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1935, Vol. LVII.

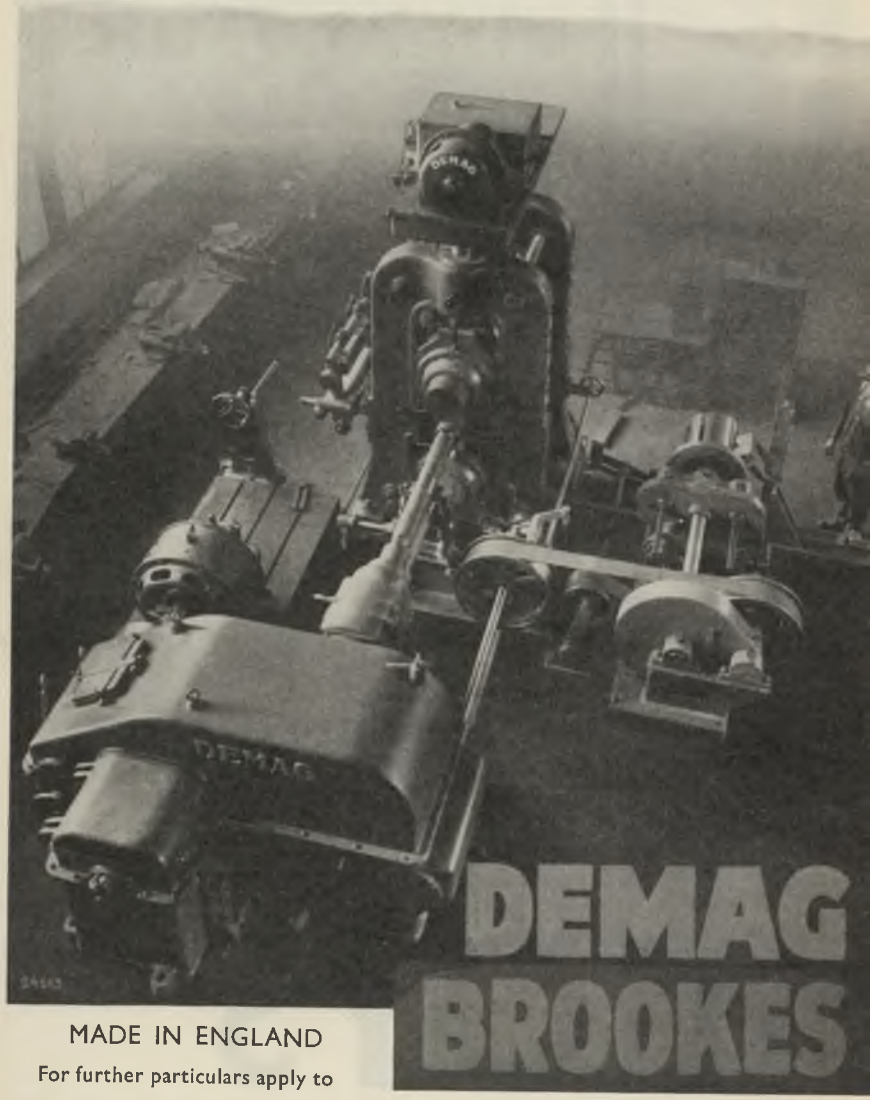
Vol. 2. **Part 6.**

The Monthly Journal of the
INSTITUTE OF METALS

and

METALLURGICAL ABSTRACTS

JUNE, 1935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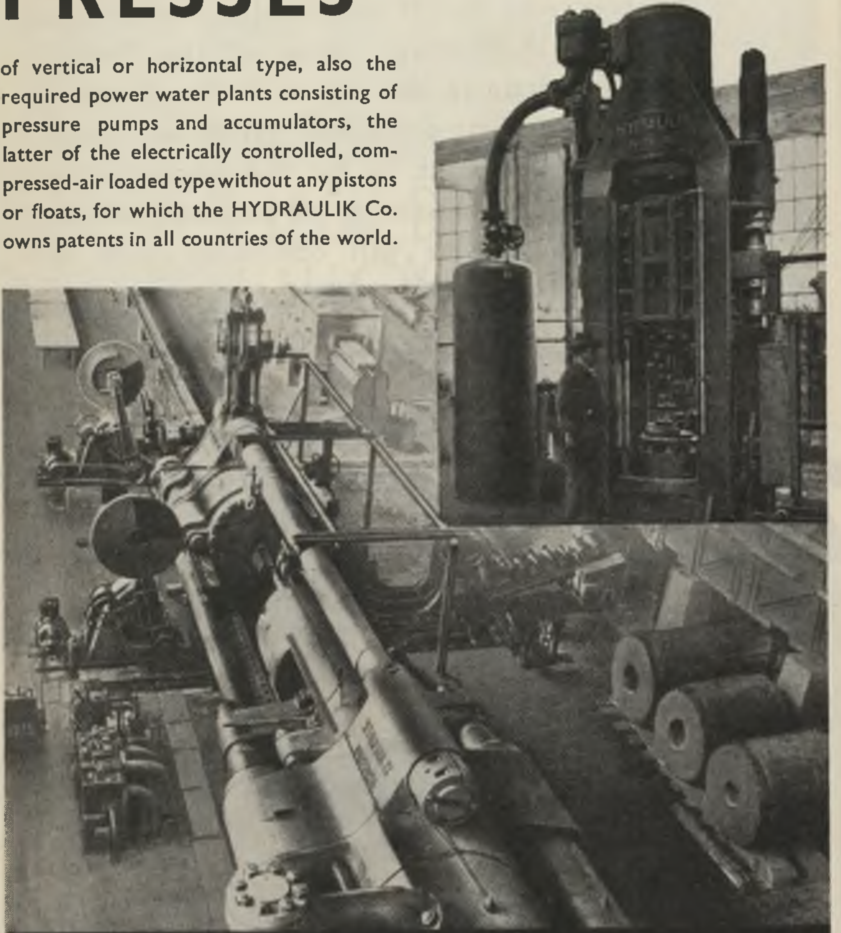
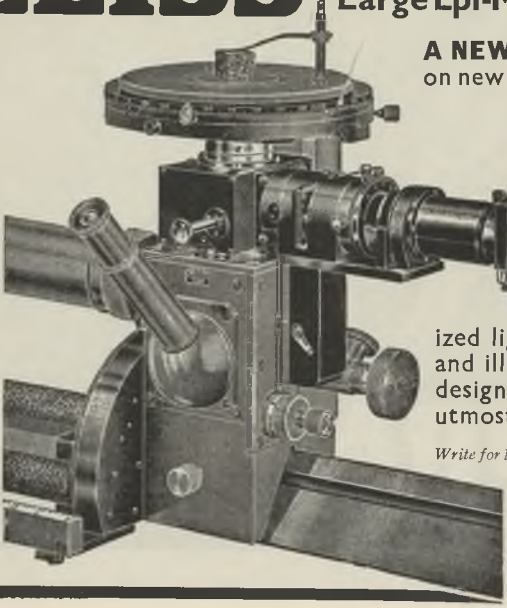
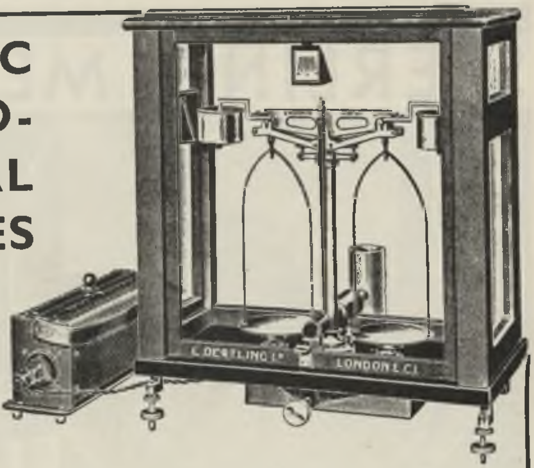


a new service to members

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 will commence with the Autumn Meeting, 1935, papers.

Annual charge 5s., post free.

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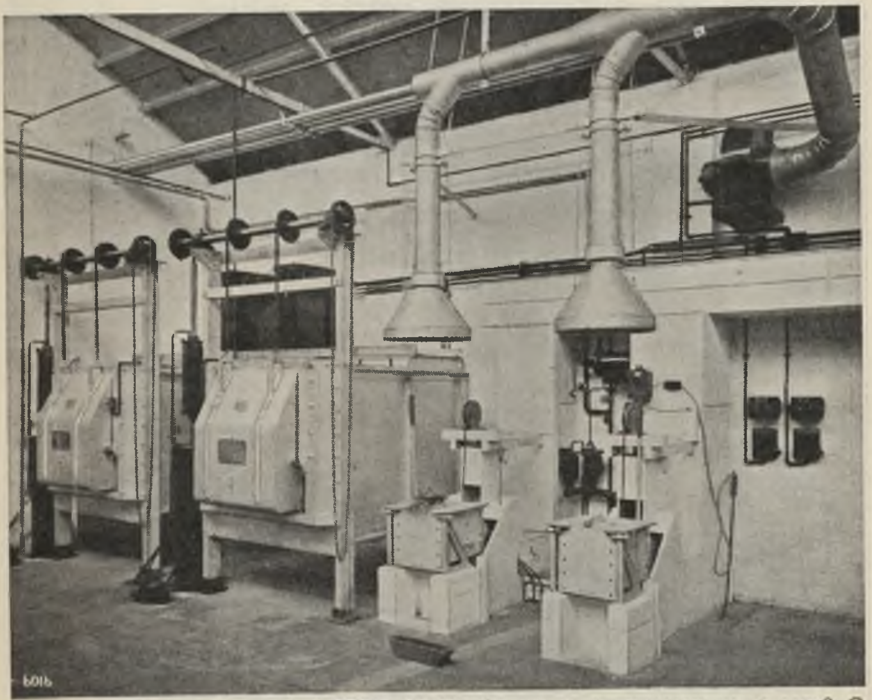
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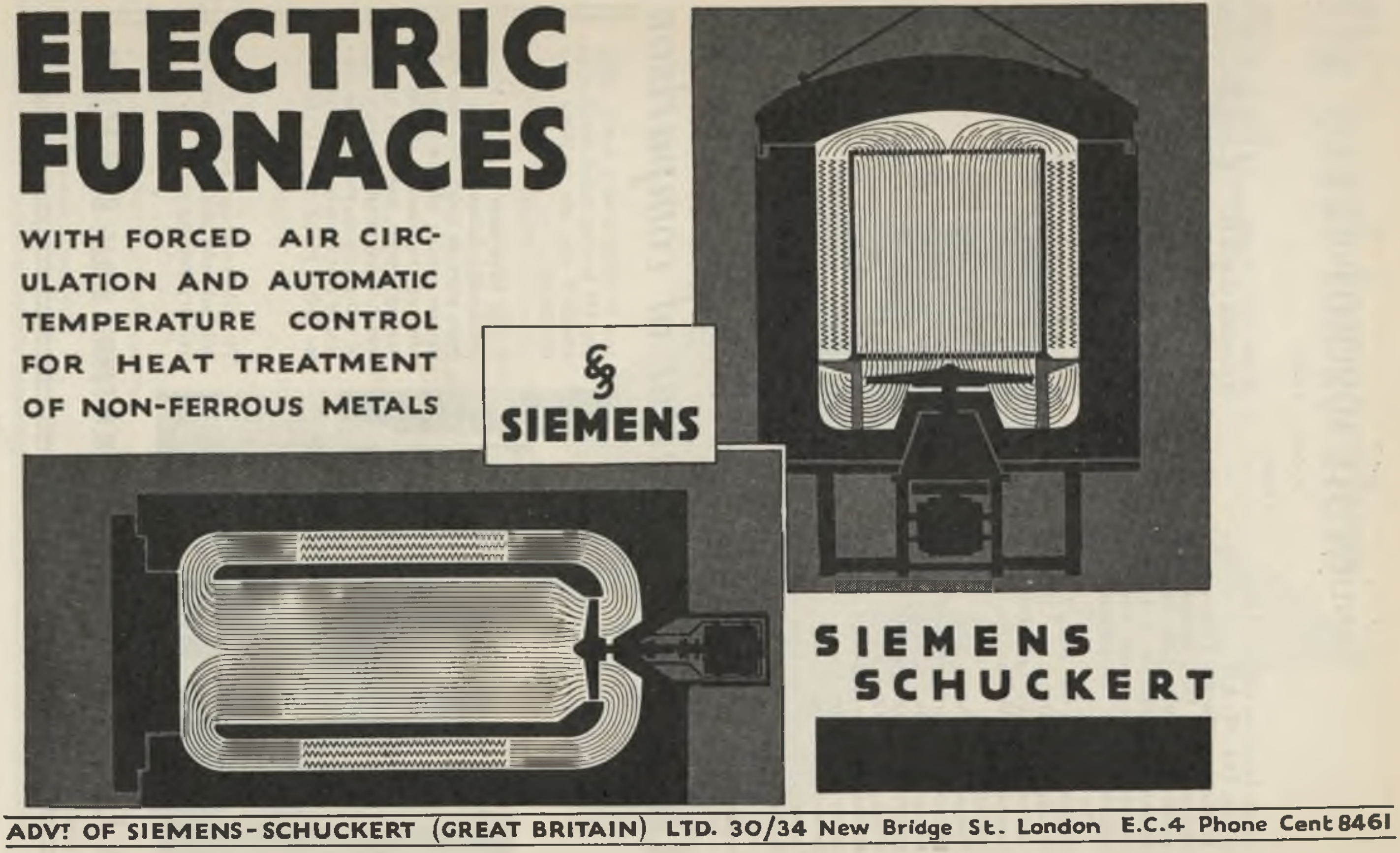

