trans. Faraday Soc.*, 1935, **31**, 1127–1135; discussion, 1135–1136).—Experiments with the electron diffraction camera on metal surfaces are described which indicate that there exist almost always very thin (mono- or bimolecular) films of waxes or paraffin hydrocarbons on the surfaces of metals. When these films spread over the surfaces, they crystallize in a perfect manner and give rise to very intense electronic diffractions. Exposure of the surfaces to the electrons for 10–15 minutes destroys the grease films, and the pattern obtained is that due to the pure metal. In the discussion *L. Tronstad* stated that these films could be detected on mercury by optical methods.—A. R. P.

***The Crystallization of Thin Metal Films.** E. N. da C. Andrade (*Trans. Faraday Soc.*, 1935, 31, 1137–1143; discussion, 1143–1150).—See *Met. Abs.*, this vol., p. 287.—A. R. P.

**The Validity of Drude's Optical Method of Investigating Transparent Films on Metals.** Leif Tronstad (*Trans. Faraday Soc.*, 1935, 31, 1151–1158; discussion, 1166–1168).—See *Met. Abs.*, this vol., p. 288.—A. R. P.

***Optical Research on Evaporated Metal Layers.** L. S. Ornstein (*Trans. Faraday Soc.*, 1935, 31, 1159–1166; discussion, 1166–1168).—See *Met. Abs.*, this vol., p. 287.—A. R. P.

**†The Determination of the Structure of Electrodeposits by Metallurgical Methods.** D. J. Macnaughtan and A. W. Hothersall (*Trans. Faraday Soc.*, 1935, 31, 1168–1177).—See *Met. Abs.*, this vol., p. 285.—A. R. P.

***Chemical and Physical Properties of Electrolytically Deposited Metals in Relation to Their Structure.** M. Schlötter (*Trans. Faraday Soc.*, 1935, 31, 1177–1181).—Electrolytically deposited metals are rarely quite pure for, in addition to traces of other metals and usually more or less hydrogen, they frequently contain anionic substances. Occluded hydrogen may be present as mechanically-held bubbles of gas or in a more strongly bound form, *e.g.* as a loose chemical compound or in solid solution. Thus when electrolytic nickel is heated the volume of hydrogen liberated increases up to 400° C., between this temperature and 800° C. gas evolution slackens, but above 800° C. it again becomes brisk. In the electrodeposition of nickel at a given $p_H$ the hydrogen content of the metal decreases with increase in current density, and at a given current density it increases with decrease in $p_H$. In the electrodeposition of metals in general there is a connection between the size of the crystallites of the deposit and the overvoltage and both depend on the nature of the anion, a higher overvoltage corresponding with a larger anion and resulting in a higher concentration of hydrogen in the deposit. Thus zinc deposited from sulphate baths contains 40 c.c. and that from cresylsulphonate baths 77 c.c. of hydrogen per grm.-atom. In the deposition of copper and silver from iodide baths the amount of iodide contained in the deposits increases rapidly with increase in current density reaching 1·27% for copper with 1 amp./dm.$^2$; at the same time the lattice is distorted, tending to become tetragonal, and the parameter is increased. Iodized silver deposits have a colour resembling gold, and a remarkably fine grain-size, are much harder than ordinary silver deposits, and remain quite untarnished in an atmosphere containing hydrogen sulphide. Iodized copper deposits have a red colour, but become blue on exposure to sunlight. Deposits of nickel containing nickel oxide or hydroxide have a high lustre and dissolve in a mixture of sulphuric and nitric acids leaving a black skeleton whereas ordinary nickel deposits are passive in the acid mixture; the e.m.f. between the two nickels when used as a thermocouple is 2·5 microvolts/° C. Ordinary chromium deposits owe their bluish lustre to the presence of oxide in the metal lattice; deposits obtained from chloride solutions with chromium anodes resemble a brilliant nickel deposit and are quite free from the blue tint.—A. R. P.

**†On Somatoid Elements of Structure in Electrolytic Metal Deposits.** V. Kohlschütter (*Trans. Faraday Soc.*, 1935, 31, 1181–1188).—The nature of somatoids is described with reference to the recent work of K. and others and the mechanism of their formation and occurrence in electrolytic deposits is discussed from a theoretical point of view.—A. R. P.

**†The Effects of Film Formation on the Structure of Electrodeposited Metallic Coatings.** E. Liebreich (*Trans. Faraday Soc.*, 1935, 31, 1188–1194).—See *Met. Abs.*, this vol., p. 285.—A. R. P.

***Structure and Properties of Nickel Deposited at High Current Densities.** William Blum and Charles Kasper (*Trans. Faraday Soc.*, 1935, 31, 1203–1211).—See *Met. Abs.*, this vol., p. 287.—A. R. P.

***Contribution to the Experimental Study of the Influence of the Support or Cathode on the Structure of Electrolytic Deposits Obtained in Aqueous Solution.** Albert M. Portevin and Michel Cymboliste (*Trans. Faraday Soc.*, 1935, **31**, 1211–1218; discussion, 1218–1231).—See *Met. Abs.*, this vol., p. 286.—A. R. P.

**†Electrode Potentials and the Form of Electrodeposited Metals.** Samuel Glasstone (*Trans. Faraday Soc.*, 1935, **31**, 1232–1237).—See *Met. Abs.*, this vol., p. 286.—A. R. P.

***Factors Affecting the Structure and Grain-Size of Electrodeposited Cadmium.** S. Wernick (*Trans. Faraday Soc.*, 1935, **31**, 1237–1242).—See *Met. Abs.*, this vol., p. 286.—A. R. P.

***Influence of the Basis Metal on the Structure of Electrodeposits.** A. W. Hothersall (*Trans. Faraday Soc.*, 1935, **31**, 1242–1253).—See *Met. Abs.*, this vol., p. 286.—A. R. P.

**The Structure of Electrolytic Chromium.** L. Wright, H. Hirst, and J. Riley (*Trans. Faraday Soc.*, 1935, **31**, 1253–1259).—See *Met. Abs.*, this vol., p. 378.—A. R. P.

***Determination of the Phase Structure of Metallic Protective Coatings by Anodic Dissolution.** A. Glazunov (*Trans. Faraday Soc.*, 1935, **31**, 1262–1267).—See *Met. Abs.*, this vol., p. 285.—A. R. P.

***Factors Influencing the Formation and Structure of Hot-Dipped Tin Coatings.** Edward J. Daniels (*Trans. Faraday Soc.*, 1935, **31**, 1277–1285).—See *Met. Abs.*, this vol., p. 285.—A. R. P.

**General Discussion on " The Structure of Metallic Coatings, Films, and Surfaces.—II."** —— (*Trans. Faraday Soc.*, 1935, **31**, 1143–1150, 1166–1168, 1218–1231, 1259–1262, 1286–1288).—See preceding abstracts.—A. R. P.

**On the Metallographic Method of Investigating Hard Metals.** N. M. Zarubin (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, **3**, 919–926).—[In Russian.] The methods used in the U.S.S.R. for preparing polished sections and etching hard alloys are surveyed, and the structural characteristics of these alloys are described. A *bibliography* is appended.—D. N. S.

***On the Process of Eutectic Crystallization and the Formation of Concentric Rings in Eutectic Alloys.** A. A. Botchvar (*Metallurg* (*Metallurgist*), **1934**, (10), 3–6).—[In Russian.] The mechanism of eutectic crystallization has been studied by observations on the azobenzene–piperonal eutectic which solidifies at 26° C. and exhibits many of the characteristics of metal eutectics. Normally crystallization is very slow, and undercooling effects readily occur. When solidification occurs at 20° C. no eutectic structure can be observed, and at 13°–20° C. separate crystals of the individual phases are first formed, and eutectic crystallization ensues only when these crystals come into contact with one another. At still lower temperatures the eutectic separates in a spherulitic form. Similar observations have been made on certain metal eutectics; in hypo- and hypereutectic alloys the eutectic crystallization occurs only after contact of the crystals of the 2 metals. The cored effect often observed in eutectic alloys is attributed to differences in the linear rate of crystallization with increase in the local concentration of one of the constituents. In bismuth–cadmium–lead–tin alloys which are allowed to cool under conditions producing coring, the metals will form concentric rings round one another in the order given, bismuth being outside and tin inside.—N. A.

## IV.—CORROSION

(Continued from pp. 427–430.)

***An Investigation of the Corrosion of Magnesium Alloys (4th Report). The Corrosion of Ternary Alloys of Magnesium.** Susumu Morioka (*Kinzoku no Kenkyu*, 1935, **12**, 322–356).—[In Japanese.] See *Met. Abs.* (*J. Inst. Metals*), 1932, **50**, 740; *Met. Abs.*, 1934, **1**, 303. The corrosibility of ternary alloys of magnesium with zinc, cadmium, tin, lead, aluminium, and antimony was studied. 15 series of ternary alloys were prepared by addition of 1–8% of any two of these metals. In the case of antimony 0·3–3% was added. Their corrosion was studied in the cast state. The following systems showed comparatively great corrosion-resistance: magnesium with zinc–tin, zinc–cadmium, tin–cadmium, tin–lead, zinc–antimony, and tin–antimony, especially in the range zinc 1–3, tin 2–8%; zinc 3–6, cadmium 1–6% (zinc + cadmium $< 10\%$); tin $> 3$, cadmium 1–3%; tin $> 4$, lead 1–6%; zinc 1–6, antimony 0·3–0·6%; tin 2–3, antimony $< 0{\cdot}8\%$, respectively. The effect of small quantities of bismuth, calcium, silicon, manganese, or cobalt added to binary alloys of magnesium has also been studied.—S. G.

***The Effect of Heat-Treatment on the Corrosion of Magnesium–Zinc and Magnesium–Aluminium Alloys.** Takejirô Murakami and Susumu Morioka (*Sci. Rep. Tôhoku Imp. Univ.*, 1934, 23, 612–634; and (abstract) *Iron Age*, 1935, 135, (23), 10–11, 46, 48, 50).—[In English.] Translated from *Kinzoku no Kenkyu*, 1934, 11, (3), 99–116. See *Met. Abs.*, 1934, 1, 303.—A. R. P.

***Black Spots on Tin and Tinned Ware.** Sven Brennert (*Tech. Publ. Internat. Tin Res. Development Council*, 1935, [D], (2), 1–27).—The black spots which are known to form sometimes on tin or tinned equipment exposed to milk or other dairy products are shown to be produced by corrosion of tin in accordance with the usual electrochemical principles. The black spots consist mainly of stannous oxide, and can be obtained experimentally in simple salt solutions, such as sodium chloride. Electrochemical investigations show that the spots do not begin to form until the tin surface exceeds a critical "dissolution potential," the value of which varies with the composition of the solution, but the spots, once formed, can continue to grow at potentials less noble than the dissolution potential. The potential of a tin surface may rise to a value above the dissolution potential through the further growth of the air-formed film on the surface of tin in neutral or nearly neutral solutions. At weak points in this film the tin can corrode with formation of black spots. The formation of the spots can be prevented by keeping the tin in contact with a less noble metal (*e.g.* aluminium or zinc), thus ensuring that the potential is kept below the dissolution potential.—E. S. H.

***Study of Intercrystalline Corrosion by the Luminous Diffusion Method.** François Canac (*Compt. rend.*, 1935, 201, 330–332).—The corrosion of a homogeneous and isotropic body having been studied (*Met. Abs.*, this vol., p. 60) by the method previously described (*Met. Abs.* (*J. Inst. Metals*), 1933, 53, 243), the case of a body consisting of elements not equally attacked is considered. Such a body is an alloy consisting of small crystallites of one metal in another. Briefly, the method consists in illuminating the surface at different angles, and in determining for each the distribution of the diffused light. Intercrystalline corrosion is characterized by families of diffusion curves showing: (1) an initial maximum at the same moment whatever the angle of incidence; (2) a level portion reached later as the angle of incidence decreases; (3) a level portion reached at the end of time, $t = A + B/\tan \varepsilon + \tan \alpha$ ($\alpha$ = angle of incidence, $\varepsilon$ = angle of reflection), if the incident and the diffused rays are on opposite sides of the normal; (4) that the initial values are proportional to $\cot \alpha$ if the internal face of the crevice diffuses and if the incident and the diffused rays are on the same side of the normal.—J. H. W.