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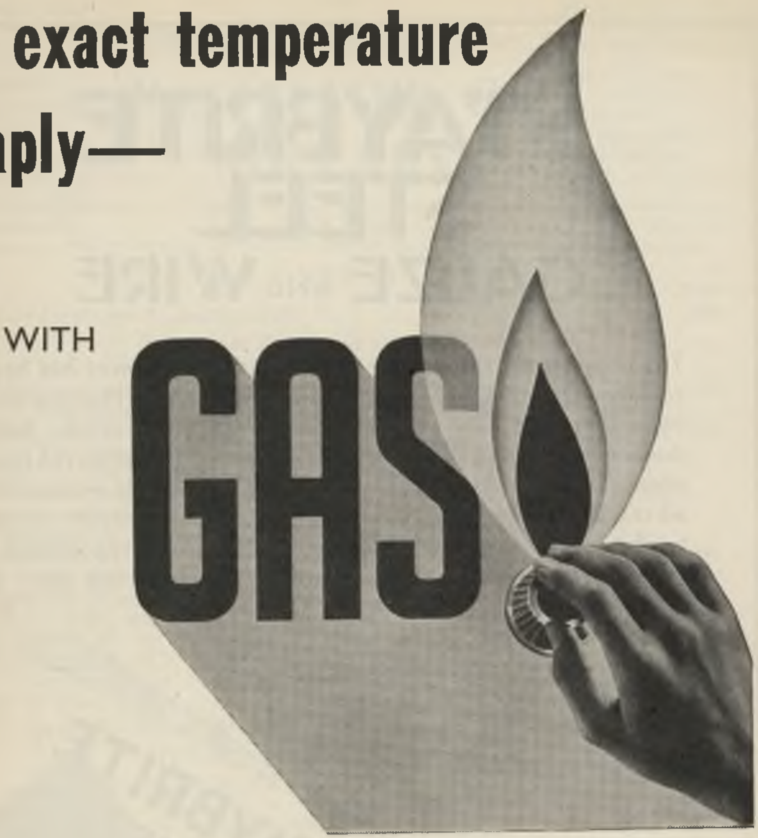
JUNE, 1935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Volume 2 **JUNE, 1935** **Part 6**

CONTENTS

Papers to be Read at the Autumn Meeting :

METALLURGICAL ABSTRACTS

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

Newcastle-upon-Tyne Meeting. Programme for September 9–12.

The Twenty-Seventh Annual Autumn Meeting of the Institute will be held in Newcastle-upon-Tyne from Monday, September 9, to Thursday, September 12. In the evening of the first day Dr. H. W. Brownsdon, M.Sc., will deliver the Fourteenth Autumn Lecture, in which he will deal with quality factors in metal melting. After the Lecture, which will be discussed, there will be an informal gathering of members in the King's Hall, Armstrong College.

Armstrong College will be the centre of the meeting, and here, on Tuesday morning, September 10, a Civic Welcome will be given to the Institute by the Lord Mayor of Newcastle-upon-Tyne. Afterwards there will be a General Meeting for the presentation and discussion of papers in the New Mining Lecture Theatre, lasting until 12.30 p.m. In the afternoon visits will be paid to the following works :

Sir W. G. Armstrong Whitworth and Company, Ltd.
Dunston Power Station of North Eastern Electric Supply Company, Ltd.
Vickers-Armstrongs, Ltd.

In the evening there will be a Civic Reception and Dance by invitation of the Lord Mayor and Lady Mayoress of Newcastle-upon-Tyne. . On Wednesday, September 11, the morning will be devoted to the reading and discussion of papers at Armstrong College, and in the afternoon the following works will be visited :

C. A. Parsons and Company, Ltd.
A. Reyrolle and Company, Ltd.
North-Eastern Marine Engineering Company, Ltd.

In the evening members and their ladies will be entertained to Dinner by the Local Reception Committee. The concluding day of the meeting, Thursday, September 12, will be devoted to a whole-day motor excursion to Borcovicus and the Roman Wall, the party returning to Newcastle-upon-Tyne at approximately 6 p.m.

Arrangements are being made for the entertainment of ladies accompanying members to Newcastle-upon-Tyne. Inexpensive hostel accommodation will be available.

A detailed programme of the meeting, including a list of papers to be presented, and a Reply Form, will be sent to all members early in July. It is hoped that a large number of members will desire to participate in the hospitality that is being so kindly offered by the members in Newcastle-upon-Tyne, where no meeting of the Institute has been held since 1911.

Membership.

As members only are permitted to take part in the social functions and works' visits connected with the Newcastle-upon-Tyne meeting, an election is being arranged on July 11 for the benefit of those who desire to participate in the Autumn Meeting, but are not yet members of the Institute. As this election occurs at the beginning of a new financial year, the Council expects that there will be many membership applications to be considered at its meeting. The Secretary will be glad to forward particulars of the Institute, and, if desired, a specimen copy of the *Monthly Journal*, to any potential member, on receipt of name and address.

Loose Copies of Papers.

For the convenience of members attending the Institute's General Meetings, the Council has authorized the supply of special loose prints of the papers, which will be overprinted from the *Monthly Journal*. Orders—which must be for one whole year in advance—should be sent to the Secretary *without delay*. The annual charge is 5*s*. post free. The service commences with the Autumn Meeting, 1935, papers (Nos. 698 *et seq*.).

Institute News and Announcements

Loyal Address to H.M. King George V.

The following is the text of a Loyal Address of Congratulation submitted to H.M. the King on the occasion of the Silver Jubilee of his Accession to the Throne by the fifteen undermentioned Engineering Institutions whose Corporate Seals were affixed :

To the King's Most Excellent Majesty.

May it please Your Majesty,

We, as representatives of, and on behalf of, the principal Engineering Institutions and Societies in the United Kingdom of Great Britain and Northern Ireland, humbly beg leave to convey to Your Majesty the Loyal Greetings and Felicitations of our 67,000 Members upon the attainment of the 25th Anniversary of Your Majesty's Accession to the Throne.

Through Your Majesty's wise and beneficent rule and encouragement of Science in Industry, the utilization of the great sources of power in Nature has been advanced to an extent unprecedented in the history of mankind, thus contributing in no small degree to the welfare of all Your Majesty's subjects.

We desire to express our deep loyalty and devotion and our high appreciation of the work Your Majesty has done towards the promotion of the Science and Art of Engineering in its bearing on the well-being of the Empire.

We pray that Your Majesty may live long to enjoy good health and happiness.

The Institution of Civil Engineers (1818).
The Institution of Mechanical Engineers (1847).
The Institution of Naval Architects (1860).
The Institution of Gas Engineers (1863).
The Iron and Steel Institute (1869).
The Institution of Electrical Engineers (1871).
The Institution of Municipal and County Engineers (1873).
The Institute of Marine Engineers (1889).
The Institution of Mining Engineers (1889).
The Institution of Mining and Metallurgy (1892).
The Institution of Water Engineers (1896).
The Institution of Automobile Engineers (1906).
The Institute of Metals (1908).
The Institution of Structural Engineers (1908).
The Institution of Chemical Engineers (1922).

The Seal of the Institute of Metals was attested by the President, Dr. H. Moore, and the Secretary, Mr. G. Shaw Scott.

The following is the text of a reply to the Address of Congratulation :

Home Office,
Whitehall,
17 *May*, 1935.

Sir,

I am directed by the Secretary of State to inform you that he has been commanded by the King to convey His Majesty's thanks to the fifteen Engineering Institutions and Societies for their Address of Congratulation presented to His Majesty on the completion of the Twenty-Fifth Year of His Reign. His Majesty much appreciates this expression of loyalty and devotion in which the President, Officers and Members of the Institute of Metals have joined,

The Secretary,
The Institute of Metals,
36 Victoria Street,
S.W.1.

I am,
Sir,
Your obedient Servant,
(*signed*) H. A. Strutt.

The Institute of Metals and the Manchester Metallurgical Society.

The Council has entered into an arrangement with the Council of the Manchester Metallurgical Society whereby all members of the Institute of Metals resident in Lancashire and Cheshire shall have the privilege of joining the society (subject to the approval of its Committee), without payment of further subscription, the Institute of Metals paying the current subscription for each such member. The new arrangement will come into force at the beginning of the session 1935–1936.

The programme of the Manchester Metallurgical Society for the coming session will appear in the Institute's programme along with the programmes of the six Local Sections of the Institute to be issued in September next. Synopses of papers to be read before the Manchester Metallurgical Society will appear in the *Monthly Journal* throughout the session.

A member of the Council of the Institute of Metals will be nominated by the Council to serve on the Committee of the Manchester Metallurgical Society, and a representative of the society will be appointed on the Local Sections Committee of the Institute.

Shipping, Engineering, and Machinery Exhibition.

The Thirteenth Shipping, Engineering, and Machinery Exhibition, incorporating the Foundry Trades Exhibition, is to be held at Olympia, London, W.14, from September 12 to 28, 1935. As in previous years the organizers of the Exhibition, Messrs. F. W. Bridges & Sons, Ltd., have kindly invited members of the Institute of Metals to visit the Exhibition and to take tea together. The visit has been arranged for Thursday, September 19. Overseas Members who have not received cards of invitation for "Institute of Metals Day" before leaving for England, should apply to the Secretary of the Institute of Metals, 36 Victoria Street, London, S.W.1.

Local Sections.

The annual meeting of the Local Sections Committee was held at the offices of the Institute on May 8, when the reports of the several sections for the past session were presented and programmes for the coming session were submitted. The reports showed that the various sections had completed a useful year's work. There is every indication that a further period of activity is in prospect for next session. The following are the officers of the Local Sections for the session 1935–1936 :

Birmingham Section.

Chairman : Maurice Cook, M.Sc., Ph.D.
Hon Secretary : J. W. Jenkin, B.Sc., Ph.D.
Hon. Treasurer : G. Bill-Gozzard.

London Section.

Chairman : C. J. Smithells, M.C., D.Sc.
Hon. Secretary : J. McNeil, A.R.T.C.
Hon. Treasurer : H. J. Gough, M.B.E., D.Sc., Ph.D., F.R.S.

North-East Coast Section.

Chairman : S. G. Homfray, B.A.
Hon. Secretary : C. E. Pearson, M.Met.
Hon. Treasurer : O. Kennedy.

Scottish Section.

Chairman : J. W. Donaldson, D.Sc.
Hon. Secretary : Harold Bull.
Hon. Treasurer : M. Brownlie.

Sheffield Section.

Chairman : Kenneth Gray.
Hon. Secretary : H. P. Gadsby, Assoc.Met.
Hon. Treasurer : Frank Mason.

Swansea Section.

Chairman : Roosevelt Griffiths, M.Sc.
Hon. Secretary and Treasurer : A. E. Smith, Ph.D.

Committees of the Institute.

The following is a list of the Committees appointed by the Council for the year 1935–1936 :

Finance and General Purposes Committee.

Charles, Lieut.-General Sir Ronald.
Clarke, H. W.
Dixon, Engineer Vice-Admiral Sir Robert (*Chair*).
Lancaster, H. C.
Morcom, E. L. (*Vice-Chairman*).
Mundey, A. H.
Preston, The Hon. R. M.
Smout, A. J. G.
Turner, Professor T.

Ex-officio :

The President.
Ex-President.
Hon. Treasurer.
Chairman, Publication Committee.

Local Sections Committee.

Andrew, Professor J. H.
Barclay, W. R. (*Chair*).
Brownsdon, Dr. H. W.
Gray, Kenneth.
Greer, H. H. A.
Griffiths, W. T.
Hanson, Professor D.
Haughton, Dr. J. L.
Mundey, A. H.
Thompson, Professor F. C.

Ex-officio :

The President.
Ex-President.
Hon. Treasurer.
Local Reception Committee's Representative.
Chairman and Secretary of :
  Birmingham Local Section.
  London Local Section.
  North-East Coast Local Section.
  Scottish Local Section.
  Sheffield Local Section.
  Swansea Local Section.

Meetings Committee.

Andrew, Professor J. H.
Barclay, W. R.
Brownsdon, Dr. H. W. (*Chair*).
Gwyer, Dr. A. G. C.
Hanson, Professor D.
Haughton, Dr. J. L.
Weeks, H. B.

Ex-officio :

The President.
Chairman, Publication Committee.

Membership Committee.

Andrew, Professor J. H.
Barclay, W. R. (*Chair*).
Brown, Engineer Vice-Admiral Sir Harold A.
Charles, Lieut.-General Sir Ronald.
Genders, Dr. R.
Gray, Kenneth.
Lancaster, H. C.
Morcom, E. L.
Mundey, A. H.
Seligman, Dr. R.
Weeks, H. B.

Ex-officio :

The President.
Local Sections' Committee Representative.

Publication Committee.

Brownsdon, Dr. H. W.
Desch, Dr. C. H.
Genders, Dr. R.
Gwyer, Dr. A. G. C.
Hanson, Professor D.
Haughton, Dr. J. L.
Hutton, Professor R. S.
Murphy, A. J.
Seligman, Dr. R. (*Chair*).
Smith, Dr. S. W.
Smithells, Dr. C. J.
Sutton, H.
Thompson, Professor F. C.
Turner, Professor T.

Ex-officio :

The President.
Chairman, Finance and General Purposes Committee.

PERSONAL NOTES

Professor Dr.-Ing. G. Sachs, Director of the Metallurgical Laboratory of the Metallgesellschaft A.G., has, from April 1, become director of the Forschungsabteilung der Dürener Metallwerke A.G. He will also remain associated with the Metallgesellschaft A.G. in an advisory capacity.

Annual Subscriptions, 1935–1936.

Members and student members are reminded that their annual subscriptions, of £3 3*s*. and £1 1*s*., respectively, become payable, according to the Rules, "*in advance on July* 1." If they will be good enough, therefore, to send their remittances to the Secretary, the Institute will be saved the expense of forwarding "reminders," which cost more than £50 a year and involve much clerical labour that might be more usefully employed. Delay in the payment of subscriptions is not only unnecessarily costly to the Institute, but it also prevents members from receiving their *Monthly Journals* promptly. The Institute's publications are not sent to members whose subscriptions are in arrear.

The use of Banker's Orders for the payment of subscriptions is strongly urged on members by the Finance Committee. Already more than 500 members use these orders, with resulting appreciable saving in time and money to themselves and to the Institute. Printed Banker's Order forms are available, and will be forwarded to any member by the Secretary.

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.

ADVANCE SUBSCRIPTION PRICE

Two Volumes: Names and Subjects	25s. post free
One Volume: Names or Subjects	15s. „ „

NOTE: If sufficient orders are secured it is hoped to publish the Names Index at the end of the present year.

METAL LOSSES IN MELTING BRASS AND OTHER COPPER ALLOYS.*

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

Synopsis.

A study has been made of the metal losses which occur when such alloys as gilding metals, brasses, and cupro–nickel are melted in crucibles in coke-fired pit furnaces, and for this purpose figures have been obtained both from carefully controlled trials and from production runs, involving the melting of considerable quantities of material under different conditions.

Observations have also been made on the metal losses occurring in melting brasses of different compositions under various conditions of fluxing in Ajax–Wyatt induction furnaces, and large-scale trials covering considerable periods and involving large tonnages of metal have been made. The loss is largely due to oxidation and the results of various methods of reducing the loss, such as varying the nature and amount of flux, the use of charcoal, coke, anthracite, and coal-gas, which have been tried are discussed.

Although one of the primary objects of industrial metal melting is to produce material satisfactory in quality, there are, nevertheless, other considerations the importance of which is vital to the whole economics of production. Not least of these is the loss which, in varying degree, occurs in melting. It will be appreciated readily that the magnitude of the loss may vary considerably for an alloy of any given kind or composition, for it is affected by many factors, such as method of melting, type of furnace used, temperature of heating, precautions for the prevention of oxidation, methods of recovery, to mention but a few. Again, with a given method of melting and production procedure the loss varies with the compositions of the alloys, those containing readily oxidizable and volatile constituents generally showing higher loss figures than those which do not contain alloying elements so readily lost. Although the subject is a very wide one, the present paper deals only with a few typical non-ferrous metals and alloys and for the most part with only two forms of melting, crucible melting in coke-fired pit furnaces and electric melting in Ajax–Wyatt induction furnaces. Its main purpose is

* Manuscript received April 4, 1935.

† Assistant Research Manager, I.C.I. Metals, Ltd., Witton, Birmingham.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LVII, 1935. Reference should accordingly be as follows: *J. Inst. Metals*, 1935, 57 (Advance copy).

to present and discuss very briefly the results which have been obtained from records kept over a considerable number of years and from experiments which have from time to time been made. Some of the experiments have been carried out on a very large scale and during the period in which records have been taken many thousands of tons of metal have been melted. A correspondingly immense amount of data has thus been available for study. No attempt whatever has been made to reproduce this information, although in the preparation of the paper it has been examined very carefully and critically. Observations have been made in a number of different casting shops in different works, and in this way a fair range of varying procedures which often depend on the idiosyncrasies of individual casters themselves, are covered. Most of the metal melted has been cast into ingots and billets of all sorts of shapes and sizes for subsequent fabrication by hot- and cold-rolling, extrusion, and other methods. Mention of the losses which occur in brass melting are very numerous in papers dealing with melting furnaces and foundry technique and references to a few of the publications in which loss values are quoted are given at the end of the paper.

It may be mentioned in passing that in the fabrication of ingots and billets into strip, sheet, rod, tube, and wire the only other losses of appreciable magnitude which can, together with such losses as occur in melting and casting, be classified as metallurgical, are those which occur as a result of annealing and cleaning. The extent of these losses, like the losses which occur in melting, is determined primarily by the amount of oxidation which takes place, and it is affected by a number of factors such as the composition of the metal, number of annealings to which it is subject, the temperature of annealing, type of furnace and fuel used, extent to which precautions are taken to minimize oxidation, number of pickling operations, nature and temperature of the pickling solutions, &c. If adequate annealing can be accomplished, as in some cases it can, without appreciable alteration of the quality of the rolled surface and finish, then no metal loss occurs in this operation. Observations on the losses occurring in the cold-rolling of comparatively small ingots of gilding metal, cupro–nickel, and 65 : 35 brass into strip in substantially similar conditions showed that the loss was greatest in the most readily oxidizable metal. In the case of brass two separate series of observations yielded loss figures of 0·43 and 0·61 per cent., whilst for cupro–nickel and gilding metal values of 0·71 and 1·02 per cent., respectively, were obtained. These figures relate only to a particular sequence of manufacturing operations and annealing and pickling conditions, but they serve to illustrate the effect of the composition of the metal on the extent of the loss.

CRUCIBLE MELTING.

In crucible melting of metals, which up to quite recently was by far the most common form in the non-ferrous industry, heats of metal are used varying in size usually up to about, and generally not much more than, 200 lb. in weight. This form of metal melting—that is, in crucibles in coke-, gas- or oil-fired furnaces—is still quite widely used, particularly where alloys of different compositions are produced in comparatively small quantities. In considering metal loss the figure dealt with is the difference figure between the weight of metal supplied to the metal caster or melter and the weight of the ingots, billets, &c., returned from that metal. It is true of course that the difference between these two weights is not wholly loss, for in most plants a substantial proportion of the metal lost may be ultimately recovered. In metal melting it is desired, in addition to producing metal of satisfactory quality, to obtain the maximum yield in the form of castings from the metal melted. There are various methods in use for treating skimmings, ashes, and other residues in connection with metal melting, but a consideration of these or of other aspects of recovery of metal lost in melting or casting is outside the scope of the present paper.

BRASS MELTING.

Commercial brasses range in composition roughly from 80 to 55 per cent. of copper, and many contain varying quantities of other elements deliberately added or accidentally occurring. In the production of high-grade brasses it is common practice for 50 per cent. or more of the metal charged to be new, and all the scrap used is of known quality and generally clean and in large pieces. On the other hand, with lower-grade brasses, which more commonly are the brasses of low copper content, although it must not be forgotten that many of the brasses of low copper content, *i.e.* 55–63 per cent. copper, are carefully prepared from pure and selected materials only, scrap of a more varied nature is often used. This may contain appreciable amounts of non-metallic matter, which, since it is weighed out as metal to the casting shops, is reckoned as metal loss. Thus the higher loss which may be noted in the results of brass billets for extrusion compared with that for ingots of say brass for cold-rolling is not due wholly to the higher zinc content of the former, although this is of course an important factor. Apart from differences in melting methods, which may very considerably influence the loss, the casting technique may also play a not inconsiderable part in the losses. Thus it is that in brass melting the loss may vary according to circumstances and conditions, from a fraction of 1 per cent. to several per cent.

In the crucible melting of brass in coke-fired pit furnaces, analysis shows that the largest sources of metal loss are the skimmings (which is the dross removed from the surface of the molten metal before casting), splashings, ashes, pot scrapings, and the stack loss.

In the various studies which have been made of the distribution of loss in metal melting, the stack loss has always been taken as a difference figure after figures have been assigned to the other sources of loss, and it appears to vary usually from about 0·5 to 1·0 per cent. It should be understood that in the stack loss is included any moisture, oil, grease, or other combustible matter which is weighed into the casting shop with the heat and so credited as metal. When melting very oily material, *e.g.* swarf, the so-called stack loss is very much higher than it is when heats containing heavier and larger scrap are being melted. In brass melting the remainder of the stack loss is largely zinc, and the extent of the stack loss varies considerably with the temperature of speltering, with the total proportion of zinc present in the mixture, and the relative proportion of zinc present as raw material and in the scrap. When pyrometers are not in regular use, as is frequently the case in pot melting shops, the stack loss may even vary with changes in the lighting conditions which affect the visual judgment of temperature.

The loss of metal in pot scrapings is small and does not generally greatly exceed about 0·1 per cent. In solid-fuel-fired furnaces the ashes from the burnt fuel carry a varying metal content. The amount of metal in the ashes is one of the most variable sources of loss. With careful operating technique the amount of metal lost in the ashes ought to be very small and should be less than 0·25 per cent.; much higher losses than this are, however, not unknown. Careless handling of the pot in the fire, very full pots, careless stirring, &c., all tend to increase the metal loss in the ashes. Splashings (by which is meant the small pieces of metal which are gathered up from the floor as sweepings or scrapings and occur as the result of spilling of metal during the handling of the full pot, during pouring, &c.) represent another variable loss, the magnitude of which depends largely on the degree of care and skill exercised in the casting operation.

The stack loss is partially controllable but non-recoverable. The losses in the ashes, skimmings and splashings are partly controllable and partly recoverable. The amount of metal in the skimmings is affected by such factors as temperature, nature of non-metallic matter on the top of the molten metal, care and skill exercised in melting, methods of prevention of drossing, skill in removal of skimmings, &c.

Some metal loss distribution figures for crucible brass melting in coke-fired pit furnaces are given in Table I, A–D. It should be under-

TABLE I.—*Metal Losses in Crucible Melting in Coke-Fired Pit Furnaces.*

	A.	B.	C.	D.	E.	F.	G.
Cast strips or billets returned, per cent. . .	97·58	98·66	96·66	98·39	99·71	98·66	99·64
Metal in skimmings, per cent.	0·72	0·33	0·90	0·41	0·08	0·20	0·08
Metal in splashings, per cent.	0·61	0·17	0·62	0·21	0·03	0·66	0·04
Metal in ashes, per cent. .	0·22	0·08	0·75	0·23	0·08	0·29	0·11
Metal in pot scrapings, per cent.	0·04	0·06	0·07	0·06	0·05	0·10	0·07
Stack loss, per cent. . .	0·83	0·70	1·00	0·70	0·05	0·09	0·06
Total metal loss, per cent.	2·42	1·34	3·34	1·61	0·29	1·34	0·36

A.—64 : 36 brass ingots. 220-lb. heats of 50 per cent. virgin metal and 50 per cent. scrap.

B.—65 : 35 brass ingots. 161-lb. heats of 100 lb. virgin metal and 61 lb. scrap.

C.—Various qualities and heats. Figures obtained over a 6 months' period.

D.—65 : 35 brass ingots. Variable heats. Average figures for a period of 3 months.

E.—97 : 3 copper–zinc alloy. 165-lb. heats. 50 per cent. scrap.

F.—97 : 3 copper–zinc alloy. 215-lb. heats. 50 per cent. scrap.

G.—80 : 20 cupro–nickel. 126-lb. heats. 64 per cent. scrap cupro–nickel.

stood that these figures, although they have been actually determined, are given only as examples, and it is not suggested that they indicate either what is ideally possible or even typical, for it is appreciated that there are so many possible variations in melting technique and so many other factors involved, the incidence of which may have very varying effects on the metal losses, that it is impossible to put forward figures as being generally representative. The figures under " A " were obtained from a series of heats melted under observation, all the weighings involved being accurately recorded but with no interference with the normal activities of the operatives. Heats weighing 220 lb., composed of 50 per cent. virgin metal and 50 per cent. scrap metal, were melted and cast into comparatively small ingots of 64 : 36 brass for cold-rolling. Under " B " are given the figures resulting from a similar study made in another works using the same melting method. The composition of the brass was only slightly different, being in this case 65 : 35, and the heats were smaller, weighing 161 lb. of which 100 lb. were virgin metal. These differences do not account, however, for the much smaller gross loss figure obtained. A comparison of the individual loss items under " A " and " B " shows that the losses in skimmings, splashings, and ashes are much higher in the former, whilst the stack loss and loss in the form of pot scrapings are not markedly different. This suggests at once that in the one series the actual handling had been much more careful than in the other. In works in which the results given under "A" were obtained, the figures given under "C" were obtained also over a period of 3 months, during which a variety of compositions and ingot sizes were covered. As might be expected, the figure for gross loss is higher than that occurring over the shorter period with less variable conditions. The figures under "D" were obtained over a period of 6 months in the same works as those obtained over a much shorter period and under less variable conditions ("B"). The comparison between "B" and "D" confirms that between "A" and "C," the longer and more variable period giving in both cases higher loss figures and in both short and long period observations, the loss in one works was higher than the other, the difference being attributed to more deft and careful handling.

In the melting of brass, whatever the method employed, the gross loss, which is not usually less than 1 per cent., is in a great measure attributable to the relatively large amount of volatile and readily oxidizable zinc in the alloy. Other things being equal, the magnitude of the loss decreases with decreasing zinc content. Thus, in the melting of brass the gross loss with alloys of the α type for cold-rolling ingots varies from about 1 to 3 per cent., according to conditions and circumstances, and with similar melting conditions this is increased to figures in excess of 3 per cent., varying up to 5 per cent. and even more for common brasses of higher zinc content. Whereas the loss may in favourable conditions not greatly exceed 1–1·5 per cent. for a 65 : 35 brass, it is commonly less than about 0·75 per cent. for a gilding metal of low zinc content. Because of the lower zinc content a smaller amount of dross or skimmings is formed which results in a lower loss figure. Further, the scrap available and used in making up alloys of this sort is not so extremely and strangely varied as it may be in brass production, particularly of the lower grades.

COPPER ALLOYS OTHER THAN BRASS.