***On the Comparison of Acid-Resistivity of Various Ferrous and Non-Ferrous Acid-Resistant Alloys.** Shigenori Kanazawa and Hikozo Endo (*Kinzoku no Kenkyu*, 1935, 12, 280–296).—[In Japanese.] The acid-resistances of about 30 alloys—ferrous, nickel-base and copper-base—were studied in 20% aqueous solutions of hydrochloric, sulphuric, and nitric acids at 50° C., and alloys are recommended for use in contact with these acids. The work is to be continued.—S. G.

***Resistance of Alloys to Pit-Water.** A. I. Shultin and V. M. Shpeizman (*Rep. Central Inst. Metals* (*Leningrad*), No. 17, 1934, 222–233; *C. Abs.*, 1935, **29**, 5401).—[In Russian, with German summary.] In studying the resistance of metals in sulphuric acid solution ($p_H = 1$), under conditions similar to those in pumping mine water through pipes, 3 kinds of metals were investigated: (1) grey cast iron with small amounts of phosphorus, copper, tin and copper, antimony and copper, molybdenum or molybdenum and copper; (2) special alloys of the Monel type, Nimol, Ni-Resist, and stainless high-chromium cast-iron; (3) bronzes. The last were used for comparison. In group (1) the most resistant metals were tin–copper and antimony–copper cast-iron samples; however, these were not so good as the bronzes. In (2) the most resistant was stainless chromium cast-iron, which was many times more resistant to corrosion than the bronzes. Tests were also made with natural pit-water.—S. G.

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## V.—PROTECTION

(Other than Electrodeposition.)

(Continued from pp. 430–432.)

***The Hardness of Sprayed Metal Layers.** —— Kessner and Th. Everts (*Z. Metallkunde*, 1935, **27**, 104–107; and (abstract) *Met. Ind.* (*Lond.*), 1935, **46**, 700).—Since the hardness of sprayed metal films depends on the oxide content and on the temperature at which the sprayed particles are quenched by impact with the article being sprayed, the hardness is decreased by raising the temperature of the article, by bringing the pistol closer to the article, and by using a reducing flame in the pistol. The condition of the sprayed film is also affected by the rate of feed of the wire through the pistol, the pressure and oxygen content of the gases burnt in atomizing the metal, and the time which elapses between the application of successive layers, hence the hardness is increased by using high gas and air or oxygen pressures, since this raises the temperature of the metal and results in more severe cooling on impact and in more oxidation of the particles. Curves are given showing the effects of these various conditions on the scratch-hardness of the films.—A. R. P.

**Care and Preservation of Bronze Statues.** Wesley Lambert (*Met. Ind.* (*Lond.*), 1935, **47**, 106).—A brief consideration of the cleaning agents and protective coatings available for the preservation of bronze statues.
—J. H. W.

**Painting Magnesium Alloys.** H. A. Gardner, G. G. Sward, and L. P. Hart (*Nat. Paint Varnish Lacquer Assoc. Circ.* No. **482**, 1935, 172–185; *C. Abs.*, 1935, **29**, 5680).—Chemical pre-treatment of magnesium alloys improves paint adhesion to such surfaces. Aqueous suspensions of zinc chromate, lead chromate, zinc oxide, titanium oxide, and carbon-black pigments inhibit corrosion, the best being zinc chromate and carbon-black. Corrosion-inhibitive pigments counteract the action of corrosion-stimulative pigments. Lead oxides, which are corrosive in aqueous pastes, gave good results in some paint vehicles. Most organic vehicles are not detrimental to magnesium alloys. Alkyl and phenolic resin–tung oil varnishes make good vehicles. Baking usually improves the adhesion of coatings. Finishing coats may be ordinary exterior finishing materials.—S. G.

†**The Manufacture of Tinplate.** Daniel H. Dellinger (*Mines Mag.*, 1935, **25**, (5), 11–15; (6), 19–21, 23; (7), 18–21, 23).—Modern practice in the manufacture of tinplate is described in detail, including the rolling, annealing, and pickling of the sheet iron, the tinning operation, and methods of testing the sheets.—A. R. P.

**On the Tinning of Galvanized Sheet Iron.** (Harbison.) See p. 474.

**Zinc Ammonium Chloride: Its Place in Modern Galvanizing (Conclusion).** H. G. Hobbs (*Iron Age*, 1935, **36**, (3), 18–21, 92–93).—See *Met. Abs.*, this vol., p. 348. The application of zinc ammonium chloride as a flux in the galvanizing of pipe, nails, wire, buckets, boilers, drums, and line hardwear is reviewed.—J. H. W.

***Improvement of the Quality of Metallic Coatings by the Use of Non-Metallic Intermediaries and Supports.** H. Reininger (*Trans. Faraday Soc.*, 1935, **31**, 1268–1276).—See *Met. Abs.*, this vol., p. 386.—A. R. P.

**Protection of Materials in Aeronautics.** Gaston Dixmier (*Recherches et Inventions*, 1935, **16**, 346–348; *C. Abs.*, 1935, **29**, 5288).—A general discussion of the application of tests to protective materials (paints, &c.) used in aeronautics to determine their actual value in use.—S. G.

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## VI.—ELECTRODEPOSITION

(Continued from pp. 432–434.)

**Barrel Plating Technique.** E. J. Dobbs (*J. Electrodepositors' Tech. Soc.*, 1935, **10**, 125–128; and *Met. Ind.* (*Lond.*), 1935, **47**, 41–42).—Three types of barrel plating plant are described and illustrated. Celluloid and Bakelite fabric can be used for barrels for acid electrolytes but rubber is proof against all solutions used for barrel plating. Compositions of electrolytes and typical operating conditions for plating steel and brass are given; a cream of tartar dip after swilling is advantageous to prevent staining. Ample swilling and drying-out facilities are necessary. Hot, non-resinous sawdust in a rotating barrel is recommended for drying out.—A. I. W.-W.

**Moving Cathode Plating Plants.** E. E. Halls (*Machinist* (*Eur. Edn.*), 1935, **79**, 402–403E).—A brief description of a moving cathode plating equipment is given and a comparison is made of such a plant with a stationary vat plant of similar capacity.—J. H. W.

**Chromium Platings of High Corrosion- and Heat-Resistance.** G. Huth (*Emailletech. Monats-Blätter*, 1933, **9**, (2), 13–14; *Ceram. Abs.*, 1933, **12**, 199).—A brief description is given of some chromium plating processes which produce deposits with high resistance to corrosion and to heat.—S. G.

**The Electrodeposition of Chromium.** E. A. Ollard (*Met. Ind.* (*Lond.*), 1935, **47**, 89–91, 185–188).—Discusses further points in practical chromium plating connected with the care and maintenance of anodes and solution (see also *Met. Abs.*, this vol., p. 350).—J. H. W.

**Nickel–Chromium Processes.** Hans Hornauer (*Emailletech. Monats-Blätter*, 1933, **9**, (3), 20–22; *Ceram. Abs.*, 1933, **12**, 236).—Gives details of several chromium plating processes, showing the effect of temperature of bath, bath compositions, &c., on the resulting deposit.—S. G.

***A New Method of Electrodepositing Metals and Alloys [Copper and Silver].** M. Schlötter (*Oberflächentechnik*, 1935, **12**, 45–46).—Dense, bright, and firmly adherent deposits of copper and silver, superior in appearance to those obtained from the usual cyanide baths, can be obtained from solutions containing thiocyanates of the metals by operating at 0·5 v. with a current density of 1 amp./dm.$^2$. The preferred silver bath contains silver thiocyanate 33 and sodium thiocyanate 20 grm./litre and the copper bath copper thiocyanate 40, ammonium thiocyanate 200, and sodium sulphite 10 grm./litre; in both cases small amounts of colloidal brighteners may be added.
—A. R. P.

***Experiments with a View to Determining the "Index of Uniformity of Thickness" of Deposits and the Throwing Power of Nickel and Chromium Plating Baths.** A. Portevin and M. Cymboliste (*Quatorzième Congr. Chim. Indust., Paris, Preprint*, **1934**, Oct., 17 pp.).—A method is described of deter-

mining the throwing power of plating baths by using an L-shaped test-piece made up of numerous small sheets of metal, the gain in weight on plating of which is readily determined; some results obtained on various nickel and chromium plating baths are shown graphically and briefly discussed.
—A. R. P.

**Black Nickel.** Joseph L. Downes (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (8), 17–22).—Good hard deposits of black nickel are obtained from a solution containing nickel sulphate crystals 10, nickel ammonium sulphate crystals 6, zinc sulphate crystals 5, and sodium thiocyanate 2 oz./gall. operated at 1–1·5 amp./ft.$^2$ at 65°–78° F. (18°–26° C.). The $p_H$ must be kept at 6·6–6·8 and the cathodes moved at 20–25 in./minute. The average deposit obtained contains nickel 52, zinc 7·5, and sulphur 14%, and since it is decidedly porous it offers little resistance to corrosion; when the finish is to be applied to ferrous metals, therefore, a good undercoat of bright nickel should first be given. The sulphur content of the solution is an important consideration, since if it falls too low the nickel content of the deposit will be low and the sulphur content high. Carbon anodes are preferable to soluble anodes, the composition of the solution being kept fairly constant by suitable additions.—A. R. P.

**Electrodeposition of Tin.** A. L. Shields (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (7), 15–25; discussion 26–34; and (abstract) *Iron Age*, 1935, **135**, (25), 27–28).—The following conditions are recommended for tin-plating refrigerator parts: electrolyte: sodium stannate 6–12, sodium hydroxide 2, sodium acetate 4 oz./gall.; temperature 75° C.; current density 25–30 amp./ft.$^2$ at 3·5–4·5 v.; anodes: tin and iron with a ratio of surface area of 2 : 1; plating time 30–35 minutes. Frequent analysis of the bath for tin and free alkali is necessary and sodium stannate must be added to make up any deficiency in the tin content. The cleaning of the parts to be plated is described and practical hints on operating the bath to get consistent results are given together with details of methods of analysis.—A. R. P.

***Electrodeposition of Tin for Refrigerating Purposes.** E. A. Johnson (*J. Electrodepositors' Tech. Soc.*, 1935, **10**, 119–124).—An analytical record over a period of 3 months of a tin-plating solution made up from stannous chloride, potassium hydrate, and glutenoid. Good throwing power was important to ensure adequate covering of complicated structures such as plate and fin coils which were plated after assembly. A weak solution and low current density were found to favour throwing power, which was of more importance than rapidity of output. Dragout losses necessitated large additions to maintain the electrolyte.—A. I. W.-W.

**On the Tinning of Galvanized Sheet Iron.** Ralph W. Harbison (*Metallbörse*, 1935, **25**, 1011, 1043).—The appearance and resistance to corrosion of galvanized iron are considerably improved by applying a thin coating of electrolytic tin. Good results are obtained from a bath containing sodium stannate 70–75, sodium acetate 10–15, sodium hydroxide 5–6, and sodium perborate 0·75–1·5 grm./litre operated at 75°–80° C. with 4–6 v. at a current density of 2–6 amp./dm.$^2$. Addition of small quantities of starch or, preferably, potassium resinate improves the brightness of the deposit. Steel sheet and pure tin anodes with a surface area ratio of 3 : 7 should be used and the free alkali content should be carefully controlled.—A. R. P.