The total loss on melting gilding metals normally does not exceed about 0·75 per cent. Similarly with alloys of the cupro–nickel variety, *e.g.* 85 : 15, 80 : 20, 70 : 30 cupro–nickel, the gross loss is not normally in excess of 0·5 per cent. Table I, E and F, gives results of a careful analysis made of the losses occurring in the production of ingots of gilding metal. The two loss figures 0·29 and 1·34 per cent., afford an example of the variation in the magnitude of the loss which may result from differences in operation, the two sets of figures summarizing the results of observations made in two different works producing the same alloy. In both instances small ingots weighing about 55 lb. each were being made, in one instance three being cast from a crucible, and in the other, four. The variation in the size of the heats, namely, 165 lb. and 215 lb., was the only marked difference. Similar charges were used consisting of a little over 50 per cent. virgin metal, the remainder being good scrap. The biggest differences in the items of individual loss occurs in the splashings and the ashes, which suggests that the lower figure for gross loss is to be attributed probably to more careful handling. This is a similar effect to that noticed in the brass series, the results of which are given in Table I, A–D. A gross loss figure, for crucible-melted rich gilding metals, taken over a period of 1 year, was 0·66 per cent. For phosphor–bronze over the same period the gross loss recorded was 0·65 per cent., while for 80 : 20 cupro–nickel it was 0·37 per cent. An analysis of the losses found to occur in melting 126 lb. heats of 80 : 20 cupro–nickel, for casting into small ingots for cold-rolling, is given in Table I, G.

BRASS MELTING IN AJAX–WYATT FURNACES.

The technique of melting brass in Ajax–Wyatt furnaces is altogether different from that adopted in crucible melting. Whereas the latter is an intermittent operation the former is continuous, for in the interests both of economy and convenience the furnaces are run continuously, and are never completely emptied of metal except at the end of their working life. The furnaces are of various capacities, but 600 and 1000 lb. units are now commonly used. This amount refers to the approximate weight of metal which is poured off after each charge is melted, but some 200 lb. or more of molten metal is left in the furnace in order to complete the secondary circuit which is essential for the working of the unit. After the metal has been poured the next heat is charged into the furnace. This is done in different ways according to the nature of the heat and the particular ideas of the individual caster. Usually in furnaces of this kind a heat of metal is run down or melted, and is ready for pouring in about 1 hr. Some time prior to pouring it is customary to remove from the surface of the molten metal, the accumulated dross which is known as skimmings.

It is customary to treat these skimmings by such operations as grinding and sieving in order to recover as much as possible of their metallic content, which is returned to the furnaces as part of the heat. The portion of ground or sieved skimmings which is returned to the furnace is known as " metallics " and generally amounts to about half the weight of the total skimmings, although the proportion varies. It consists mostly of metal, the metal content being of the order of 80–90 per cent. The finer portion, which is not returned to the furnace, is known as " fines " and consists mostly of metallic oxides and other non-metallic material. Its metal content varies from somewhat under 10 per cent. to about 20 per cent. When furnaces of this type were first used in this country—some 4 years ago—it was not the practice to make any special or extra addition to the furnace except that it was customary to add two handfulls of salt prior to skimming.

With furnaces operating continuously and melting on each occasion much greater quantities of metal than is possible in crucibles, it is not nearly so easy to make a detailed analysis of the metal loss as it is in the crucible melting, and in order to obtain figures which can be accepted as reasonably reliable, even though they are admittedly only approximate, it is necessary to carry on observations for a much greater length of time and to deal with a very much greater quantity of metal. Since no solid fuel is used, there is no metal lost in ashes. The loss which in crucible melting corresponds in an approximate way to pot scraping is in Ajax–Wyatt furnaces merged in the skimming loss. Oxide and dross tend to build up on the walls of the furnaces, and it is the practice to remove this once daily or possibly, as circumstances demand, more frequently

TABLE II.—*Metal Losses in Brass Melting in Ajax–Wyatt Furnaces under Different Conditions of Melting.*

	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.
Ingot yield, per cent.	97·69	98·78	97·67	98·68	98·63	97·35	96·14	98·06	98·73	98·46	99·19	98·82	96·89
Weight of gross skimmings, lb. per heat	29	19	31	18	21·5	17	24·2	21·6	12·6	18	4·3	5·5	52
Metal lost as metal in fines, percentage of the heat	0·95	0·17	0·45	0·20	0·18	1·21	1·30	0·60	0·21	0·33	0·14	0·13	0·97
Metal lost as oxide in fines, percentage of the heat	1·25	1·02	1·72	1·10	1·07	1·22	2·07	0·93	0·47	0·96	0·36	0·51	1·51
Metal unaccounted for, per cent.	0·11	0·10	0·16	0·11	0·12	0·22	0·49	0·41	0·59	0·25	0·27	0·54	0·63
Total metal loss, per cent.	2·31	1·29	2·33	1·41	1·37	2·65	3·86	1·94	1·27	1·54	0·81	1·18	3·11

A.—70 : 30 brass without borax flux.
B.—70 : 30 brass with borax flux.
C.—63 : 37 brass without borax flux.
D.—63 : 37 brass with borax flux.
E.—6 Furnaces on 3 months' run. Borax used as flux and metallics returned to furnaces.
F.—5 Furnaces on 11 weeks' run. Borax used as flux but no metallics returned to furnaces.
G.—1 Furnace on 11 weeks' run. No borax used and no metallics returned to furnace.
H.—2 months' run, salt flux. 72 : 28 brass.
I.—Same furnace as "H." 2 months' run. 2 lb. charcoal added per heat. 72 : 28 brass.
J.—1 month's run. 70 : 30 brass. 60 per cent. light scrap in heats. 4 lb. bituminous coal added per heat.
K.—5 weeks' run. 70 : 30 brass. Thick layer of charcoal. Furnace skimmed only once per shift.
L.—5 weeks' run. 64 : 36 brass. Thick layer of charcoal. Furnace skimmed only once per shift.
M.—7 weeks' run. Brass containing 57–59 per cent. copper and 1·5 per cent. lead. 1000-lb. heats containing 75 per cent. light scrap. Salt flux.

by chipping, and these chippings or " peckings " as they are sometimes termed, are withdrawn from the furnace with the next lot of skimmings. In casting from Ajax–Wyatt furnaces, which are provided with a tilting mechanism, very little splashing occurs, and in fact, apart from a little metal which may overrun from a full mould, splashing can be regarded as negligible, for any such metal which does overrun falls on the metal platform or the turntable, or the casting platform, and can be picked up and thrown back into the furnace.

When observations and experiments were first commenced a number of years ago in furnaces of the Ajax–Wyatt type careful records were taken on one furnace during a week's run. This particular furnace was melting 70 : 30 brass, and the charges consisted of 75 per cent. of virgin metal. The details regarding ingot yield and the distribution of loss in this trial are indicated in Table II, A. Most of the loss is due to volatilization and oxidation of zinc. This forms on the surface of the molten metal as dross and it is impossible to remove it from the furnace without removing at the same time some entangled metal. Now if the furnace were operated under such conditions that the oxidation of the zinc were largely prevented this loss would be substantially reduced. The oxidation is increased by keeping open the lid, spout, &c., of the furnace and so allowing free ingress of air, as well as by the breaking of the surface of the molten metal by stirring and pushing in the solid metal constituting the charge. Attempts were made to limit, or to reduce, the access of air by luting up those portions of the furnace which allowed the air to enter most freely. In this way it was found that the loss could be reduced from the then normal figure of just over 2 per cent. to just under 2 per cent., but this procedure is rather difficult to carry out and was not found to be practicable for a battery of furnaces in regular use.

Various attempts were made to reduce the amount of skimmings formed and hence the metal loss, by modifying the methods of charging the furnace, such as, for example, adding the metal in small quantities so that it could be pushed at once beneath the surface of the bath. An experiment was carried out on a furnace of 600 lb. normal capacity, but instead of pouring the full 600 lb. of metal only 400 lb. were poured so as to leave a deeper bath of molten metal, but no substantial improvement was obtained.

Different methods of stirring and adding the salt have been tried, but in the majority of instances such modifications have not led to any very marked reduction in the metal loss. It would seem that it is during the melting operation rather than later that the bulk of the oxidation occurs, and it has been observed that if a normal charge is skimmed clean only 1½ lb. of metal was subsequently recovered in the form of skimmings, after it had been left on standby load for 1 hr. without any precautions being taken regarding air exclusion.

The use of common salt, in much greater quantities than it was customary to use, was tried with the object of providing a continuous layer of molten salt over the bath of metal. The salt addition was made after pouring so that the new charge of metal was fed into the bath through the molten salt layer. No appreciable improvement in respect of reduction of metal losses followed this modification, but when borax was substituted for common salt a very considerable reduction in the weight of gross skimmings removed, and metal lost, followed. There is another considerable advantage in the use of borax connected with the recovery of metal from the skimmings. The portion which is recovered after grinding and sieving the skimmings has a metal content of about 80–90 per cent., but when this is returned to a furnace of clean molten metal and stirred in without the use of a flux, not more than about half the metal is recovered as pourable metal with the heat. With the use of borax, however, most of the metal contained in the metallics portion of the skimmings is recovered when it is returned to the furnace. For example, from 100 lb. of metallics added to a bath of molten metal without flux, and then stirred in, 60 lb. of skimmings were obtained and some 40 lb. of metal were recovered from the metallics, whereas when a similar weight of metallics was added to a bath to which 2 lb. of borax had been added, the weight of skimmings obtained was only about 15 lb.

In order to determine the effect of the use of borax on metal losses, a trial run was made over a period of 18 days during which 283 heats of metal were melted in the same furnace as that for which the records noted under " A " in Table II were recorded when melting 70 : 30 brass. Immediately after pouring a heat the current was put on full load and 2 lb. of borax were added to the bath. When the borax was melted—this being indicated by the disappearance of the dull red glow—the charging was commenced. This was an intermittent operation, and approximately 35 minutes after the completion of the charging the metal was ready to pour; this was effected after the skimmings had been removed from the surface. In this particular trial only 70 : 30 brass was used, and heats were melted similar in make up to those used in the previous observations, when no special fluxing additions were made. The figures obtained for the yield of metal and for the loss distribution are given in Table II, B. A comparison with the corresponding figures under " A " shows that the use of borax resulted in a reduction of the metal loss of a little more than 1 per cent.

To check further this finding, a similar series of observations was made with a furnace melting 63 : 37 brass. In this instance the amount of scrap in the charge approximated to 50 per cent. Observations were made over a period of 7½ days when melting heats of this kind under the ordinary conditions, that is with no flux additions to the bath other than a handful or two of salt shortly before skimming and pouring. The figures for ingot yield and distribution of losses in these conditions of working are given in Table II, C, from which it will be seen that they are very similar to those obtained when melting 70 : 30 brass. In the same furnace, observations were made with similar heats of metal, but the procedure was modified as before by the addition of 2 lb. of borax per heat after pouring and before the commencement of charging. The results so obtained are indicated in Table II, D, from which it will be noticed that a reduction of approximately 1 per cent. in the metal loss resulted from the use of borax, just as it did when 70 : 30 brass was melted.

Further experiments were carried out to determine whether greater quantities of borax than 2 lb. per heat could be used with advantage, but no improved results were obtained in these experiments.

Following the four series of separate observations which have been referred to, a battery of six furnaces was put on a 3 months' run with the modified procedure, that is with the addition of borax, and figures relating to ingot yield and loss distribution are given in Table II, E. During this period over 2000 tons of metal were melted. The results confirm the short time tests made with borax and which are reported in Table II, B and D. During this 3 months' run, when the total loss was 1·369 per cent., the metallics from the ground and sieved skimmings were regularly returned to the furnaces, and it was thought that it would be of interest to ascertain what the loss would be with a similar

TABLE III.—*Summary of Percentage Metal Losses Observed in the Melting of Brass in Ajax–Wyatt Induction Furnaces using Salt and Borax as Fluxes.*

Borax Flux and Metallics Returned to Furnaces, Per Cent.	Borax Flux but no Metallics Returned to Furnaces, Per Cent.	Salt Flux and Metallics Returned to Furnaces, Per Cent.	Salt Flux but no Metallics Returned to Furnaces, Per Cent.	Form of Loss.
0·18	1·21	0·45	1·30	Metal as metal
1·07	1·22	1·72	2·07	Metal as oxide
0·12	0·22	0·14	0·49	Metal unaccounted for
1·37	2·65	2·31	3·86	Total

method of working with the same furnaces when no metallics were returned. Accordingly, observations were made on the furnaces over a period of 11 weeks, during which five of them worked under these conditions; with the sixth furnace an exception was made, common salt and not borax being added as flux. The figures for ingot yield and loss distribution are given in Table II, F and G, and it will be seen that without the return of metallics the total loss when borax is used is about 1·3 per cent. more than it is when the same flux is used and the metallics are returned to the furnace. Similarly, when salt is used as flux the loss, when no metallics are returned to the furnace, is substantially higher, being actually 1·5 per cent. more than it is when metallics are returned in the usual way. The loss figures obtained under different conditions are summarized in Table III. The data so far given show that:

(1) In every case the metal lost as oxide constitutes a substantial amount of the total metal loss.

(2) When metallics are not returned to the furnaces when borax is used as flux, the increase in total loss is due almost entirely to a loss of metal in the form of metal; in other words, the return of metallics to the furnaces results in a practically complete recovery of metal from the metallics.

(3) When salt is used as a flux the recovery of metal from metallics is not nearly so complete.

(4) The use of borax in place of common salt as flux results in a reduction in the metal loss to a notable extent.

(5) This saving may be expressed in another way, namely, that with the use of borax the losses when no metallics are returned are but little more than those when salt is used and the expense and trouble of grinding skimmings, recovering and returning metallics to the furnaces are resorted to.

Although the results of numerous trials and experiments with borax as a flux instead of common salt indicated the substantial reduction it was possible to effect by this modification, the practicability and economics of the expedient must of course be considered before its value can be correctly assessed. Actually it was found that the use of borax in the quantities indicated was very harmful to the refractory lining of the furnaces. The cost of the flux has to be offset against the metal loss reduction resulting from its use, as well as the lower metal content, and consequently lower selling values of the "fines" portion of the skimmings which are not returned to the melting shops.

Following these considerations and the evidence that a large proportion of the loss was attributable to oxidation of the molten metal, further trials were made to determine to what extent the loss would be reduced by maintaining over the molten metal a layer of carbonaceous matter such as charcoal, bituminous coal, anthracite, &c. In Table II, H, are given the figures obtained on a furnace over a run of 2 months, during which time it was melting 72 : 28 brass under normal conditions of working, that is, with the addition of a small quantity of common salt. Immediately following these observations the method of working was altered and about 2 lb. of wood charcoal was added immediately after each heat was poured. Further observations were made for a month on the same furnace during which time heats of the same kind and quality of metal were melted. The figures obtained relating to the losses under the altered conditions are given in Table II, I. If these are compared with the corresponding values under " H," in the same table, it will be seen that the metal loss is 0·7 per cent. less than it was found to be in normal conditions, and the average weight of skimmings is 9 lb. less. A number of observations was made on the weights of skimmings removed from furnaces melting different qualities of brass, working both with and without the return of metallics. The results, which are summarized in Table IV, show clearly the use of charcoal in effecting a reduction in the amount of skimmings or dross formed and consequently in the metal loss.

Table IV

Nominal Composition of Brass.	Weight of Skimmings, Lb. per Heat.					
	No Metallics Returned to Furnaces.			40 Lb. Metallics per Heat Returned to Furnaces.		
	Normal Working.	With Charcoal Addition.	Difference.	Normal Working.	With Charcoal Addition.	Difference.
72 : 28	21	13	8	24	16	8
70 : 30	22	13	9	27	19	8
67 : 33	19	11	8	23	12	11
65 : 35	19	10	9	24	18	6
64 : 36	23	14	9	26	20	6
60 : 40	37	26	11	43	36	7
		Average 9			Average 7½	

To ascertain the extent to which oxidation can be reduced by modification of the ambient conditions prevailing in the furnace, experiments carried out to determine the effect of maintaining an atmosphere of coal-gas gave even better results than a layer of wood charcoal, when measured by reduction in the weight of skimmings. In this application, however, the use of coal-gas would be prohibitively expensive. Observations were also made on short runs, during which additions of 4 lb. of anthracite and 4 lb. of bituminous coal were made. These additions were almost as effective as a coal-gas atmosphere in reducing the weight of skimmings, while the use of 2 lb. of charcoal per heat was found to reduce the weight of the skimmings from about 22 to 13 lb. per heat. The weights per heat when using coal-gas, anthracite, and bituminous coal were respectively 8, 9, and 9 lb. When the cost of the addition is offset against the reduction in metal loss, the coal addition is the most economical. The results of the loss analysis made from observations on a furnace over a period of 1 month during which time heats of 70 : 30 brass were melted consisting of 60 per cent. of very light and bulky scrap and 40 per cent. virgin copper and zinc, are given in Table II, J. During this trial 4 lb. of coal were added per heat. The figures show a definite reduction in weight of skimmings per heat and percentage total metal loss when compared with the melting with a small salt addition (Table II, H), even though in the latter case heats with a greater proportion of virgin metal and much heavier scrap were used. The effect of the form of the scrap is quite an important factor affecting the metal loss in continuous brass melting in Ajax–Wyatt furnaces, and it is not necessary to enlarge on the fact that the loss in melting is less when the scrap is of the heavy variety, such as ingot ends, shearings from thick strip or plate, than when it is light and bulky. The use of coal, however, entails the risk of the metal becoming contaminated with impurities, but no perceptible pick up of sulphur, for example, was noted in the course of the trials although the possibility was closely watched, and it has moreover the disadvantage of emitting noxious fumes. The figures in Table II, M, which should be compared for example with those under " A," " C," and " H " in the same table, are given to illustrate the effect of high zinc content in the alloy and high proportion of light scrap in the charge on increasing the loss figure.

Since the use of carbonaceous coverings on the molten metal resulted in a very definite decrease in the amount of dross formed and in the metal loss, it was natural to suppose that measures to effect more complete protection of the metal from oxidation by using greater quantities of, say, charcoal would result in reducing the loss still further. Some preliminary experiments in this direction when a layer of charcoal several inches in thickness was maintained on the molten metal over a period of several heats and was not removed as hitherto, before each heat was poured, showed that this modification in procedure resulted in the loss being still further substantially reduced. Further trials were made over a period of 5 weeks with a furnace melting 70 : 30 brass and another melting 64 : 36 brass. To commence the run the molten metal was skimmed and sufficient wood charcoal added to provide a covering about 3 or 4 in. deep. This layer was maintained by additions of charcoal from time to time, and the furnaces were not skimmed until the end of each 8-hr. shift, each heat of metal being charged through the charcoal layer. With suitable precautions, charcoal could be prevented from coming over with the metal into the mould. The loss analyses obtained from these trials are given in Table II, K and L. The difference in the loss figure is largely attributed to the difference in the quality of scrap used. To test thoroughly this method of working a whole battery of furnaces, melting brasses of different compositions composed of heats which varied in respect of quality and nature of scrap, was run under observation. Although, according to the results obtained in this trial, the loss was reduced to the order of 1 per cent., considerable working difficulties arose. Whilst no trouble was experienced with charcoal entering the ingot mould when multi-hole runner boxes were used, difficulties in this direction were encountered to an appreciable extent with single-hole runner boxes for narrower ingots. Charging light scrap through the relatively thick layer of charcoal and dross constituted a very real difficulty. With this method of working, although the building up of the furnace lining, that is the accretion of oxide and non-metallic matter on the refractory surface, occurred to a much less extent than when salt or borax flux was used, and consequently the furnace required " pecking " only about once or twice a week instead of every day, fine dust accumulated on the bottom of the furnace which, when it found its way into the channel, affected the working of the unit.

In the light of the results of these various experiments and trials a method was adopted which is a compromise of several of those tried. After a heat is poured about 2 lb. of wood charcoal are added to the furnace and the metal comprising the next heat is then charged. When the melting is completed and the charge ready for pouring, about ½ lb. of a mixture of salt and borax is added and stirred into the layer of dross and charcoal, after which the whole is withdrawn or skimmed off, the metal poured, another lot of charcoal added, and the cycle of operations so continued. This method of working has proved to be very satisfactory with regard to metal loss reduction, economic considerations and satisfactory working, and actual records extending over more than 2 years, on furnaces melting brasses of the α type for casting into rolling ingots, have shown that with this procedure the loss does not generally much exceed 1 per cent.

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THE PROPERTIES OF SOME SPECIAL BRONZES.*

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Synopsis.

Additions of aluminium, manganese, aluminium plus manganese, iron, and silicon have been made to copper–tin bronzes.

(1) *Aluminium.*—Within the range of compositions investigated, alloys consisting of one solid solution work readily, hot or cold. Alloys possessing a duplex structure can be worked with much greater difficulty, and are specially difficult in hot-working. The range of compositions in which easy working properties can be obtained can be extended by annealing duplex alloys to give a homogeneous structure. Annealed alloys possess very good ductility; the maximum tensile strength attained in annealed alloys was 30 tons/in.^{2} in an alloy containing 4 per cent. aluminium and 5 per cent. tin. Alloys containing 2 per cent. or more aluminium are fairly resistant to oxidation at high temperatures, particularly if the cast surface is not damaged. Polished alloys have a pleasing appearance, and are fairly resistant to tarnishing in the air. The scale formed when the alloys are heated is very difficult to remove, either mechanically or by pickling processes.

(2) *Manganese.*—Manganese has a relatively small influence on the working properties of a 5 per cent. tin bronze. As much as 6 per cent. of manganese must be added before an appreciable embrittling effect is apparent. Alloys within the range of composition investigated can be worked hot or cold.

Manganese increases the softening temperature of the tin bronzes.

(3) *Aluminium and Manganese.*—Copper–tin bronzes containing aluminium and manganese, within the range investigated, are difficult to cold-work, without annealing, if the aluminium content exceeds about 0·25 per cent. With aluminium contents up to about 3 per cent. they may be cold-worked if they are previously rendered homogeneous in structure by annealing. Aluminium increases the tensile strength of manganese–tin bronzes, without appreciably reducing the ductility.

(4) *Iron.*—Iron, in the form of American washed iron, alloys readily with copper, and 4 per cent. of iron can be incorporated without difficulty. No trouble was experienced in obtaining good castings. Iron–tin–copper alloys containing 5 per cent. of tin and up to 4 per cent. of iron can be rolled, and the ductility decreases only slightly even when 3 or 4 per cent. of iron is present. Iron up to 1·5 per cent. has little effect on the tensile properties of a 5 per cent. tin bronze, but 2 per cent. or more of iron increases the tensile strength at the expense of the ductility. The iron is distributed uniformly throughout the solid alloy in the form of small particles, the structures being very similar to those of iron–copper alloys

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containing no tin. 4 per cent. of iron greatly refines the cast structure of a 5 per cent. tin bronze.

(5) *Silicon.*—Silicon has a marked effect on the cold-working properties of a 5 per cent. tin bronze. An alloy containing 3 per cent. of silicon can be cold-worked only with great difficulty in the "as cast" condition; after annealing at 800° C. for 4 hrs. the cold-working properties are slightly increased. The addition of 4 per cent. of silicon to a 5 per cent. tin bronze renders the material unworkable both hot and cold. The addition of silicon greatly increases the strength of a tin bronze.

INTRODUCTION.

COPPER–TIN alloys capable of being hot- or cold-worked have been known for a long time, and simple bronzes containing up to 10 per cent. of tin, or even more, are commonly produced in wrought form, and find a variety of uses. For some purposes, it is usual to add small quantities of other elements to such bronzes, phosphorus, silicon, and zinc being most frequently employed. Very little systematic investigation has been carried out on the working properties of bronzes containing added elements. The experiments described in the present paper constitute a survey of the effects of aluminium, manganese, aluminium plus manganese, silicon, and iron on the hot- and cold-working properties of the bronzes, and on the mechanical properties of the rolled products. Some observations have also been made of the microstructures of the various alloys used.

I.—COPPER–TIN BRONZES CONTAINING ALUMINIUM.

Alloys containing from 3 to 10 per cent. tin and from 1 to 7 per cent. aluminium were prepared.* Electrolytic copper and "Chempur" tin were used, and the aluminium contained 0·2 per cent. silicon and 0·22 per cent. iron.

The copper was melted under charcoal in a coke-fired furnace, and the aluminium and tin were added, in this order, shortly before the metal was poured; the alloys were cast into small chill moulds whose dimensions were 10 in. × 2 in. × $\frac{1}{2}$ in. The moulds were lightly dressed with bone-ash and French chalk, and were heated to 150° C.

As is usual with copper alloys containing aluminium, some difficulty was experienced in obtaining ingots free from surface blemishes, formed by the trapping of the oxide skin against the wall of the mould. After some experiments had been carried out, the method adopted was to tilt the mould, and to pour the stream of metal down the narrow edge; in this way the defects were mainly confined to this edge, and their effects could be estimated.

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* In all alloys the percentage of the elements other than copper is indicated by the figures in the sample number. Thus $A_3M_2S_6$ implies aluminium 3, manganese 2, and tin 6 per cent.

Four series were prepared, and the ingots were then treated as follows :

Series 1. Reduced to 80 per cent. of original thickness by cold-rolling, or until they began to crack, whichever occurred earlier.

Series 2. Heated for about 1 hr. to 750°–800° C. and hot-rolled from this temperature.

Series 3. Annealed for 12–14 hrs. at 700°–750° C., reduced 50 per cent. by cold-rolling, re-heated for 1 hr. to 700° C., and cold-rolled to a total reduction of 80 per cent. of the original area.

Series 4. Annealed at 750° C. for 14 hrs., and hot-rolled from this temperature.

Rolling Properties.

In each of the above-mentioned series of tests, rolling was continued until the material began to break down by the formation of characteristic shear cracks at the edges or on the rolled surface ; the degree of reduction of thickness at which this occurred was noted. The results are summarized in diagrams, in which the composition is plotted on the usual triangular scale, lines being drawn to separate those alloys which did not crack from those which did so. The reduction in thickness, expressed as a percentage of the original, is indicated for each line on the diagram. In these diagrams occasional cracks, clearly due to ingot defects, have been ignored.

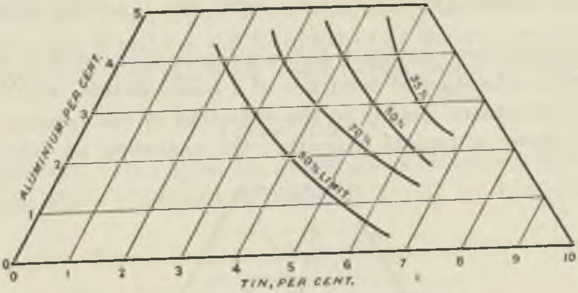

Fig. 1.—Alloys As Cast, Cold-Rolled.