**Zinc Plating.** J. F. Calef (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (7), 36–47).—Progress in zinc plating from a cyanide bath during recent years is summarized and a brief account of modern practice is given. The best deposit from the point of view of colour and brightness is obtained from a bath containing zinc cyanide 4–5, free sodium cyanide 4–5, sodium hydroxide 3·5–4·5, sodium fluoride 0·5–1, and gum arabic 0·1–0·15 oz./gall.
—A. R. P.

**The Evolution of the Plating Bath.** H. J. T. Ellingham (*J. Electrodepositors' Tech. Soc.*, 1935, **10**, 109–118).—An historical survey with dates from 1801. —A. I. W.-W.

**Practical Results of Electrodeposition Researches.** —— (*Met. Ind.* (*Lond.*). 1935, **47**, 237–239).—Outlines the results of investigations carried out by the Department of Scientific and Industrial Research and the British Non-Ferrous Metals Research Association.—J. H. W.

## VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY

(Other than Electrodeposition.)

(Continued from p. 435.)

***Eutectic Galvanic Elements.** —— (*Zhurnal Obstchei Khimii* (*J. Gen. Chem.*), 1934, [A], **4**(**66**), (8), 1094–1101).—[In Russian.] The galvanic cells Cd|$CdCl_2$ or $CdSO_4$|Bi–Sn–Pb alloy; Al|$AlCl_3NaCl$|Cu; Bi|$CdCl_2$|Cd, Zn|$ZnSO_4$|Cu were investigated. In the first three a eutectic is formed on the more noble metal exactly as though it had crystallized out of a molten mixture of the metals. The source of the e.m.f. is the free energy of the formation of the eutectic, and vanishes when the more noble metal is wholly covered by the eutectic, since equilibrium between the two electrodes is thereby attained. At temperatures above the melting point of the eutectic the e.m.f. does not vanish, since the eutectic melts and flows away, exposing a fresh surface. —M. Z.

***The Cathodic Film in the Electrolytic Reduction of Aqueous Chromic Acid Solutions.** Erich Müller [with Donald W. Light] (*Trans. Faraday Soc.*, 1935, **31**, 1194–1203).—See *Met. Abs.*, this vol., p. 302.—A. R. P.

## VIII.—REFINING

(Continued from p. 435.)

**The Vacuum Distillation of Metals. II.—Refining Tin and Lead by Evaporation in a High Vacuum.** W. Kroll (*Met. Ind.* (*Lond.*), 1935, **47**, 155–156).—Lead and arsenic are almost completely removed from tin by vacuum distillation, antimony and silver to a lesser degree, and copper and iron scarcely at all. In the vacuum distillation of lead, tin, copper, and silver all remain in the residue, arsenic is completely driven off and antimony partly so. The percentage of bismuth is not reduced in the residue for low bismuth contents (*e.g.* 0·37%), but was reduced from 50% in the alloy to 39% in the residue. Zinc is almost completely removed at 603° C., and appreciably so at even 374° C. The vacuum was in the range below 0·001 mm. of mercury.—J. H. W.

## IX.—ANALYSIS

(Continued from pp. 435–437.)

***Use of 8-Hydroxyquinoline in Determinations of Aluminium, Beryllium, and Magnesium.** Howard B. Knowles (*J. Res. Nat. Bur. Stand.*, 1935, **15**, 87–96; *Nat. Bur. Stand. Research Paper* No. 813).—The methods commonly used for precipitating Al by 8-hydroxyquinoline from $CH_3COOH$ solution, buffered with $CH_3COONH_4$, do not sufficiently define the conditions requisite for complete precipitation. A method is described in which Al is precipitated as the oxyquinolate from a solution which has been partially neutralized with $NH_4OH$, using bromocresol purple as indicator. Results obtained in the separation of Al from Be and Mg, and in the separation of Be in the presence of Al, Fe, Ti, and Zr, by this method, are given.—S. G.

***Rapid Method of Aluminium Alloy Analysis.** I. J. Klinov and T. I. Arnold (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 894–895).—[In Russian.] Si, Cu, and Fe are determined colorimetrically.—D. N. S.

***Determination of Small Quantities of Aluminium in "Special" Iron-Containing Copper–Zinc Alloys.** M. M. Shubin (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 889–893).—[In Russian.] The precipitate of $Al(OH)_3 +$ $Fe(OH)_3$ obtained in the usual way is dissolved in $H_2SO_4$ and the Fe separated by addition of $Na_2S$ to the feebly ammoniacal tartrate solution. The Al is then precipitated from an aliquot portion of the filtrate with $(NH_4)_2HPO_4$ after removal of $H_2S$ and neutralization. In a 5 grm. sample containing 1·8% Fe and 0·10% Al, the quantity of the latter could be determined with 0·01% accuracy. —D. N. S.

***On the Colorimetric Determination of Aluminium with Alizarin "S."** A. P. Mussakin (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 1085–1088).—[In Russian.] Atack's method is modified by adding the neutral standard Al solution to the alizarin "S" solution until the colour matches that of the solution under examination (containing an equal amount of alizarin "S"). —D. N. S.

**The Spectrographic Analysis of Aluminium and Aluminium Alloys.** A. G. C. Gwyer (*Metallurgist* (Suppt. to *Engineer*), 1935, 10, 48).—A brief review of the subject. The advantages and disadvantages of the method are discussed. —R. G.

**The Determination of Bismuth in Copper.** —— (*Chem. Trade J.*, 1935, 97, 31).—See also *Met. Abs.* (*J. Inst. Metals*), 1933, 53, 367. The method proposed by the Chemical Sub-Committee of the Fiscal Policy Joint Committee of the Brass, Copper, and Nickel Silver Industries is as follows: the metal (2 grm.) is dissolved in $HNO_3$ and the solution evaporated with 3 c.c. of $H_2SO_4$ until copious fumes are evolved. The mass is dissolved in 30 c.c. of $H_2O$, 1 grm. of citric acid is added, followed by $NH_4OH$ until a clear blue solution is obtained then by KCN solution until the blue colour is discharged, and the Bi is extracted by shaking the solution, diluted to 200 c.c., with successive 10 c.c. volumes of a 0·1% solution of diphenylthiocarbazone in $CHCl_3$. The $CHCl_3$ layer is evaporated to a small volume, 1 c.c. of $H_2SO_4$ is added, and heating is continued until the acid fumes strongly, $H_2O_2$ being added as required to destroy organic matter. The solution of the Bi is then diluted and the Bi determined colorimetrically by the usual iodide method.—A. R. P.

***On the Colorimetric Determination of Cerium and Titanium by Gallic Acid.** F. M. Schemjakin (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 1090–1091).—[In Russian.] (1) A standard solution is prepared by mixing 2·7 c.c. of $Ce(NO_3)_3$, containing about $5 \times 10^{-5}$ grm./c.c. Ce with an equal volume of 0·001*N*-gallic acid under a protective film of 2 c.c. of ether or toluene. On addition of 5·3 c.c. of 0·1*N*-$NH_4OH$ containing 1% $Na_2SO_4$ a blue solution is formed. The sensitivity of the method is $1 \times 10^{-5}$ grm./c.c. (2) A standard solution is prepared by mixing 4 c.c. of 5% solution $CH_3CO_2Na$, 8 c.c. of 1% gallic acid and from $3 \times 10^{-7}$ to $1 \times 10^{-4}$ grm./c.c. Ti and diluting to 50 c.c. The sensitivity is $3 \times 10^{-7}$ grm./c.c. Fe, Mo, W, V, Cr, and Ce interfere. —D. N. S.

**Analysis of Chrome–Nickel Alloys Using Perchloric Acid.** Frank W. Scott (*Chemist-Analyst*, 1935, 24, (3), 4–5).—The alloy is dissolved in hot 35% $HClO_4$ and the solution evaporated until the acid evolves copious fumes; heating is continued for 10–15 minutes to render the $SiO_2$ insoluble and to oxidize the Cr to $CrO_3$. After cooling, the solution is diluted, the $SiO_2$ collected, and the filtrate titrated for Cr with $FeSO_4$ and $KMnO_4$. The titrated solution may be used for the determination of Ni by the glyoxime method after addition of tartaric acid and neutralization with $NH_4OH$. Mn must be determined on a separate sample by the persulphate method.—A. R. P.

**The Separation of Columbium and Tantalum.** D. D. Peirce (*J. Amer. Chem. Soc.*, 1931, **53**, 2810).—A brief letter. P has found that Cb may be electrolytically deposited from a saturated solution of $Na_2CO_3$ containing ignited $Cb_2O_5$ with a current density of 3 amp./dm.$^2$ at 103° C. The cathode used was of copper. Ta is not deposited in similar conditions.—L. A. O.

***A New Method of Fractional Detection of Copper.** L. M. Kulberg (*Zhurnal Prikladnoi Khimii* (*J. Applied Chem.*), 1934, [B], **7**, (6), 1079–1080).—[In Russian, with German summary.] When Cu is displaced from HCl solution by metallic Sn and the deposit agitated with a solution of $ZnSO_4$ containing $(NH_4)_2Hg(SCN)_4$, a characteristic purple precipitate is obtained. The method is applicable in the presence of all cations, is sensitive to $10^{-7}$ grm. Cu, and is very rapid.—M. Z.

***A Note on the Preparation of Silver-Free Copper.** Bart. Park (*J. Amer. Chem. Soc.*, 1930, **52**, 3165–3166).—For spectrographic purposes, Cu was purified from Ag by triple recrystallization of the sulphate followed by electrolysis of the solution between Pt electrodes, in stages. The metal deposited subsequent to the first 12 grm. was found to show no trace of the Ag line at 3181 which is the most persistent and capable of revealing the presence of as little as 0·0002% Ag.—R. G.

***Adaptation of the Dimethylglyoxime–Benzidine Test for Cobalt to the Usual Scheme of Quantitative Analysis.** Alfred W. Scott (*J. Amer. Chem. Soc.*, 1933, **55**, 3647–3648).—The method gave satisfactory results even when the concentration of Ni was 50 times that of Co.—L. A. O.

***The Quantitative Precipitation of Sulphides in Buffered Solutions. I.—Cobalt Sulphide.** Malcolm M. Haring and Martin Leatherman (*J. Amer. Chem. Soc.*, 1930, **52**, 5135–5141).—Conditions for quantitative precipitation are given. The CoS is ignited to oxide, reduced in $H_2$, and weighed as Co. The effect of variation in acidity on the precipitation is described.—R. G.

**Determination of Small Quantities of Germanium in the Presence of Arsenic.** S. A. Coase (*Analyst*, 1934, **59**, 747–749).—Electrolysis of an alkaline solution of germanate and arsenate results in complete removal of the Ge as $GeH_4$, which is evolved together with $H_2$ at the cathode. Passage of the gases through a hot tube affords a Ge mirror, which is then compared with that obtained from solutions containing a known weight of Ge.—A. R. P.

***Volumetric Determination of Lead in Alloys Containing Tin, Antimony, and Copper.** N. A. Tananaeff (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, **3**, 983–984).—[In Russian.] The $PbSO_4$ precipitate obtained in the usual way is boiled with an excess of $0{\cdot}1N$-$Na_2CO_3$ for 15 minutes, the $PbCO_3$ filtered off, and the excess alkali titrated in the filtrate.—D. N. S.

**Some Newer Qualitative Tests for Lead.** C. Franklin Miller (*Chemist-Analyst*, 1935, **24**, (3), 17).—A nitrate solution of Pb gives a bright blue colour when treated with $\frac{1}{10}$ its volume of a 20% solution of resorcinol in $C_2H_5OH$ followed by $NH_4OH$ in slight excess, covered with a layer of nujol, and set aside overnight. Cd and Zn give similar colours. The diphenylthiocarbazone and tetramethyldiaminodiphenylmethane tests for Pb are also described.—A. R. P.