Series 1.—Fig. 1 refers to the alloys of Series 1, cold-rolled from the "as cast" condition. It is clear that, as aluminium is added to simple bronzes, the amount of tin must be reduced in order to retain equivalent cold-working properties. Tin added to aluminium–copper alloys clearly produces a similar effect.

Series 2.—Fig. 2 shows the same effects in the alloys of Series 2, which were hot-rolled from 750° C., after 1 hr. at that temperature.

Hot-rolling was less successful than cold-rolling, and some of the ingots were definitely "hot-short." Alloys A_3S_6 and A_4S_5 cracked badly at the first pass, while alloys A_4S_3, A_4S_4, and A_3S_5 cracked at a very early stage in the reduction. The microstructures of these brittle alloys were therefore examined, and in all cases were found to be duplex in character, consisting of dendrites of α solid-solution, with an interdendritic constituent similar to the eutectoid of the bronzes. Fig. 3 (Plate I) shows a typical example. On annealing at 700°–750° C. for 12 hrs., the duplex structure disappeared, and simple polygonal crystals constituted the whole of the alloy, as shown in Fig. 4 (Plate I). It was concluded that alloys with a duplex structure are difficult to roll, and that the difficulty is greater in hot-rolling than in cold-rolling.

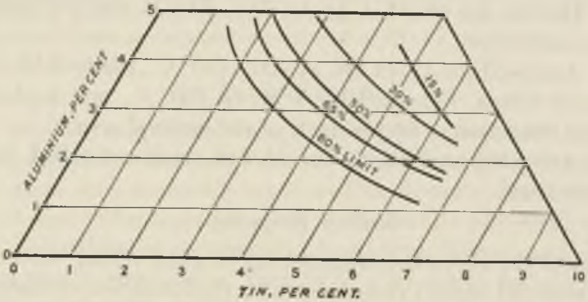

FIG. 2.—Alloys Annealed for 1 Hr. at 750°–800° C. and Hot-Rolled.

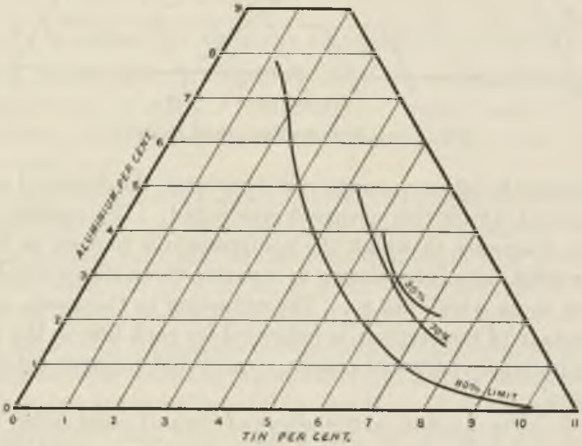

FIG. 5.—Alloys Annealed for 12 Hrs. at 750° C. and Hot-Rolled.

Series 3.—The alloys of this series were annealed for 12 hrs. at 700° C., to produce a polygonal structure. They were then reduced by only 50 per cent., after which they were annealed again at 700° C. for 1 hr., and finally cold-rolled by another 30 per cent. of the original thickness, giving a total of 80 per cent. reduction. This treatment is much more gentle than that of either Series 1 or 2 and all the alloys were rolled successfully.

Series 4.—The results of the tests on all alloys are summarized in Fig. 5, which shows that the annealing treatment enabled nearly all the alloys to be rolled to 80 per cent. reduction without cracking. A few alloys, on the extreme edge of the range investigated, developed small cracks before this degree of reduction had been attained. The limits of solid solubility shown by Stockdale[1] who investigated the constitution of these alloys, practically coincides with the limit of work found, and these results confirm the conclusion that alloys possessing a solid-solution type of structure offer little difficulty in rolling. The constitution and some properties of these alloys have also been investigated by Guillet,[2] Andrew and Edwards,[3] and Morlet,[4] and their results are in agreement with this work where comparison is possible.

Tensile Tests.

Tensile tests were carried out on the alloys of Series 1, as cold-rolled, and on the alloys of Series 4, annealed at 700° C. for 1 hr. after rolling.

TABLE I.—*Tensile Tests on Alloys Annealed at* 700° *C. for* 1 *Hr.*

Alloy Number.	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in. Per Cent.	Remarks.
A_1S_4 . . .	20·75	56·0	
A_1S_5 . . .	22·02	74·0	
A_1S_6 . . .	23·35	84·0	
A_2S_3 . . .	21·27	73·0	
A_2S_4 . . .	23·30	71·5	
A_2S_5 . . .	25·50	68·0	
A_2S_6 . . .	26·63	68·0	
A_3S_3 . . .	24·28	57·5	Broke at small spill.
A_3S_4 . . .	25·92	66·0*	Poor surface.
A_3S_5 . . .	28·55	49·0	
A_3S_6 . . .	28·78	79·0	
A_4S_3 . . .	27·12	78·0	
A_4S_4 . . .	28·19	58·0	
A_4S_5 . . .	29·75	74·0	
Cu 90%, Sn 10% .	27·02	65·0	Scaling left rough surface.
A_2S_7 . . .	25·54	38·0*	Broke at spill—poor.
A_7S_2 . . .	28·38	84·0	
Cu 93%, Al 7% .	27·95	75·0	

* Broke outside 2·0 in. length; measured on 3·0 in. length.

The cold-rolled alloys gave results for the tensile strengths which varied between 48 and 55 tons/in.^{2} with an elongation of between 0·8 and 2·2 per cent. on 2 in.

Some of the alloys of Series 1 were too badly cracked to enable test-pieces to be cut from them. The results of the annealed alloys are given in Table I. The ductility of all the annealed alloys was quite good, being about 65 per cent.

Brinell Hardness and Softening Temperature of Cold-Rolled Sheet.

The Brinell hardness numbers of the alloys, both in the "as cast" condition, and in the form of rolled sheet, are given in Table II. The effect of annealing at various temperatures within the softening range is also given, from which the appropriate softening temperatures for the different alloys can be deduced.

TABLE II.—*Brinell Hardness of Alloys As Cast and after Annealing Cold-Rolled Strip.*

Alloy Number.	As Cast.	As Cast, Annealed 700° C. 12 Hrs.	Cold-Rolled.	Annealed 200° C. 1 Hr.	Annealed 310° C. 1 Hr.	Annealed 420° C. 1 Hr.	Annealed 500° C. 1 Hr.	Annealed 420° C. 1 Hr., Furnace-Cooled.
A_1S_4 .	72	61	194	200	161	85	73	81
A_1S_5 .	79	69	194	202	163	92	81	90
A_1S_6 .	84	69	206	218	192	98	84	95
A_2S_3 .	69	63	207	220	170	90	72	80
A_2S_4 .	80	63	209	218	179	104	82	92
A_2S_5 .	85	66	216	211	193	113	85	97
A_2S_6 .	92	70	206	223	196	137	103	114
A_3S_3 .	77	58	204	220	183	110	81	98
A_3S_4 .	85	64	208	220	187	138	107	118
A_3S_5 .	95	70	201	226	200	143	108	124
A_3S_6 .	104	74	196	199	195	160	120	132
A_4S_3 .	79	60	209	218	184	133	107	120
A_4S_4 .	92	63	218	218	198	140	110	133
A_4S_5 .	104	68	201	213	202	156	120	129

Brinell Hardness, $\frac{P}{D^2} = 10$. Time, 30 seconds.

Surface Oxidation and Scaling.

The original surfaces of the "as cast" ingots containing more than 2 per cent. of aluminium are comparatively resistant to scaling up to temperatures of 800° C. If, however, the cast surface is removed, as by filing or machining, all the alloys form a dark-coloured oxide skin at 300°–400° C., the temperature of formation increasing as the aluminium content increases. In a normal 10 per cent. tin bronze, the scale which forms at high temperatures rapidly thickens and is easily detached, but when aluminium is added the thickness of the oxide scale is diminished and it becomes very adherent and tenacious. This effect is the greater the larger the amount of aluminium added.

The scales formed on these alloys are difficult to remove by pickling; immersion for 2 hrs. in 20 per cent. hydrochloric acid, 20 per cent. hydrochloric acid plus 10 per cent. sulphuric acid, 10 per cent. and 20 per cent. sulphuric acid, or 20 per cent. nitric acid, has practically no effect. In the experiments described in this paper, the scale was removed from annealed alloys by means of emery cloth, before cold-rolling was carried out. This scale had a dark-grey colour, and was separated from the alloy by a reddish intermediate layer, which must be removed if a good appearance is to be obtained on sheet, as it not only gives the alloy a patchy appearance, but tarnishes rapidly in atmospheric air whereas the true alloy underneath is relatively resistant to tarnishing in air.

II.—Copper–Tin Bronzes Containing Manganese.

The influence of manganese on the structure and mechanical properties of cast standard bronze was investigated by Guillet,[2] and by von Miller [5] on a few cast alloys of lower tin content. In the present work, the alloys were prepared, in a manner similar to that already described, within the solid solubility range of annealed alloys as shown by Verö,[6] who studied the constitution of this system.

Manganese was added as 30 per cent. cupro-manganese shortly before casting. This alloy was made from manganese containing less than 0·9 per cent. iron, less than 0·4 per cent. aluminium, and less than 0·4 per cent. silicon: the majority of the alloys, therefore, contained less than 0·1 per cent. impurities. Electrolytic copper and "Chempur" tin were used, as previously.

The external surfaces of the alloys were fairly good, but a tendency was observed to form an internal shrinkage cavity. Shrinkage cracks were also occasionally associated with this cavity. Superficial surface defects were not easy to avoid completely, although they were eliminated to a large extent by using a warm mould and a fast rate of pouring: this tended, however, to accentuate shrinkage defect. The black oxide skin commonly found on copper alloys containing manganese was observed on all alloys containing up to 3 per cent. of manganese and 4 per cent. of tin: it was practically absent on alloys containing more manganese. The tops of the ingots in contact with the air oxidized rather quickly, but the rate of oxidation is reduced as the manganese content is increased.

Rolling Tests.

The ingots "as cast" were cold-rolled without any annealing. All the alloys with up to and including 4 per cent. manganese rolled without difficulty; the alloy M_6S_5 began to crack at a reduction of about 60 per cent.; the alloy M_8S_5 buckled in the rolls and broke at a reduction of 10 per cent., whilst one portion of the ingot was taken to 15 per cent. reduction when it broke down by the formation of numerous cracks.

Fig. 6 (Plate I) shows the as-cast structure of M_8S_5; this is duplex, and consists of a matrix of cored α and a second constituent similar to the δ eutectoid of the tin–copper system. On annealing at 800° C. for 30 minutes the structure becomes homogeneous, as shown in Fig. 7 (Plate I).

A similar series of alloys was subjected to hot-rolling. The ingots were heated slowly for 2 hrs. to 780° C., held for 30–40 minutes at that temperature, at which they were hot-rolled. The maximum reduction of 80 per cent. was given to all the alloys, which hot-rolled quite well. Manganese appears to have no deleterious effects on the hot-working properties of the bronzes.

Tensile Tests.

The results of tensile tests on the alloys in various conditions are given in Tables III and IV. In the annealed alloys, the properties

TABLE III.—*Tensile Tests on Cold-Rolled Alloys.*

Alloy.	As Rolled.		Annealed 700° C. for 1 hr.	
	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in. Per Cent.	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in. Per Cent.
M_1S_4 . .	46·4	5·0	20·8	56
M_1S_5 . .	48·7	4·4	21·3	64
M_1S_6 . .	49·1	2·5*	21·6	67
M_2S_3 . .	44·6	5·0	20·3	49
M_2S_4 . .	48·4	4·8	21·2	53
M_2S_5 . .	50·5	5·1	21·5	64
M_2S_6 . .	52·0	1·7	22·7	69
M_3S_3 . .	45·7	5·0	21·1	47
M_3S_4 . .	48·9	5·2	21·8	57
M_3S_5 . .	51·8	4·0	22·5	64
M_3S_6 . .	52·5	4·9	23·1	69
M_4S_3 . .	46·5	5·0	21·6	51
M_4S_4 . .	49·3	2·9	22·2	60
M_4S_5 . .	51·5	3·2	23·0	65
M_6S_5 . .	46·5†	1·2	23·6	64
M_5S_1 . .	40·4	4·0	20·2	49

* On 3 in. † Rolled less than others.

TABLE IV.—*Tensile Tests on Hot-Rolled Alloys.*

Alloy Number.	As Rolled.		Annealed and Water-Quenched after 1 Hr. at 700° C.	
	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.
M_1S_4 . .	39·75	5·0	20·30	56
M_1S_5 . .	42·20	5·3	20·85	62
M_1S_6 . .	44·30	6·5	21·95	75
M_2S_3 . .	35·40	5·0	20·83	51
M_2S_4 . .	37·45	7·0	20·90	53
M_2S_5 . .	40·50*	5·0	21·15	38†
M_2S_6 . .	42·00	10·0	22·65	70
M_3S_3 . .	35·35	15·0	21·20	52
M_3S_4 . .	39·10	11·0	20·80*	43
M_3S_5 . .	40·50	11·5	21·72	58
M_3S_6 . .	41·30	14·0	22·80	56
M_4S_3 . .	34·70	14·0	21·20	47
M_4S_4 . .	36·35	17·0	22·00	56
M_4S_5 . .	39·15	15·5	22·40	65

* Broke at spill. † On 3 in.

vary very little with composition, and it is clear that manganese exerts a very small influence. Table IV includes the results of annealing followed by quenching in water, and a comparison with the results of tests on annealed strip shown in Table III indicates that quenching is without influence.

Softening Tests.

The results of Brinell hardness tests on the alloys as cast, as cold-rolled, and as annealed at various temperatures within the softening range are given in Table V. Manganese appears definitely to increase the annealing temperature at which complete softening occurs.