***The Use of the Antimony Electrode in the Electrometric Estimation of Magnesium.** B. B. Malvea and James R. Withrow (*J. Amer. Chem. Soc.*, 1932, **54**, 2243–2247).—The Sb electrode made of commercial stick Sb was a satisfactory substitute for the hydrogen electrode in the electrometric estimation of Mg in its salts and in mixtures of Ca and Mg salts. Ca to the extent of 8–25 times the amount of Mg did not interfere. The minimum concentration of MgO was 0·10 grm. in 150 c.c. of solution. At low dilutions the results were unsatisfactory if Ca was present in any appreciable amount, or was even equivalent in amount to the Mg.—L. A. O.

***The Quantitative Precipitation of Sulphides in Buffered Solutions. II.—Nickel Sulphide.** Malcolm M. Haring and Benton B. Westfall (*J. Amer. Chem. Soc.*, 1930, 52, 5141–5145).—The conditions necessary for the quantitative precipitation are described. It was found that adsorption of sulphides on glass surfaces appeared to vary with the state of strain of the glass.—R. G.

**Volumetric Determination of Silver.** K. Bihlmaier (*Mitt. Forschungsinst. Edelmetalle,* 1935, 9, 52–59).—The thiocyanate method is described with special reference to its use in the analysis of silver alloys.—A. R. P.

***Investigations into the Analytical Chemistry of Tantalum, Columbium, and Their Mineral Associates. XXIX.—Separation of Tungsten from Niobium, Tantalum, Titanium, and Zirconium.** A. R. Powell, W. R. Schoeller, and C. Jahn (*Analyst,* 1935, 60, 506–514).—In the ordinary course of an analysis the W, Ta, Nb, and some or all of the Ti and Zr are obtained as a mixture of oxides which presents many difficulties in separation since some of these elements interfere with the normal reactions of others. From admixture with $TiO_2$, $WO_3$ may be separated by fusion with $Na_2CO_3$ and leaching of the fused cake with 10% NaOH, the $TiO_2$ remaining insoluble. This method is unsatisfactory in the presence of Nb and Ta; complex mixtures, therefore, should be fused with 4 grm. of $K_2CO_3$, the cake extracted with $H_2O$ and the solution, without filtration, digested on the water-bath with a solution of 1 grm. of $MgSO_4$ and 2 grm. of $NH_4Cl$, which precipitates all the metals except W. The filtrate is acidified with HCl, made just neutral with $NH_4OH$ and boiled with $NH_4Cl$, tannin, and cinchonine to recover the W. The precipitate is digested with HCl to dissolve the Mg, neutralized and boiled with $CH_3{\cdot}CO_2NH_4$ and tannin to recover the Ta, Nb, Ti, and Zr; the ignited precipitate should again be treated as before to ensure complete removal of the W.—A. R. P.

***Phenylarsonic Acid as a Reagent for the Determination of Tin.** J. S. Knapper, K. A. Craig, and G. C. Chandlee (*J. Amer. Chem. Soc.*, 1933, 55, 3945–3947).—This method separates Sn quantitatively from a number of elements commonly occurring with it in alloys, but not from Zr or Th.—L. A. O.

***New Methods of Determining Zinc.** B. P. Zelenetski (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 1081–1085).—[In Russian.] Four methods are described: (1) ZnS is precipitated from an acetate solution by $H_2S$, the excess of which is expelled by boiling, $NH_4OH$ and $AgNO_3$ are added, and the precipitate of $Ag_2S$ thus obtained is dried and weighed; (2) the ZnS obtained as above is treated with standard I solution, excess of which is titrated with $Na_2S_2O_3$; (3) the Zn is precipitated as ZnS in the absence of $CH_3{\cdot}CO_2H$, with continuous neutralization of the mineral acid formed (methyl orange indicator), the excess of $H_2S$ is boiled off, the ZnS dissolved in $KMnO_4$ and $H_2SO_4$, $H_2C_2O_4$ added to decolorize the solution, and the excess determined by titration with the same $KMnO_4$; (4) $H_2S$ is passed through the cold, accurately neutralized solution, and the mineral acid formed is constantly neutralized with ammonia (methyl orange indicator).—D. N. S.

**Rapid Separation and Determination of Zinc in Gold and Bronze Pigments.** Frederick G. Germuth (*Chemist-Analyst,* 1935, 24, (3), 10–11).—Zn may be removed from metal powders containing it in association with Cu or Sn by digesting the powder with 2*N*-HCl at 40°–50° C. for 5 minutes; the resulting solution is free from interfering impurities and, after filtration, can be titrated directly with $K_4Fe(CN)_6$.—A. R. P.

***The Metallic Precipitation of Zirconium.** Howard S. Gable (*J. Amer. Chem. Soc.*, 1930, 52, 3741).—A preliminary note. $Zr(SO_4)_2$ was found to be soluble in $CH_3OH$. The solution was treated with metallic Zn which became covered with a dark deposit, $H_2$ being evolved. This deposit was scraped off and treated with HCl when any Zn removed with it was dissolved, leaving Zr on the bottom of the container. The reactions taking place were: $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$ and $2Zn + Zr(SO_4)_2 \longrightarrow 2ZnSO_4 + Zr$.—L. A. O.

**A Rapid Method for the Determination of Sulphur in Ferromagnetic Alloys.** Beverly L. Clarke, L. A. Wooten, and C. H. Pottenger (*Indust. and Eng. Chem.* [*Analyt. Edn.*], 1935, **7**, 242–244).—Combustion of Ni alloys in $O_2$ requires a very high temp. to ensure complete elimination of the S as $SO_2$. A quicker method for determining S in these alloys comprises heating 10 grm. in an alundum boat in a current of $H_2$ for 1 hr. at 1100°–1200° C. and collecting the $H_2S$ in 30 c.c. of 5% ammoniacal $Cd(NO_3)_2$ solution; the solution is then treated with 10 c.c. of 0·1*N*-$AgNO_3$ to convert the CdS precipitate to $Ag_2S$, filtered, made acid with $HNO_3$ and titrated with $NH_4CNS$ to determine the excess of Ag. Alternatively the CdS may be determined iodometrically. —A. R. P.

**New Analytical Methods in Metallurgy.** M. Niessner (*Metallwirtschaft*, 1935, **14**, 322–324).—A review of the advances made during the last 20 years in the analytical chemistry of the metals, with especial reference to Feigl's drop reactions.—v. G.

## X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

(Continued from p. 437.)

***Electron-Optical Photography by Means of Electrons Released Photo-Electrically.** J. Pohl (*Z. tech. Physik*, 1934, **15**, 579–581).—From Vorträge u. Diskussionen auf dem 10 Deutschen Physiker- u. Mathematikertages, 1934, Sept. Apparatus employing a magnetic electron-microscope for the examination of photo-cathodes is described. The power of the method employed is illustrated by a comparison of the surfaces of various metals photographed by the apparatus and by ordinary light. The method is applied to platinum in order to investigate the effects of gas charge and crystal structure on the distribution of emission from the metal.—J. S. G. T.

***Method for Carrying Out Microscopic Investigations at Low Temperatures.** S. Erk (*Physikal. Z.*, 1935, **36**, 451–452).—Deposition of water vapour on the microscope objective, &c., and on the material being examined is prevented by the use of a protective water-free atmosphere produced by the evaporation of liquid air, solid carbon dioxide, ether, &c. Apparatus, employing liquid air, enabling microscopic investigations to be carried out down to – 120° C. is described.—J. S. G. T.

***An Apparatus for Electron Diffraction at High Voltages.** G. P. Thomson (*Trans. Faraday Soc.*, 1935, **31**, 1049–1051).—See *Met. Abs.*, this vol., p. 305. —A. R. P.

## XI.—PHYSICAL AND MECHANICAL TESTING, INSPECTION, AND RADIOLOGY

(Continued from pp. 438–440.)

**Hardness Testing.** R. A. Halloway (*Heat-Treat. and Forging*, 1935, **21**, 377–381).—The theory of testing and the instruments for making the tests are explained.—J. H. W.

***Buckling of Linked Beams Having Strength in Flexure and Shear.** R. A. Fairthorne (*Aeronaut. Res. Cttee. R. and M.* No. **1616**, 1934).—Mathematical expressions are derived for determining the stresses which cause buckling under various conditions.—A. R. P.

**Examination of a Metal by the Method of Ultra-Acoustic Vibrations.** S. M. Ramm (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, **3**, 719–720).—[In Russian.] For revealing internal defects (cavities) in metals, an apparatus has been constructed based on the principle that a pencil of ultra-acoustic waves passes through homogeneous metal without reflection, but is reflected when striking a cavity. The mirror-like surface of transformer oil placed on the specimen on the opposite side to that on which the waves impinge, serves as the indicator of the transmitted waves which are reflected on to a screen as ripples when the specimen is homogeneous. A quartz vibrator with a frequency of 500–2000 kilocycles is used to produce the ultra-acoustic vibration.—D. N. S.

**New Fatigue Tester.** —— (*Iron Coal Trades Rev.*, 1935, 131, 275).—A new type of fatigue tester for sample steel bars is described, which can also be adapted for testing non-magnetic metals. The bar is supported at its two nodes and vibrated electromagnetically, thus allowing a large number of cycles of stress to be applied in a relatively short time. By measuring the deflection of the bar at an antinode, the actual stress applied can be calculated using the modulus of elasticity $E$ determined from the frequency of the vibrating bar. The number of cycles before failure is indicated by a recorder. A means of tripping the gear on the occurrence of a crack in the specimen is provided. —L. A. O.

**A Method of Testing Weld Seams.** H. Schmuckler (*J. Amer. Weld. Soc.*, 1935, 14, (7), 16–17).—The conical milling-cutter apparatus is described, and applications for testing seams, cutting out bad parts, and machining the ends of fillet-welds in order to improve fatigue-strength, are discussed.—H. W. G. H.

## *RADIOLOGY.*

***X-Ray Illumination. Method of Sliding Beam. Determination of Live Section.** M. D. Wosdwischenski (*Zavodskaia Laboratoria* (*Works' Laboratory*), 1934, 3, 911–914).—[In Russian.] A method is described for the X-ray examination of welded seams of various complex profiles which do not permit the X-ray plate to be placed close to the point under examination; it consists in placing the film parallel to the axis of the X-ray pencil so that the points of porosity can be found by measuring the intensity of the blackening of the film from the sliding ray pencil along its surface. It is possible in certain cases by microphotometry of the film to determine their section by the width of the maxima on the photomicrograph.—D. N. S.

**Critical Study of Possibilities of Measurement of Elastic Stresses by X-Rays.** H. B. Dorgelo and J. E. de Graaf (*De Ingenieur*, 1935, 50, E31–35; *C. Abs.*, 1935, 29, 5047).—[In Dutch.] The X-ray spectra of specimens of various metals (aluminium, iron) under stress were studied, Co radiation was used for steel, Cu radiation for aluminium. The location of the ring patterns obtained was determined with 0·01 mm. accuracy, corresponding to a minimum stress of 2 kg./mm.$^2$ for iron (1 kg./mm.$^2$ for aluminium). Several reasons are advanced for the conclusion that other mechanical methods, *e.g.* Martens stress meter, are preferable for such work.—S. G.

**A Study of Materials by Means of X-Rays.** L. Triau (*Electricité*, 1935, 19, 106–111; *C. Abs.*, 1935, 29, 5047).—A general discussion and explanation of the use of X-rays for examining the structure of metals and detecting defects in welds, with a description of the instruments used.—S. G.

**The X-Ray Examination of Welds.** R. A. Stephen (*Iron and Steel Inst. Symposium on Welding of Iron and Steel, Group 4, Advance Copy*, 1935).—The advantages of the method are emphasized and brief details of the technique for examining butt, lap, and tee welds are given. The types of defect to be found in M.S. welds are described and some examples are illustrated. —H. W. G. H.