III.—COPPER–TIN BRONZES CONTAINING ALUMINIUM AND MANGANESE.

This series was divided into two groups; (1) alloys with a constant content of tin (5 per cent.), with manganese additions of 1–4 per cent., and small percentages of aluminium added as a deoxidizer; and (2) a few alloys containing 5–6 per cent. tin with 2 and 3 per cent. of manganese and aluminium.

The addition of 0·1 per cent., 0·25 per cent., and 0·5 per cent. aluminium, primarily as a deoxidizer, was made to the following four alloys as shown below :

Alloys	Aluminium
M_1S_5 B M_2S_5 B M_3S_5 B M_4S_5 B	0·1 per cent. aluminium.
M_1S_5 C M_2S_5 C M_3S_5 C M_4S_5 C	0·25 per cent. aluminium.
M_1S_5 D M_2S_5 D M_3S_5 D M_4S_5 D	0·5 per cent. aluminium.

The cupro–manganese was first added to the molten copper and the melt skimmed clean; then the aluminium was added, the alloy being stirred with a graphite rod, allowed to stand for a few minutes and again skimmed clean; finally the tin was stirred in, and the melt rapidly cleaned and cast.

TABLE V.—*Brinell Hardness of Alloys As Cast, Cold-Rolled, and Annealed.*

Alloy Number.	As Cast.	As Cold-Rolled.	Annealed 200° C., 1 Hr.	Annealed 300° C., 1 Hr.	Annealed 400° C., 1 Hr.	Annealed 500° C., 1 Hr.	Annealed 700° C., 1 Hr.
M_1S_4 . .	77	220	228	165	107	97	74
M_1S_5 . .	80	225	236	157	110	101	77
M_1S_6 . .	87	239	251	174	129	115	79
M_2S_3 . .	68	206	216	166	106	100	70
M_2S_4 . .	78	288	238	181	115	105	75
M_2S_5 . .	82	232	243	183	123	108	78
M_2S_6 . .	91	238	251	184	134	113	81
M_3S_3 . .	71	218	225	177	115	110	76
M_3S_4 . .	79	226	229	184	121	115	79
M_3S_5 . .	85	242	247	192	133	120	81
M_3S_6 . .	96	244	254	188	133	119	83
M_4S_3 . .	74	224	226	179	121	112	78
M_4S_4 . .	82	236	239	197	132	124	80
M_4S_5 . .	91	248	249	202	142	128	84
M_6S_5 . .	94	235	247	197	152	135	85
M_5S_1 . .	78	200	202	162	109	102	67
M_8S_5 . .	107						

The ingots obtained were generally cleaner and cast slightly better than those free from aluminium, whilst the effect on the ingot tops in contact with the air was most marked, the formation of a black oxide skin being rapidly suppressed as the aluminium content approached

PLATE I.

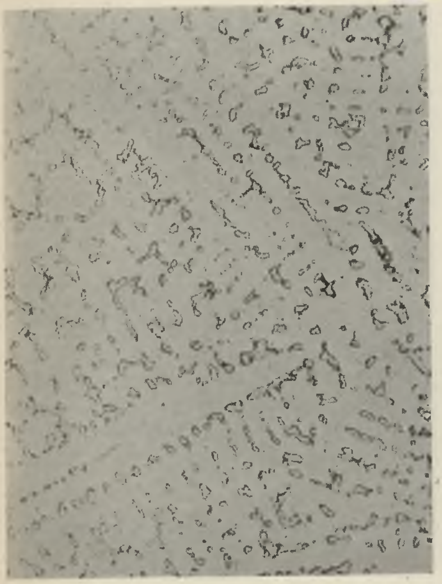

FIG. 3.—A_4S_5. Typical "As Cast" Structure of the Duplex Alloys. × 150.

FIG. 4.—A_4S_5. Annealed at 750° C. for 12 Hrs. × 150.

FIG. 6.—M_8S_5. "As Cast" Structure after 15% Reduction. × 150.

FIG. 7.—M_8S_5. Annealed at 800° C. for 30 Minutes. × 150.

PLATE II.

FIG. 8.—$A_3M_3S_6$. As Cast. Typical Duplex Structure of this Series. × 150.

FIG. 9.—$A_2M_3S_5$. Annealed at 800° C. for 1 Hr. × 150.

FIG. 10.—$A_2M_2S_6$. Annealed at 800° C. for 1 Hr. × 150.

FIG. 11.—$F_{1.5}S_5$. As Cast. Cored Solid Solution and Iron Particles. × 150.

FIG. 12.—F_4S_5. Iron Particles Etched in 1% Nitric Acid in Alcohol. × 150.

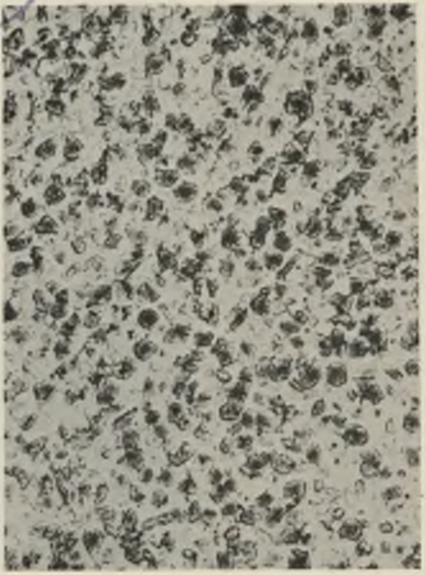

FIG. 13.—F_4S_5. Etched in Copper Ammonium Chloride. × 150.

FIG. 14.—Si_2Sn_5. As Cast. × 150.

FIG. 15.—Si_4Sn_5. As Cast. × 150.

FIG. 16.—Si_3Sn_5. Annealed, Unetched. × 250.

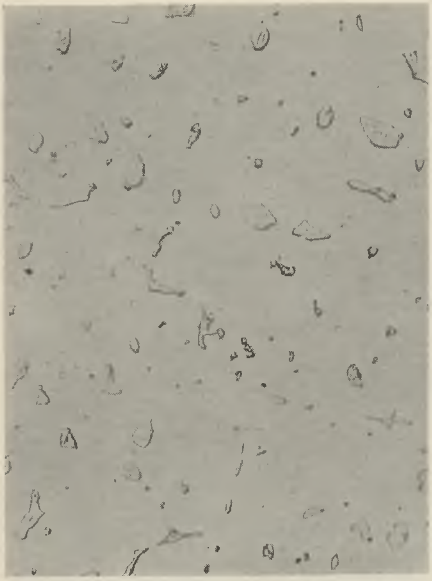

FIG. 17.—Si_4Sn_5. Eutectoid and Particles. Annealed, Etched. × 150.

FIG. 18.—Si_4Sn_5. Particles seen in Fig. 17. Annealed, Unetched. × 250.

0·5 per cent., particularly with the higher percentages of manganese; the ingots were quite free from black skin. The ingots were cold-rolled to a reduction of 80 per cent.; all rolled well except M_2S_5 D, M_3S_5 D, and M_4S_5 D, which cracked slightly at the edges. The influence of the aluminium could be detected clearly in these tests.

It is clear that if aluminium is used as a deoxidizer, not more than 0·25 per cent. may be added, without reducing the cold-rolling properties for any alloy containing 3 or more per cent. manganese and 5 or more per cent. tin. In general, the addition of a small amount of aluminium is beneficial.

Tensile Tests.

Tensile test-pieces, cut from the rolled sheet, were annealed at 700° C. for 1 hr. and cooled in air. It was not considered necessary to test the sheet as rolled. The tensile strengths were, in general, slightly higher than those for the corresponding alloys free from aluminium, while the elongation was not materially affected.

Alloys Containing Higher Percentages of Aluminium.

The study of the effect on the alloys produced by the small amounts of aluminium was extended to a further series of alloys with higher aluminium contents. It was not practicable to study the influence of aluminium on all the original compositions, owing to the large number of alloys that would be involved. Combinations of 2 and 3 per cent. of aluminium and manganese added to alloys containing 5 and 6 per cent. tin were chosen, making eight alloys in all.

An examination of the structures indicated that there would be little hope of cold-rolling these in the "as cast" condition, and it was decided to anneal all the ingots. Fig. 8 (Plate II) shows the structure of $A_3M_3S_6$ as cast; this is typical of the series, little difference existing between the first and last, and all showing a severely cored α matrix, in which the hard eutectoid had separated on cooling.

The alloys were annealed for 5 hrs. at 800° C. (1 hr. to reach temperature), and slowly cooled in the furnace. All were cold-rolled successfully after this treatment, those containing the higher percentages of alloying elements breaking down at a slightly earlier stage than the others, though all withstood a reduction of 70 per cent. before signs of cracking appeared.

Figs. 9 and 10 (Plate II) show the structure of specimens cut from ingots $A_2M_3S_5$ and $A_3M_2S_6$ annealed at 800° C. for 1 hr., the spots in Fig. 10 being holes or minute particles of iron or a second phase exaggerated considerably by the etching medium.

Tensile Tests.

Tensile tests were carried out on the sheet and the Brinell hardness of the alloys determined in the as cast, as rolled, and annealed conditions; the results are given in Table VI.

TABLE VI.—*Tensile Tests on and Brinell Hardness of Alloys As Rolled and Annealed.*

Alloy Number.	Brinell Hardness, As Cast.	As Rolled.			Annealed 700° C. for 1 Hr.; Air-Cooled.		
		Tensile Strength, Tons/in.².	Elongation on 2 in., Per Cent.	Brinell Hardness	Tensile Strength, Tons/in.².	Elongation on 2 in., Per Cent.	Brinell Hardness.
$A_2M_2S_5$.	87	55·7	3·0	244	24·5	66	82
$A_2M_2S_6$.	105	41·9*	nil	259	26·9	67	88
$A_2M_3S_5$.	97	58·0	4·0	263	25·5	73	83
$A_2M_3S_6$.	113	60·8	3·5	277	23·9†	59†	87
$A_3M_2S_5$.	101	60·0	4·0	266	28·2	69	89
$A_3M_2S_6$.	124	62·1	2·0	268	32·3	49	114
$A_3M_3S_5$.	110	62·0	4·5	267	28·0	72	86
$A_3M_3S_6$.	121	61·4†	nil	269	29·4	76	88

* Spill, broke outside gauge. † Broke at spill.

IV.—COPPER–TIN BRONZES CONTAINING IRON.

A standard tin content of 5 per cent. was adopted in this series and five alloys were made containing up to 1·5 per cent. iron. As they all rolled well, five additional alloys with higher iron contents were investigated.

The iron was added to the molten copper in the form of an American washed iron having the following analysis :

	Per Cent.
Carbon	3·5
Silicon	<0·1
Manganese	<0·1
Sulphur	<0·02
Phosphorus	<0·02

The carbon is eliminated on alloying so that in the case of the 4 per cent. iron alloy, the total impurities added only amounted to 0·01 per cent. This iron has a relatively low melting point, and is readily dissolved by the copper without loss.

Scintillations occurred when casting the alloys with the higher iron contents. These alloys also formed dark oxide skins, and the porosity down the pouring edge increased with the iron content. The ingots were comparatively free from surface defects.

All the alloys cold-rolled easily, 80 per cent. reduction being obtained on those containing up to 2·5 per cent. iron and 75, 70, and 70 per cent. on the 3·0, 3·5, and 4·0 per cent., respectively, before shearing edge cracks were visible. Iron had very little effect on the working properties of the 5 per cent. tin alloy, which agrees with the slight increases shown by Brinell hardness determinations on the cast ingots given in Table VII. The marked step between $F_{1\cdot5}S_5$ and F_2S_5 is considered to be due to a cold mould and some casting differences at the commencement of a second set of alloys, but it may be a genuine change, at or near this composition, in the solubility of iron in the alloy. Brinell hardness and tensile tests were carried out on the strip as rolled, and in the annealed condition; the results being given in Table VII. A yield-point was noted in four alloys in the annealed specimens: it was only slight and should be interpreted cautiously.

Table VII.—*Tensile Tests on Copper–Tin Bronzes Containing Iron.*

Alloy Number.	Brinell Hardness, As Cast.	As Rolled.		Annealed 700° C. for 1 Hr.; Air-Cooled.		
		Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.	Remarks.
$F_{0\cdot25}S_5$	73	48·5	3·5	22·40	64	
$F_{0\cdot5}S_5$	78	48·4	4·5	22·25	62	
$F_{0\cdot75}S_5$	79	47·2*	4·0	23·10	60	
F_1S_5	84	48·5	3·0	24·75	50	
$F_{1\cdot5}S_5$	90	48·4	5·0	24·45*	60	
F_2S_5	110	51·5	2·5	28·75	36	
$F_{2\cdot5}S_5$	109	50·6*	2·0	28·80	35	Yield-Point ? 18 tons/in.^{2}
F_3S_5	116	51·8	3·5	28·80	38	Yield-Point ? 19 tons/in.^{2}
$F_{3\cdot5}S_5$	113	53·8	3·0	29·60	40	Yield-Point ? 20 tons/in.^{2}
F_4S_5	118	55·2	4·0	29·00†	28	Yield-Point ? 20 tons/in.^{2}

* Spill. † Bad spill, skin.

A few alloys of this system were also investigated "as cast" by von Miller.[5]

Microstructure.