## XII.—TEMPERATURE MEASUREMENT AND CONTROL

(Continued from p. 440.)

†**The Installation and Maintenance of Thermo-Electric Pyrometers.** G. H. Barker (*Metallurgia*, 1935, 12, 57–58, 87–89, 121–122).—The operating principles of thermo-electric pyrometry, and the construction of the indicating, recording, and controlling instruments, and their sensitive elements are discussed, and consideration is given to important factors in the construction and use of pyrometers, *e.g.* the metals used, protecting tubes, installation of thermocouples, running of compensating leads, the resistance of the thermo-electric circuit, and the checking of installed pyrometers. Brief consideration is also given to the principle, standardization, and uses of radiation pyrometers. —J. W. D.

**Thermo-Electric Pyrometers as Applied to Workshop Practice.** G. W. Ashton (*Mech. World*, 1935, 97, 325–326).—Practical rules for the use and care of thermo-electric pyrometers are discussed.—F. J.

## XIII.—FOUNDRY PRACTICE AND APPLIANCES

(Continued from pp. 440–441.)

†**Brass Die-Castings.** —— (*Met. Ind.* (*Lond.*), 1935, 47, 127–131).—An informative review of modern die-casting methods and machines.—J. H. W.

†**Propeller Manufacture.** Wm. Ashcroft (*Metallurgia*, 1935, 12, 107–110).—Some principles involved in the manufacture of propellers are discussed including improvements which have been made in propeller design as a result of experimental and research work, the preparation and building of moulds, the metals used, and the melting and casting procedure. Special consideration is given to some of the problems associated with the metals used, particularly the high-tensile brasses which have been developed in order to meet the erosion which occurs in high-speed propellers, and the necessity for strict supervision in dealing with the composition, as well as the melting and casting of such alloys, if abnormal gassing, lack of homogeneity, high melting losses, and segregation troubles are to be eliminated.—J. W. D.

**On the Preparation of Zinc-Bearing Machine Bronzes.** E. R. Thews (*Metallbörse*, 1935, 25, 305–306, 337–338).—The melting, casting, and deoxidation of bronzes containing zinc are discussed, with special reference to the effects of additions of lead and of variations in the casting temperature on the mechanical properties of the alloys.—A. R. P.

**Silver in the Foundry.** E. A. Smith (*Found. Trade J.*, 1935, 53, 194).—A brief historical account of the use of silver is given. The use of a flux and of deoxidizers, such as cadmium, zinc, and phosphor–copper, in the casting of pure silver, and the applications of the cast metal are described.—J. H. W.

**Modern Crucible Melting Equipment.** R. H. Stone (*Indust. Heating*, 1935, 2, 181–186).—For non-ferrous work the factors to commend crucible melting are wider range in the choice of fuels, low investment, flexibility as to kinds of metals melted and rate of operations, and excellence of the metal which is protected from direct contact with flames and the products of combustion. In new installations using gas or oil-fuel, individual furnaces designed for proper combustion and standard refractory shapes are recommended. Secondary air admission around the burner port is unnecessary in a properly designed furnace, and it greatly reduces the flame temperature. An increase in the diameter of the furnace lining up to a point above the middle line is advocated in order to give better combustion. The lining should be chipped frequently in order to prevent the projection of direct flame against the side of the crucible. A recent type of furnace operates with oil at 2000 lb. pressure. —W. A. C. N.

†**Recent Developments in Foundry Melting Practice, Oxidation, and Carburization Factors.** J. E. Fletcher (*Fuel Economy Rev.*, 1935, 14, 27–32).—Recent developments in foundry practice, including the control of oxidation, heat distribution in balanced blast cupolas, influence of duration of melts on heat expenditure, handling of melting plant, and carburization of air are briefly discussed.—J. S. G. T.

**The Determination of Moisture in Moulding Sands.** S. E. Dawson and F. T. Hanks (*Found. Trade J.*, 1935, 53, 113–114).—Describes a new type of apparatus, consisting essentially of a special form of electrodes used in conjunction with an ohm-meter and a suitable battery, for determining the moisture content of foundry sands, and the method of using it.—J. H. W.

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

(Continued from pp. 441–442.)

**The Practice of Scrap Metal Melting.** E. R. Thews (*Metallbörse*, 1935, 25, 817–818, 849–850, 881–882).—Fluxes and other protective media in the production of brass alloys and in the remelting of brass scrap are discussed.
—A. R. P.

## XV.—FURNACES AND FUELS

(Continued from p. 442.)

**The Electric Furnace in the Non-Ferrous Industry.** A. G. Robiette (*Found. Trade J.*, 1935, 53, 131–133, 213–214).—The use of the electric furnace for non-ferrous metal melting is reviewed both as regards the metallurgical and economic aspects; in particular the details of the melting practice, mixing action, refractory materials, metal loss, absorption of gases, and operating costs of the Detroit Rocking electric furnace for brass and bronze melting are given. Many nickel alloys can also be melted in this furnace.—J. H. W.

**High Temperature Furnaces.** —— (*Indust. Heating*, 1935, 2, 215–216).—An electric furnace is described, capable of being raised to 1260° C., which uses metal resistors that can be operated in either an oxidizing or a reducing atmosphere. The new wire is said to have a resistance 45% greater than nickel-chromium and also a higher current carrying capacity. No water cooling of the element terminals is required.—W. A. C. N.

**Graphite Resistor Radiation Furnaces and Their Application to High Temperatures.** Henri George (*Electrochem. Soc. Preprint*, 1935, (Oct.), 317–322).—New radiation furnaces employing a graphite resistor are described in detail. The 100-kw. size has a capacity of 100 kg. The 4-ton furnace has 3 graphite resistors each 50 mm. in diam., and Y-connected to the transformer. The furnaces are cylindrical in design, and are usually revolved or rocked to facilitate mixing of the furnace charge. For special cases when temperatures are desired above the melting point (1800° C.) of the refractory lining, the furnaces are rotated at high speed, which causes the charge itself to serve as "lining." Thus, large batches of thoria may be fused in the centrifugal furnace. Temperatures of 3000° C. are attainable without introducing any carbon into the product. 20 kg. of silica can be melted in 6½ minutes starting cold.—S. G.

†**Modern Furnace Grates.** Hans Schulze-Manitius (*Feuerungstechnik*, 1935, 23, 86–90).—Recent improvements in furnace grates are briefly described.
—J. S. G. T.

**Air-Heating Blowers.** E. Schirm (*Feuerungstechnik*, 1935, 23, 76–77).—See also *Met. Abs.*, this vol., p. 442. Air blowers incorporating a heat-interchanging device are further described.—J. S. G. T.

**Pulverized Coal as a Standard Industrial Fuel.** H. D. Tollemache (*Fuel Economy Rev.*, 1935, 14, 21–24).—Supplies of standardized pulverized coal are now available, and works supplying such fuel are to be erected in industrial centres throughout the country. Advantages of such supplies are briefly referred to.—J. S. G. T.

***The Combustion of Carburetted Water-Gas in Luminous Flames.** R. J. Altpeter and O. L. Kowalke (*Gas-Age Record*, 1935, 76, 109–114).—Experimental work and results relating to the space requirements of luminous flames of carburetted water-gas, and the sizes and shapes of combustion furnaces are described and discussed.—J. S. G. T.

## XVI.—REFRACTORIES AND FURNACE MATERIALS

(Continued from pp. 443–444.)

**Refractory Materials in White-Metal Flame Furnaces.** Edmund R. Thews (*Tonind.-Zeit.*, 1935, 59, (3), 30–32; *Ceram. Abs.*, 1935, 14, 167).—Practice shows that grog brick with an alumina content of 36–46% is the best refractory material for the bottom part of flame furnaces for melting white-metal alloys rich in lead. The refractory mortar used in these furnaces and conditions of melting are discussed.—S. G.

**Standards for Refractory Materials.** Comitato Termotechnico Italiano (*Centro Studi Ceram.*, 1934–1935, 2, (2–3), 18–22; *Ceram. Abs.*, 1935, 14, 167).—Tentative standards compiled by the Italian Thermo-Technical Committee are given for refractory materials, *i.e.* materials with a fusing temperature determined according to C.T.I. standards above 1500° C. and having mechanical resistance at high temperatures. Standards for raw materials, finished refractories, and chemical analyses are included.—S. G.

## XVIII.—WORKING

(Continued from pp. 445–446.)

**Seamless Tube Manufacture.** Gilbert Evans (*Metallurgia*, 1935, 12, 113–115).—See also *Met. Abs.*, this vol., pp. 74, 360. A review of the more important developments which have taken place in the direct manufacture of seamless tubes from ferrous or non-ferrous billets deals with the Mannesmann Rotary Piercing Machine, the Stiefel Disc Rotary Piercing Machine, Evans' Rotary Piercing Machine, the Push Bench Process, and the Diescher and Foren Tube Mills. The history, general principle, application, and suitability of each are briefly considered.—J. W. D.

***Sheet-Metal Scissors.** —— (*J. Sci. Instruments*, 1935, 12, (1), 28).—Describes sheet-metal scissors for cutting straight or curved shapes in sheet metals up to No. 16 gauge. The cutting mechanism consists of 2 circular knife-edged cutting wheels.—W. H.-R.

**†Production and Use of Sheet Zinc.** Julius Gutmann (*Z.V.d.I.*, 1935, 79, 551–555).—The production, working, and use of sheet zinc and its properties are described.—K. S.

**Hot-Rolling of Bimetal.** A. A. Metzger (*Metallurg* (*Metallurgist*), 1934, (10), 58–64).—[In Russian.] The rolling and pack-annealing processes are described.
—N. A.

**Cold-Rolling.** L. Weiss (*Z. Metallkunde*, 1935, 27, 73–75).—Mathematical. Methods of calculating the rolling pressure and its dependence on friction and diameter of the rolls are discussed, and graphical representations of the possible reductions of the work in each pass with various roll diameters, friction conditions, and sheet thicknesses are given.—A. R. P.

***On the Calibration of Rolls for Rolling Non-Ferrous Metals on Wire Mills.** E. I. Roscher, S. D. Zipurdeev, and S. N. Yakovlev (*Metallurg* (*Metallurgist*), **1934**, (9), 63–77; (10), 65–78).—[In Russian.] The shape of the dies used in the first two passes is determined by the shape of the ingot to be rolled; their size and the degree of reduction in them can be calculated from the angle of grip and the lateral extension. The shape of the next set of dies is determined by the properties of the metal to be rolled, taking into consideration the shape of the strip after the second pass. Big reductions take place only in the third pass. The reduction in passing from square to oval form must be greater than in passing from oval to square. In rolling metals with a small lateral extension (*e.g.* Manganin) the reduction in passing from square to oval must be less, and in passing from oval to square greater than for highly plastic metals. In rolling highly plastic metals, the ratio of the axes of the ovals must be greater than for metals with a low lateral extension. The pre-finishing oval and the finishing-off round dies have a special relation to one another.—N. A.

**Light Gauge Strips Classified According to Varying Thickness.** —— (*Amer. Metal Market*, 1935, **42**, (170), 9, 12).—A new machine is described which will separate sheet produced from cold-rolled strip into several different classes, and will hold the tolerance from standard gauge within exceedingly small limits.—L. A. O.

**Graphical Computation.** F. M. Scharff (*Blast Fur. Steel Plant*, 1935, **23**, 611–615).—Explains the use of graphs for the representation of data in rolling practice. The construction of the parallel and projective types of scale are considered.—R. Gr.

**Working Ranges of Nickel–Copper Alloys.** George F. Geiger (*Inco*, 1935, **12**, 26).—A chart is given showing the temperature ranges for pouring, hot-working, annealing, and low-temperature treatment (stress removal) of the nickel–copper alloys.—R. G.

**German Researches on the Working of Metals.** —— (*Metallurgist* (Suppt. to *Engineer*), 1935, **10**, 37–39).—A summary of the results of 9 researches given in *Mitt. K.-W. Inst. Eisenforschung*, 1934, **16**, Lieferungen 2, 4, 5, 9, 10, and 20. The work deals mainly with steel, but is partly of general application, and reference is made to comparisons with lead, &c.—R. G.

## XIX.—CLEANING AND FINISHING

(Continued from pp. 446–447.)

**Finishing Monel Metal and Nickel.—I–II.** W. F. Burchfield (*Abrasive Ind.*, 1933, **14**, (6), 13; (7), 13; *Ceram. Abs.*, 1933, **12**, 348).—The cycle of operations in finishing Monel metal and nickel is determined by the type of article, desired finish, and equipment available. Equipment and grinding media are discussed. Methods that have been employed successfully in finishing types of Monel metal and nickel are described.—S. G.

**Polishing Monel Metal.** Andrew V. Re (*Abrasive Ind.*, 1933, **14**, (11), 18).—S. G.

**Polishing Pastes.** Henry R. Power (*Metal Cleaning and Finishing*, 1933, **5**, 519–520).—S. G.

**Correct Abrasive Terminology.** Henry R. Power (*Metal Cleaning and Finishing*, 1933, **5**, 169–170).—S. G.

**Blasting with Aluminous Abrasive.** Henry R. Power (*Metal Cleaning and Finishing*, 1933, **5**, 129–130; *Ceram. Abs.*, 1933, **12**, 211).—The continued development of electrically-fused alumina as the premier non-silica air-blasting material has revealed a wide variety of applications where its use in replacing sand has accomplished not only sanitary and humanitarian ends, but has also speeded up production. Some applications are discussed in detail.—S. G.

**Sand and Metallic Abrasive Blasting as Industrial Health Hazard.** J. J. Bloomfield and Leonard Greenburg (*J. Indust. Hygiene*, 1933, **15**, 184–204). —S. G.

**Enamelling Copper and Copper Alloys.** —— (*Emailletech. Monats-Blätter*, 1933, **9**, (5), 35–38).—S. G.

## XX.—JOINING

(Continued from pp. 447–448.)

**Brazing with Silver Solders.** A. J. T. Eyles (*Hardware Trade J.*, 1935, **161**, 46, 57).—The advantages of silver-soldered joints—economy, reliability, and strength—are pointed out. The liquidus temperatures of typical solders are tabulated, and it is explained that, for a given ratio of copper and zinc, an increase in silver content lowers the "flow-point." In alloys containing 65% or more of silver, the substitution of cadmium for zinc raises the flow-point, but, in alloys containing lower percentages of silver, 4–5% of cadmium lowers the flow-point. Suitable fluxes are described, borax being the most useful, and some recommendations on technique are given.—H. W. G. H.

**Recent Advances in Soldering and Brazing.** C. L. G. Ashby (*Met. Ind.* (*Lond.*), 1935, **47**, 151–153).—The requirements of soldering and brazing materials and the manner in which they are fulfilled by modern alloys are described.—J. H. W.

†**Welding and Soldering of Light Metals.** E. Lüder (*Maschinenbau*, 1935, **14**, 369–371).—Important considerations for the shape of the joint between light metals and heavy metals are discussed, and some practical examples of soldering and welding are described.—K. S.

**The Present State of Fusion Welding of Aluminium and Its Alloys.** H. Buchholz (*Autogene Metallbearbeitung*, 1935, **28**, 209–217).—See *Met. Abs.*, this vol., p. 120.—H. W. G. H.

**Welding Magnesium Alloys.** A. Eyles (*Machinist* (*Eur. Edn.*), 1935, **79**, 408E).—Some precautions to be taken in welding magnesium alloys are briefly described.—J. H. W.

**A New Design of Spot-Welding Electrodes.** G. Komovski (*J. Amer. Weld. Soc.*, 1935, **14**, (7), 14–15).—The current density in various sections of tapered electrodes is discussed and its distribution graphically represented. A new design of electrode is described, in which deformation of the tip is reduced by a hard steel casing.—H. W. G. H.

**A Comparative Study of Direct and Alternating Currents in Arc Welding.** J. Legrand (*Iron and Steel Inst. Symposium on Welding of Iron and Steel, Group 2, Advance Copy*, 1935).—A series of tests is described to show the relationship between the characteristics of the plant and those of the arc. It is concluded that a.c. is to be preferred for welding steels and aluminium, and d.c. for bronze, copper, and nickel, on account of the fusion being less rapid. —H. W. G. H.

**Some Notes on the Selection of Electric Arc Welding Plant.** R. W. Happé (*Iron and Steel Inst. Symposium on Welding of Iron and Steel, Group 2, Advance Copy*, 1935; and *Welder*, 1935, **7**, 606–607, 610–613).—The essential features of a.c. and d.c. welding plants are discussed with a view to assisting a welder with little electrical knowledge to assess the comparative values of different machines.—H. W. G. H.

**Electric Arc Welding Bronze Overlays on to Steel.** Charles H. Jannings (*Iron Age*, 1935, **136**, (1), 21–25, 178).—The essential factors in depositing bronze overlays on to steel by the metallic arc process are outlined, and the use of an automatic welding head for depositing the bronze on rocker rings in locomotive engines is described.—J. H. W.

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**Oxy-Acetylene Welding Practice and Technique.** C. G. Bainbridge (*Iron and Steel Inst. Symposium on Welding of Iron and Steel, Group 2, Advance Copy*, 1935; and *J. Amer. Weld. Soc.*, 1935, 14, (7), 18–22; *Welding Ind.*, 1935, 3, 205–208, 216).—Operating data on the "rightward" welding of mild steel are given. The details given may be useful in the application of this method to other materials.—H. W. G. H.

**Use of Inflammable Liquids in Hydraulic Back-Pressure Valves.** M. Maier (*Autogene Metallbearbeitung*, 1935, 28, 227–229).—The use of such liquids as petrol, benzol and toluol, is found not only to present no danger, but even to be advantageous, particularly in cases where there is risk of water freezing. They must not, of course, be used in valves having parts made of rubber. —H. W. G. H.

## XXI.—INDUSTRIAL USES AND APPLICATIONS

(Continued from pp. 448–452.)

**Aluminium in Building. III.—Internal Applications.** E. Herrmann (*Aluminium*, 1935, **17**, 423–440).—See *Met. Abs.*, this vol., pp. 123, 402. Examples are given of the use of aluminium and its alloys for the interior parts (doors, staircases, radiators, air conditioners, &c.) of buildings and for furnishings.—A. R. P.

**Structures in Aluminium.** E. T. Painton (*Structural Eng.*, 1935, **13**, [N.S.], 106–113; *Met. Ind.* (*Lond.*), 1935, **46**, 243–245, 303–306, 308; *Light Metal Rev.*, 1935, **1**, 334–352).—Paper read before the Scottish Branch of the Institution of Structural Engineers. Gives practical examples of the use of aluminium and its alloys in crane booms or jibs, fire-escape ladders, travelling cranes, conservatory framing, and bridges. The properties of structural components are described and their advantages compared with those of iron and steel.—L. A. O.

**Aluminium Beer Pipes.** A. Romund (*Aluminium*, 1935, **17**, 447–448).—Aluminium pipes have many advantages over tin pipes for handling beer, for not only are they stronger mechanically but they do not produce turbidity in the beer when left in contact with it for prolonged periods, they keep the beer at a more equable temperature, and have no effect on the appearance or flavour. Methods of joining and cleaning the pipes are briefly discussed. —A. R. P.

**Aluminium Alloy Sand- or Die-Castings (As Cast) (Suitable for Pistons, &c.).** —— ((*British*) *Air Min. Material Specification* No. **D.T.D. 238**, 1934, 3 pp.).—Covers the alloy generally known as "Hiduminium R.R. 53." See also *Met. Abs.*, 1934, **1**, 636.—S. G.

**Aluminium Alloy Die-Castings (Suitable for Pistons).** —— ((*British*) *Air Min. Material Specification* No. **D.T.D. 255**, 1934, 3 pp.).—Covers the alloy generally known as "Ceralumin C."—S. G.

**Aluminium Alloy Sand- or Die-Castings (Heat-Treated) (Not Suitable for Pistons).** —— ((*British*) *Air Min. Material Specification* No. **D.T.D. 243**, 1934, 3 pp.).—Covers the alloy generally known as "Hiduminium R.R. 53 B." See *Met. Abs.*, 1934, **1**, 636.—S. G.

**Aluminium Alloy Sand- or Die-Castings (As Cast) (Not Suitable for Pistons).** —— ((*British*) *Air Min. Material Specification* No. **D.T.D. 248**, 1934, 3 pp.).—Covers the alloy generally known as "Hiduminium R.R. 53 B." See *Met. Abs.*, 1934, **1**, 636.—S. G.

**Aluminium Alloy Sand- or Die-Castings (Not Suitable for Pistons).** —— ((*British*) *Air Min. Material Specification* No. **D.T.D. 250**, 1934, 3 pp.).—Covers the alloy generally known as "Ceralumin D."—S. G.

**Silicon–Aluminium Alloy Castings (Heat-Treated).** —— (*(British) Air Min. Material Specification* No. **D.T.D. 240**, 1934, 3 pp.).—Covers the alloy generally known as "Alpax Beta." See *Met. Abs.*, 1934, **1**, 636.—S. G.

**Silicon–Aluminium Alloy Castings (Fully Heat-Treated).** —— (*(British) Air Min. Material Specification* No. **D.T.D. 245**, 1934, 3 pp.).—Covers the alloy generally known as "Alpax Gamma."—S. G.

**Aluminium Alloy Forgings—Softened (Suitable for Crankcases).** —— (*(British) Air Min. Material Specification* No. **D.T.D. 246**, 1934, 3 pp.).—The sp. gr. of this alloy is not greater than 2·80. This specification covers the alloy generally known as "Hiduminium R.R. 56 NS."—S. G.

**Aluminium–Nickel–Silicon Brass Tubes (Annealed).** —— (*(British) Air Min. Material Specification* No. **D.T.D. 253**, 1934, 3 pp.).—Covers the alloy generally known as "Tungum."—S. G.

**[Use of Copper and Brass in Air-Conditioning Plant.]** —— (*Copper and Brass Research Assoc. Bull.*, 1935, (83), 1–16).—The issue is devoted to air-conditioning and the uses of copper and brass in air-conditioning plant.
—J. S. G. T.

**British Standard Specification for Medium-Hard Copper Strip, Bars, and Rods for Electrical Purposes.** —— (*Brit. Standards Inst.*, No. **518**, 1933, 1–12).—Electrolytic copper is required, of resistance not exceeding 0·0247504 ohm (97% of International Standard conductivity for annealed copper). The usual clauses dealing with dimensions, finish, &c., are included. Tensile, Brinell hardness, and bend tests are specified.—R. G.

**The History and Development of Copper and Its Use as Light-Gauge Tubes for Domestic Purposes.** S. F. Dunkley (*Gas Times Reprint*, **1935**, July 13, 16 pp.).—The properties and resistance to corrosion of copper are discussed and an illustrated account is given of various methods of making joints in light-gauge copper gas tubes.—A. R. P.

**Copper Stools for Ingot Metals.** —— (*Amer. Metal Market*, 1935, **42**, (153), 6).—A brief note. Extensive experiments have been conducted by the Batelle Memorial Institute into the feasibility of using copper "stools" in regular mill practice, and successful results have been obtained in casting low-carbon and rimming steels as ingots. The advantages are said to be longer mould life, fewer stickers, less stripping trouble, higher ingot yield, and an increase in the life of the stools. Thus far over 500,000 lb. of copper, either tough-pitch or the deoxidized grade of more than 95% electrical conductivity, are being used for this purpose.—L. A. O.

***Lubrication of Engines with Different Bearing Metals with Special Reference to Copper–Lead Alloys.** C. M. Larson (*Soc. Automotive Eng. Preprint*, **1934**, June, 10 pp.).—The effects of various new motor lubricating oils on Babbitt and copper–lead bearings and *vice-versa* have been investigated. The results show that certain bearing metals cause some mineral oils to deteriorate more readily than others and that high acidity of the oils cause more rapid wear of the bearing as well as more rapid decomposition of the lubricant. The coeff. of friction depends on the nature of the bearing and on the composition of the oil.—A. R. P.

**Bronze : Its Use as a Forming and Drawing Die Material.** J. D. Zaiser and G. K. Dreker (*Iron Age*, 1935, **136**, (4), 22–23, 78).—Discusses the applications of Ampco, a bronze of the copper–aluminium–iron type, having a Brinell hardness of up to 340, as a forming and drawing die material.—J. H. W.

**New Metals for Big Ends.** —— (*Motor*, 1935, **67**, (1728), 11).—A brief article discussing the possibility of using lead–bronze, or a copper–silver–cadmium alloy for the big-ends of motor-cars.—L. A. O.

**45 Per Cent. Nickel Alloy Sheets and Strips of 15 Tons 0·1 Per Cent. Proof Stress.** —— (*(British) Air Min. Material Specification* No. **D.T.D. 237**, 1934, 5 pp.).—S. G.

**45 Per Cent. Nickel Alloy Sheets and Strips of 40–50 Tons 0·1 Per Cent. Proof Stress.** —— ((*British*) *Air Min. Material Specification* No. D.T.D. 232, 1934, 5 pp.).—S. G.

**Keeping Electrical Contacts Clean.** B. W. Jones (*Maintenance Eng.*, 1933, 91, (1), 4–5; *Ceram. Abs.*, 1933, 12, 199).—If the electrical resistance between copper points builds up materially in use to overheat the electrical unit, the contacts must be cleaned regularly or some material other than copper must be used for the contacts. Silver is the one material that will give good results. It can usually be used in the form of a thin sheet brazed to the copper block. —S. G.

**White Metal Bearings.** —— ((*British*) *Air Min. Material Specification* No. D.T.D. 244, 1934, 1 pp.).—S. G.

**Metallic Gland Packing for High Pressures.** A. W. Jenner (*Mech. World*, 1935, 97, 327–328).—Certain industrial processes, particularly the newer ones, require gas compression to very high pressures. As some of these gases are poisonous or inflammable and all of them are valuable, adequate gland sealing is an important problem. The packing described and illustrated is of the labyrinth type, formed by nesting a number of " white-metal " rings of dished or conical shape. The basic principles of this type of packing are described. —F. J.

## XXII.—MISCELLANEOUS

(Continued from p. 452.)

**Organization of a Stores Department [in Aluminium Foundries].** E. Becker (*Aluminium*, 1935, 17, 442–447).—Card indexes and similar devices for the systematic operation of the department to prevent waste are described. —A. R. P.

**Some Results of Work at the Ufaley Nickel Plant.** V. V. Zakharov (*Zvetnye Metally* (*Non-Ferrous Metals*), 1934, (8), 70–91).—[In Russian.]—S. G.

**Centenary of Henry Wiggin and Co., Ltd.** —— (*Mech. World*, 1935, 97, 427).—A brief historical review of the founding of the firm of Henry Wiggin and Co. and of its progress until its recent association with the Mond Nickel Co., Ltd.—F. J.

**The Production of Nickel Alloys.** —— (*Mech. World*, 1935, 97, 534–536).—The processes carried out at the works of Messrs. Henry Wiggin and Co., Ltd., Birmingham, in the production of nickel and nickel alloys are illustrated and described.—F. J.

**Tin and Civilization.** D. J. Macnaughtan (*Amer. Metal Market*, 1935, 42, (43), 5, 7).—An address to the Institute of Metals Division of the American Institution of Mining and Metallurgical Engineers, in which the uses and development of tin during the last 3000 years are briefly reviewed.—A. R. P.

**Quality of Zinc Made in the U.S.S.R. and Introducing the New Standard [of Zinc Purity].** E. A. Preobrazhenskaya (*Zvetnye Metally* (*Non-Ferrous Metals*), 1934, (4), 87–92; *C. Abs.*, 1935, 29, 4304).—[In Russian.] Statistical and descriptive. A discussion of the inferiority of Russian zinc and the methods for improving its quality to meet the required standards.—S. G.

**Wanted—An Index for Measuring the Surface of a Mineral Powder.** A. J. Weinig (*Eng. and Min. J.*, 1935, 136, 336–342).—The determination of fineness of a powder should take cognizance of the amount of surface to weight. Methods are suggested with a mathematical explanation.—R. Gr.

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**The Work of the 14th Congress on Industrial Chemistry [Paris, Oct. 27, 1934].** Ch. Berthelot (*Rev. Mét.*, 1935, 32, 32–47).—A description of the Maison de Chimie and its organization, with brief statements of the work of the main departments on fuels, metallurgy, and industrial chemistry.—H. S.

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## XXIV.—BOOK REVIEWS

(Continued from pp. 411–412.)

**Principles of Phase Diagrams.** By J. S. Marsh. With a Foreword by John Johnston. (Alloys of Iron Research Monograph Series.) Med. 8vo. Pp. xv + 193, with 180 illustrations. 1935. New York: McGraw-Hill Book Co., Inc. ($3.30); London: McGraw-Hill Publishing Co., Ltd. (18*s.* net).

Generally speaking the phase rule may be taught to the student in two ways. It may be stated as an empirical law on which equilibrium diagrams must be based, and in this case the wise teacher will give a warning that in some cases the rule in its simple form may appear to break down, and that these finer details can be appreciated only by a knowledge of the underlying theory. Alternatively the theoretical basis may be taught, but in this case the teaching must be thorough. The present author has recognized the necessity for an understanding of the theoretical basis, and it is, therefore, with the greatest reluctance that we can only say that we do not think his book will be of much value on the theoretical side. A considerable amount of general thermodynamics is included, but in many cases the bearing of this on the phase rule is far from clear, and many of the real difficulties are ignored. The proof of the phase rule is confined to half a page so that many of the assumptions involved tend to be concealed, and this general failure to deal properly with equilibria between phases leads to much confusion. If the reader seeks advice about the components of a system he will find (pp. 9–10) that by a "chemical species is meant any chemical element or combination of elements of unvarying proportion, and each chemical species may be called a component of the system." Later (pp. 59 and 93) he will find it stated that phases of fixed composition are theoretically most improbable. This deduction, which would imply that only elements could be considered as components (since combinations of elements of unvarying proportion would be theoretically most improbable) is fallacious, and Gibbs himself considered cases where one component was absent from a phase, and distinguished in the clearest way between actual and possible components of phases. On

p. 50 the equilibrium of a partially dissociated compound is briefly dealt with, but the way in which the phase rule is affected by this phenomenon is nowhere clearly described although it is vital in many alloy systems, and directly affects the choice of components and the numerical form which the phase rule assumes.

Except for a very puzzling mistake or misprint in the description of the Roozeboom triangle the description of the ternary diagrams is clear and useful, and the general descriptive work is very helpful, although an apparent confusion between atomic and molecular percentages occurs on p. 11. A strong protest must, however, be entered against the nomenclature proposed for complex systems. New words may well be required, but the scientist does not receive a sufficient classical education to understand words derived from Greek. If words of "honest linguistic parentage" are to be invented they should be correct, and the author's "-chortic" should be "-chortastic," whilst "-steric" should be "-sterictic." We have submitted "-cygic" to two classical tutors who have failed to recognize it, so that we have some excuse for finding it too difficult. Incidentally if a word based on "to melt" is to be used it would appear that the solidus rather than the liquidus curve should be called a binary ditectic line in Fig. 42. We hope, therefore, that this system of nomenclature will be discarded completely, and that combinations of English words will be used so that their meaning is self-evident.

—W. HUME-ROTHERY.

**Aluminiumguss in Sand und Kokille.** Von Roland Irmann. Med. 8vo. Pp. viii + 119, with 70 illustrations. 1935. Leipzig: Akademische Verlagsgesellschaft m.b.H. (Kart., R.M. 6.80.)

In a foreword, the author explains that this book is based on a course of instruction in foundrywork which he has conducted, and that a profound consideration of theoretical principles is, therefore, avoided. Nevertheless, the treatment of the subject matter is on a sound scientific basis. . The raw materials of the aluminium foundry, the classification of aluminium alloys, and the sorting of secondary metal are first discussed. Melting practice is then considered, attention being paid to the economic and metallurgical aspects of the various types of furnaces available. A separate chapter deals with "castability" and the factors which influence this complex property. A long chapter follows on the technique of sand-casting; suitable alloys, sand, gating, and moulding practice being expounded. There is a similar chapter on the various forms of chill- and die-casting, and some shorter sections dealing with the finishing and surface treatment of castings, repairing imperfect castings, heat-treatment, and the effect of foundry technique on the mechanical properties of castings. Finally, the more important casting alloys and their properties are collected in a useful table.

This reasonably-priced little book may be highly recommended to all aluminium founders. A solitary criticism must, however, be made: the use of a solder, such as that suggested, for filling blowholes in aluminium castings, is to be deprecated.—H. W. G. HIGNETT.

**Technologie des Aluminiums und Seiner Leichtlegierungen.** Von Alfred v. Zeerleder. Zweite verbesserte Auflage. Med. 8vo. Pp. xi + 300, with 204 illustrations. 1935. Leipzig: Akademische Verlagsgesellschaft m.b.H. (Br., R.M. 12.60; geb., R.M. 14.)

It will cause no surprise that a second edition of Dr. von Zeerleder's book has been called for in little more than a year, for the esteem in which the author is held both in this country and abroad assured it a good reception, and the book, indeed, is excellent of its sort and fills a decided gap in the literature of aluminium.

At first sight the new edition differs but little from the old, for of the 11 additional pages, 9 are taken up in the very useful work of bringing the bibliographical section up to date. Careful examination, however, shows that the whole book has been carefully revised, and in addition to certain corrections made in the text, a large number of the illustrations have been redrawn or otherwise altered and improved. A few new drawings have been added. Two new pages have been added to the list of aluminium alloys with their German equivalents, compositions, and properties, but this section could do with still more revision; for instance, several British alloys are quoted which have long been obsolete.

Apart from these trivial imperfections, the volume contains little to criticize and much to admire; it is still the best book we know of in any language, showing lucidly and concisely what can be done with aluminium and how.—H. W. L. PHILLIPS.

**Chemical Analysis of Aluminium.** Methods Standardized and Developed by the Chemists of the Aluminum Company of America, under the Direction of H. V. Churchill and R. W. Bridges. Demy 8vo. Pp. 83, with 2 illustrations. 1935. New Kensington, Pa.: Aluminum Research Laboratories. (50 cents, post free.)

The appearance of this book, coming from so authoritative a source, will be welcomed by all workers in this field; also by others, for the ludicrous analytical results occasionally put forward, even by chemists of repute, show that this branch of chemistry is not without its pitfalls. In setting forth, in a form accessible to all, a series of methods which have been well tried out and proved reasonably satisfactory, the authors have done valuable work.

The book is not free from faults. In the section on the separation of aluminium it is not made sufficiently clear that in the analysis of the commercial metal aluminium is invariably determined by difference, there being no reliable method for doing so direct. Nor is it made clear that when estimating the impurities it is not always necessary to separate the aluminium.

Apart from this, the accounts given are reasonably clear and generally contrive a blending of details of procedure, with the reasons for them, without too much " cookery book " on the one hand or too much straying off into controversial discussions on the other. Nevertheless, the reader must bear in mind that the book is intended only to give the analytical methods developed by the staff of the Aluminum Co. of America and does not claim to be a text-book of aluminium analysis, hence the methods given are not exhaustive and in certain instances are not those followed by other large producers.

The book is well printed and produced and most reasonably priced; it may be heartily recommended.—H. W. L. Phillips.

**Lithium. Theoretical Studies and Practical Applications.** By Hans Osborg. With a Foreword by B. S. Hopkins. Med. 8vo. Pp. 68, with numerous illustrations. 1935. New York: Electrochemical Society. ($1.10.)

Although the metal lithium has been known for over 100 years it is only within the last decade or so that it has attained any industrial importance. From the metallurgist's point of view it is one of the most effective deoxidizers known and, in addition, is an effective scavenger for sulphur and nitrogen in alloys. Thus the use of lithium as a lithium–calcium alloy for deoxidizing copper and purifying nickel and Monel metal has resulted in remarkable improvements in the electrical and mechanical properties. Lithium has also found important uses in the preparation of bearing metals with a lead base, and of age-hardenable aluminium alloys, *e.g.* Scleron. Hence the appearance of this little book which gives an excellent *résumé* of the preparation, properties, and uses of the metal and its compounds, is to be welcomed, and its purpose will be fulfilled if it serves to stimulate further interest and research into the properties and uses of this remarkable metal. Intending workers in this field will find plenty of avenues of research indicated and a very full bibliography (over 130 references) if they desire more information on any particular point than is given in this booklet. Metallurgists will find the ten equilibrium diagrams given in the appendix of considerable interest; most are exceedingly complex and one, at least, requires a great deal of amplification.—A. R. Powell.

**Testing Precious Metals: Gold, Silver, Palladium, Platinum. Identifying—Buying—Selling.** By C. M. Hoke. Second Edition, Revised and Enlarged. Post 8vo. Pp. iv + 61. 1935. New York: Jewelers' Technical Advice Co., 22 Albany St. ($1.00.)

All who deal in precious metals should know how to distinguish the various metals and alloys from one another and from base metals of similar appearance; this is the little book they want. It describes in simple language the touchstone test and the methods of recognizing the presence of the various metals in the streaks produced in the test, and should therefore be of value to jewellers, pawnbrokers, and all who buy and sell gold, silver, and the precious metals. There is a useful appendix containing lists of terms and tables used in connection with the precious metals, equipment used in testing them, common alloys and their components, and reactions of the common metals to acids and the oxy-coal-gas flame.—A. R. Powell.

**A Comprehensive Treatise on Inorganic and Theoretical Chemistry.** Volume XIV.—Fe (Part III), Co. By J. W. Mellor. Med. 8vo. Pp. viii + 892, with 277 illustrations. 1935. London: Longmans, Green & Co. (63*s.* net.)

The present volume of Mellor's treatise completes the treatment of iron and also deals with that of cobalt.

About one half of the volume (418 pages) is devoted to the chemistry of the salts of iron, including the halides, sulphides, sulphates, carbonates, nitrates, and phosphates. These are considered in the fullest possible manner and many phase diagrams are included for the complex salts.

The remainder of the volume is devoted to the consideration of the chemistry of cobalt. Here the treatment follows the lines adopted in the earlier volumes. The history of the discovery and development of the chemistry of the metal is treated first, and this is followed by an account of the occurrence of the metal in various parts of the earth together with a list of some 70 cobalt-containing minerals and their distribution. The extraction of cobalt by furnace and leaching processes is next described and, following this, the separation of cobalt from nickel is considered, some 31 methods for the separation being detailed. The next section deals with the preparation of metallic cobalt, and under this heading the preparation of malleable cobalt, single crystals of cobalt, pulverulent cobalt, pyrophoric cobalt, cobalt mirrors, filaments, and colloidal cobalt is outlined. The succeeding 40 pages contain an account of the physical properties of the metal: here are considered with very full numerical data, the crystals and X-radiograms, allotropic transformations, specific gravity, atomic and ionic radii, hardness and tensile strength, compressive strength, elastic modulus, torsion modulus, compressibility, thermal expansion and conductivity, specific and atomic heat, melting and transition points, thermal properties (heat of solution, oxidation, and transformation, entropy), optical properties (index of refraction, absorption coefficient, reflecting power, polarization angle, refractive power and spectra), electrical properties (resistance, electropotential, tribo-electricity, ionic mobility, deposition potential, energy of ionisation, overvoltage), properties of the passive state, and magnetic properties. Fourteen pages are devoted to the chemical properties of the metal, here the behaviour of metallic cobalt with a large number of elements and compounds is detailed. A short discussion on the physiological action of cobalt salts and the uses of the metal and its derivatives completes the section. A discussion on the atomic weight, valency, co-ordination number, isotopes, and the structure of the atom comes next and is followed by a description of the intermetallic compounds and alloys of cobalt with copper, silver, gold, calcium, beryllium, magnesium, zinc, cadmium, mercury, boron, aluminium, thallium, titanium, tin, lead, nickel, molybdenum, tungsten, iron, and manganese, together with many ternary alloys; phase-rule diagrams accompany the description of many of the alloys. The compounds of cobalt come next: these are treated in the order, oxides, hydroxides, fluorides, chlorides, bromides, iodides, sulphides, sulphates, carbonates, nitrates, and phosphates. Complex salts, double compounds, and ammines are included and described with the individual salts. A very large number of references accompany each section of the volume.

This volume, like its predecessors, is written in a clear and convenient manner. It is very thorough and complete and it brings together in an easily consultable form the salient facts and data of the inorganic and physical chemistry of iron and cobalt. The work will be of the greatest use for reference purposes and should therefore be available to all chemists. It is a volume which may be warmly recommended.—JAMES F. SPENCER.

**Neuzeitliche galvanische Metallveredlung. Wege und Winke zur Erzielung hochwertiger Metallauflagen und Arbeitsmethoden der Heutigen Galvanotechnik.** Von K. Altmannsberger. Med. 8vo. Pp. 160, with 11 illustrations. 1935. Coburg: Müller und Schmidt. (Kart., R.M. 5.)

This book is not intended to cover the whole field of electroplating, like so many of the recent publications, but aims rather at dealing with some of the modern developments such as chromium plating and nickel plating of die-castings. The author makes an effort to emphasize new processes, such as the deposition of chromium from buffered chloride solutions, which it is claimed have a cathode efficiency of 85–95%. Whilst paying special attention to the application of recent scientific studies, the book will doubtless provoke criticism from others engaged in this field of work, but for this very reason it deserves to be brought to their attention.

**Traité de Galvanoplastie.** Par J. Salauze. Roy. 8vo. Pp. xv + 679, with 200 illustrations. 1935. Paris: Dunod. (Relié, 128 francs; broché, 118 francs.)

Both the theory and practice of electro-deposition are covered by this well-printed treatise, which offers a clear exposition of the subject characteristic of the French language in which it is written. The modern advances in electroplating owe much to the attention which is now being given to the underlying scientific principles. The introductory chapters on the basic principles of electro-chemistry are therefore fully justified and the author follows them by others covering the general application of these principles to plating processes, the preparation of work, plant and other equipment, and the testing of deposits. The remaining half of the book is devoted to detailed treatment of the practical applications to individual metal depositions. Good illustrations, including many photomicrographs, and a reasonable number of references to original papers add to the value of the treatise.

**Korrosion IV.** Bericht über die Korrosionstagung 1934, am 20 November 1934, in Düsseldorf. Veranstaltet von Verein deutscher Eisenhüttenleute, Verein deutscher Chemiker, Deutsche Gesellschaft für Metallkunde und Verein deutscher Ingenieure. Demy 8vo. Pp. iv + 76, with 39 illustrations. 1935. Berlin: V.D.I.-Verlag G.m.b.H. (R.M. 5.)

The 1934 meeting of the German corrosion research committee, of which this book is a record, was concerned almost entirely with the corrosion of ferrous metals in water pipes, gas pipes, and heating plant. Only one or two brief references to work on non-ferrous metals occur in a few of the papers. The book contains 10 papers, some of which are purely of a review nature, and brief discussions on them. Gas, water, and heating engineers should find something of value and interest in the papers especially those dealing with protection from corrosion.—A. R. POWELL.

**Chemical Industries.** A Compilation of the Data and Information Essential to the Conduct of All Process Industries, *i.e.* Process of Manufacture entailing Chemical or Other Scientific Formulæ with a List of Materials, Plant Equipment, and Raw Products Necessary in These Trades. Edited by D. M. Newitt. 4to. Pp. 361 + lxxxix, illustrated. 1935. London: Leonard Hill, Ltd., 17 Stratford Place, W.1. (10*s.*)

This volume represents the 10th edition of the Chemical Engineering and Chemical Catalogue which has already established itself as an indispensable guide to the British chemical industry and a valuable reference book to all engaged in the chemical industries. The change of title is accompanied by a radical change in the arrangement of the subject-matter, which still further enhances the value of the book as a work of reference. Instead of grouping together in alphabetical order the various firms using publicity space and following on with all the information data, indexes, bibliography, &c., the whole of the subject-matter is divided into 12 sections dealing, respectively, with power plant; water treatment; chemical engineering and factory data; size reduction, mixing, and blending; separating and grading of materials; handling, conveying, and transportation of materials; air conditioning; instruments and laboratory apparatus; chemicals; fine chemicals; indexes; publishers' announcements and bibliography. Each of the first 10 sections begins with several pages of scientific data and information, and this is followed by advertisements of firms supplying materials appropriate to the particular industry or industries, so that each section is a complete reference book in itself. The slip method of indexing the sections permits of any particular point being turned up in a few seconds.

It is encouraging to note that the number of firms taking space has jumped from 82 to nearly 200, and the number of advertising pages has correspondingly increased. The scientific sections have been considerably revised and amplified, and the errors and misprints found in earlier editions have been almost completely eliminated. Nevertheless we hope to see these sections still further improved in succeeding editions. The publishers are to be commended on their enterprise in increasing the utility and scope of the work and it is now up to firms who have not yet taken this method of bringing their products and services before the chemical industry to book space for the next edition to give the publishers an opportunity of making the book a real reflex of the vigorous life of the British chemical industry.—A. R. Powell.

**Taschenbuch für die Lichtbogenschweissung.** Von Karl Meller. Cr. 8vo. Pp. viii + 189, with 83 illustrations. 1935. Leipzig: S. Hirzel. (Geb., R.M. 5.)

Meller's "Handbuch," which was reviewed in *J. Inst. Metals*, 1933, **53**, 542, is a standard work on arc-welding. This little pocket-book is a condensed and simplified version of the larger work, intended especially for welding operators and foremen. It is, however, a remarkably concise and clear exposition of arc-welding principles which cannot fail to be of value to all who are interested in the subject. The proportion of space devoted to non-ferrous metals (10 pages) is much higher than in the larger work—which is as it should be.

Clear printing on good paper, and a strong binding, complete excellent value for money.
—H. W. G. Hignett.

**Unsere Verbrauchsgüter und ihre Herstellung. Ein technologisches Lesebuch.** Von Kurt W. Geisler. Med. 8vo. Pp. vi + 177, with 117 illustrations. 1935. Berlin: V.D.I.-Verlag G.m.b.H. (Br., R.M. 3.90; V.D.I.-Mitgl., R.M. 3.50.)

This remarkable little book covers, in the space of 172 pages, almost the whole field of industrial chemistry. The covering is naturally thin, but it is sufficient to hold together the basic facts of the chemistry of metals, glass, ceramics, building materials, cements, wood, paper, textiles, artificial silk, rubber, leather, linoleum, plastics, fuels, foods, dyes, oils, fats, waxes, acids, alkalis, and explosives. Clever diagrams make the descriptions easy to follow and to remember. A few books of this kind in English would solve our problems of technical education; students would find examinations easy, and professors would be able to devote more time to research work.—H. W. G. Hignett.

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