In all the alloys, the iron is in the form of small particles uniformly distributed in an α matrix: no eutectoid or other phase was seen in any of the alloys. Fig. 11 (Plate II) illustrates the typical cored structure seen in all the cast ingots except the last one, containing 4 per cent. iron; none contained serious unsoundness. Fig. 12 (Plate III) shows the iron particles—etched with 1 per cent. nitric acid in alcohol—

in 4 per cent. iron alloy, the etched "as cast" structure of which is illustrated in Fig. 13 (Plate III). The normal dendritic structure of the bronzes is absent, although each of the small crystals seen in this photomicrograph is actually cored, as usual, which produces the blurred effect in this print. The grain refinement of the bronzes is attributed by Ju-n Asato [7] to the peritectic reaction introduced by the addition of iron or cobalt, but it may be due to an inoculation effect caused by the separation of iron in the liquid alloy producing a very fine crystal structure. The iron particles before etching are pale blue, and when only very few are present, as in the 0·25 per cent. iron alloy, care must be taken during polishing or they are vigorously attacked and are mistaken for holes.

V.—COPPER–TIN BRONZES CONTAINING SILICON.

In this series, only four alloys were used to determine the working properties; 1, 2, 3, and 4 per cent. of silicon being added to alloys containing 5 per cent. of tin. The silicon (iron 0·78, aluminium 0·18, calcium 0·1 per cent.) was added to the molten copper in pieces and held below the surface of the melt, when it readily dissolved. The use of "fines" or a 10 per cent. silicon–copper hardener (unless the latter were very free from skin and oxide) produced losses due to the non-solution of particles on which a skin formed that isolated them from the melt.

The progressive addition of silicon changes the colour of the alloy from the normal to silvery-white on the surfaces of the chill-cast ingots, which are very sonorous though brittle in the case of the 4 per cent. silicon alloy. Ingots of the same size as used previously were rolled. They were tested "as cast" and "as cast and annealed."

TABLE VIII.—*Cold-Rolling Tests.*

Alloy Number.	As Cast.	Annealed at 780°–800° C. for 4 Hrs., Furnace-Cooled.
Si_1Sn_5 .	Rolled well; 80% reduction, without cracking.	Rolled well; 80% reduction.
Si_2Sn_5 .	Tough but cracked at 67% reduction.	Rolled well; 80% reduction with slight cracking.
Si_3Sn_5 .	Just workable only; cracked at 30% reduction.	Reduced by 50% reduction. Edges cracked. Annealed 30 minutes at 800° C. and continued to 80% reduction.
Si_4Sn_5 .	Not workable.	Not really workable; 5% reduction only.

A recent German patent [8] indicates that the hot-working properties of the bronzes are materially improved by the addition of small percentages of silicon up to a maximum of 3 per cent., which agrees with the limiting addition found by the authors.

The Brinell hardness numbers of the alloys and the results of tensile tests on the strip as rolled and after annealing at 700° C. for 1 hr. are shown in Table IX.

TABLE IX.—*Brinell Hardness of and Tensile Tests on Copper–Tin Alloys Containing Silicon.*

Alloy Number.	Brinell Hardness, As Cast.	As Rolled.		Brinell Hardness, As Rolled.	Annealed 700° C. for 1 Hr.		Brinell Hardness, Annealed 700°/1 Hr.
		Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.		Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.	
Si_1Sn_5	102	54·25	2·5	251	26·41	71·0	90
Si_2Sn_5	115	59·55	3·5	262	31·76	63·0	118
Si_3Sn_5	150	61·05	5·0	266	35·50	56·0	148
Si_4Sn_5	190						

Microstructures.

The alloys were examined as cast and in the annealed condition, the principal effect of silicon on the copper–tin alloys being the appearance of a second phase in them.

The cast structures of Si_2Sn_5 and Si_4Sn_5 are shown in Figs. 14 and 15 (Plate III); these consist of an α phase matrix with a form of eutectoid (possibly ternary), of which one phase differs from the δ matrix and is occasionally left unabsorbed after annealing. In alloys containing 3 per cent. and 4 per cent. of silicon, a third constituent may be seen in small particles, somewhat similar in form and characteristics to silicon. This phase is only seen very occasionally in the cast alloys, but after annealing, the particles increase in number and size. Fig. 16 (Plate IV) shows them in an unetched specimen containing 3 per cent. silicon after annealing, which had caused all the eutectoid to be absorbed. Figs. 17 and 18 (Plate IV) also show this constituent in a 4 per cent. silicon alloy in etched and unetched specimens after annealing, which in this alloy does not completely remove the eutectoid phase.

The amount of eutectoid in the cast 4 per cent. silicon alloy explains why it is not workable : even after annealing, a considerable quantity remains unabsorbed : the presence of precipitated particles of the third constituent may also contribute to its failure under cold-work.

The Brinell hardness figures for the 2 and 3 per cent. silicon alloys, both " as cast " and in the form of annealed strip, show the great influence of the silicon. The high figures in the annealed state are not caused by the eutectoid, since it has been absorbed. The elongations for these alloys (63 and 56 per cent., respectively) indicate also a high degree of ductility with a strength of over 30 tons/in.^{2} after annealing.

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THE INTER-RELATION OF AGE-HARDENING AND CREEP PERFORMANCE. PART I.—THE AGE-HARDENING OF NICKEL–SILICON–COPPER ALLOYS.*

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E. H. BUCKNALL,‡ M.Sc., Member.

With an Appendix on the Relationship of Time, Temperature, and Concentration as Factors in Age-Hardening.* By E. H. Bucknall,‡ M.Sc., and C. H. M. Jenkins,† D.Sc., A.R.S.M.

Synopsis.

A report is given of an investigation on the age-hardening of nickel–silicon–copper alloys containing 3 and 5 per cent. nickel + silicon in the atomic ratio 2 Ni : 1 Si. This work, which was carried out as a preliminary to the study of the inter-relation of the age-hardening of this material and its creep performance, has provided sufficient information to serve as a basis for the creep test programme and to assist in the interpretation of the creep results.

The alloy containing 3 per cent. nickel + silicon when quenched from 900° C. undergoes age-hardening at temperatures of 300°–750° C. The maximum hardness is attained progressively more rapidly the higher the ageing temperature, being reached, for example, in more than 64 days at 400° C. and in less than 1 minute at 700° C. In general, a linear relationship appears to apply between the logarithm of the time and the reciprocal of the absolute temperature of attainment of maximum hardness. The maximum hardness is greater the lower the ageing temperature. The attainment of maximum hardness is generally followed by softening.

Microscopical and chemical evidence of the progress of ageing has been obtained, but X-ray study has not been of great assistance in this instance.

In the Appendix consideration is given to points relating to the age-hardening of nickel–silicon–copper alloys and their comparison with information in the literature relating to other age-hardenable alloys. Particular attention is directed to the importance of the relationship between temperature and time of attainment of maximum hardness, which is shown to be of general application. A similar relationship applies to the attainment of maximum resistivity during ageing. These relationships are regarded as confirming the commonly accepted theory of age-hardening.

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This paper describes work carried out in the Metallurgy Department of the National Physical Laboratory for the Committee on Materials for High-Temperature Service of the Department of Scientific and Industrial Research.

INTRODUCTION.

Study of the inter-relation of age-hardening and creep performance appears to be of considerable importance in connection with the resistance of materials to flow at elevated temperatures, since in the course of an investigation of alloys for use at high temperatures at present in progress in the National Physical Laboratory, it has been shown by Jenkins and Tapsell[1] that certain complex iron–nickel–chromium alloys, which have a high resistance to creep at 800° C., undergo age-hardening on exposure to temperatures between 600° and 1100° C.

Jenkins and Tapsell put forward the suggestion that the retention of initial strength for long periods at 800° C. is a result of age-hardening, which is probably accelerated by the straining of the material. The complexity of these alloys, however, prevented any definite opinion being formed as to the precise nature of the relationship between age-hardening and creep performance.

In order to obtain more definite evidence on this matter a study is being made of age-hardening alloys of a less complex constitution, and nickel–silicon–copper alloys which harden at comparatively elevated temperatures have been selected for this purpose. The experimental work completed up to the present has included a preliminary survey of the ageing of alloys containing 3 and 5 per cent. nickel + silicon with 0·3 per cent. manganese; also a 5 per cent. nickel + silicon alloy. In each alloy the nickel and silicon are present in approximately the ratio of two atoms of nickel to one atom of silicon as in the alloys prepared by Corson[2] and other investigators.

In the course of these experiments it has been found necessary to make extensive reference to the literature of age-hardening with especial reference to those papers in which attention is devoted to the softening as well as hardening stages of ageing. Data which have been accumulated in this way have been studied by graphical methods. The results of this study are presented in the Appendix to the present paper.

PREVIOUS LITERATURE RELATING TO NICKEL–SILICON–COPPER ALLOYS.

The constitution of the ternary alloys of copper, nickel, and silicon does not appear to have been studied systematically. Some information on this subject is given, however, by Corson,[2] Jones, Pfeil, and Griffiths,[3] Crepaz,[4] and Wilson, Silliman, and Little.[5] Corson regards Cu and

Ni_2Si as forming a pseudo-binary series, and infers that the Ni_2Si is the phase which separates during the ageing of the copper-rich alloys. Wilson, Silliman, and Little, and Gonser and van Wert [7] on the other hand appear to believe that the origin of the ageing properties is a complex constitutional change occurring in the copper-rich alloys containing nickel and silicon in the ratio 2 atoms Ni/1 atom Si at a temperature between 500° and 700° C. The age-hardening of these alloys has been the subject of considerable study by the above-named authors, by Bain [6] and by Ellis and Schumacher.[8]

The most detailed results given by Corson [2] refer to an alloy containing 5 per cent. nickel + silicon (in the atomic ratio 2 Ni/1 Si) which was quenched from 930° C. and subsequently reheated for periods of 1–10 hrs. at temperatures between 350° and 650° C. Corson shows that the Brinell hardness may increase from 60 to 200 during ageing. Jones, Pfeil, and Griffiths,[3] working with alloys containing 0·2–0·4 per cent. manganese obtained, by heat-treatment for 1 hr. at 500° C., a maximum increase in Brinell hardness of from 60 to 190. Wilson, Silliman, and Little's hardness measurements were made by the Rockwell method and, therefore, may only be compared with those of the other authors after conversion to Brinell hardness values by means of the formula of Petrenko.[9]

Gonser and van Wert [7] have shown recently that alloys containing 2·08 and 2·95 per cent. nickel + silicon (in the atomic ratio 2 Ni/1 Si), quenched from above 700° C. and aged at 425°–550° C., maximum hardness is attained progressively more rapidly as the ageing temperature is increased, but that the hardness attainable increases with decrease in ageing temperature.

Ellis and Schumacher and Gonser and van Wert have shown that the ageing of nickel–silicon–copper alloys is markedly accelerated by cold-working subsequent to quenching, as has also been demonstrated by Jones, Pfeil, and Griffiths [10] for the related nickel–aluminium–copper series.

EXPERIMENTAL INVESTIGATION.

A preliminary survey of the ageing was carried out on three alloys —5T, 5P, and 5M, each of which contained approximately 5 per cent. nickel + silicon (in the atomic ratio 2 Ni/1 Si). Alloy 5T was made from Thermit silicon of indifferent purity, and contained an appreciable content of impurities, notably iron and aluminium. The silicon used in preparing alloy 5P was taken from a stock of silicon purified in the authors' Department.[11] Alloy 5M was made by remelting a quantity of alloy 5P with 0·4 per cent. manganese.

Preliminary experiments indicated that, unless special precautions were taken in the water-quenching of the *pure* alloy 5P from temperatures at which it was homogeneous, very variable hardness resulted. For example, five specimens quenched after prolonged treatment at 900° C. gave the following average results: 74, 112, 117, 164, and 170 (Brinell hardness, 2/40/30). On reheating these specimens at a temperature of approximately 400° C. for 43 hrs. and quenching, the softer specimens hardened while the harder specimens softened, the Brinell hardness of all the specimens then lying within the range 120 to 130.

In subsequent work with alloy 5P more consistent results were obtained by more rigid control of the quenching conditions, yet the average Brinell hardness of specimens of 5P quenched after treatment at 900° C. is 79 as compared to 65 for alloy 5T and 66 for alloy 5M; hence it may be concluded that the cooling rate obtained by water-quenching is insufficient to retain the alloy 5P fully soft. The hardness values obtained after tempering this alloy (see above) were consistent with the results of reheating partially-hardened material.

The highest and lowest Brinell hardness values attained in the preliminary survey are given in Table I.

TABLE I.

Alloy.	Description.	As Cast.		Worked and Annealed.	
		Highest.	Lowest.	Highest.	Lowest.
5T	Impure 5% Ni + Si (Thermit Si)	164	68	183	65
5P	Pure 5% Ni + Si (purified Si)	116 *	70	170	74
5M	Pure 5% Ni + Si (purified), plus addition of 0·4% manganese	172	65	172	68

* This value would in all probability have been exceeded by a more appropriate tempering treatment.

It was found that the alloy 5P was partly melted during heat-treatment at 1000° C. According to Corson [2] the solidus for this alloy should lie at approximately 1050° C.

The hardness increments given above are not so large as those obtained by Jones, Pfeil, and Griffiths [3] for an alloy containing nickel 2·16, silicon 0·83, and manganese 0·2–0·4 per cent. Their results, and those of Corson [2] and Ellis and Schumacher,[8] indicate that little or no increase in attainable hardness increment occurs beyond this composition, and that beyond 3 per cent. of nickel and silicon the increment may decrease. It was concluded, therefore, that most of the work would best be confined to an alloy containing approximately 3 per cent. nickel + silicon (in the atomic ratio 2 Ni/1 Si) together with

0·3 per cent. manganese, made from materials of high purity. A new alloy of this composition, 3M, was therefore prepared. The main age-hardening study consisted in work with this alloy and a limited number of comparison experiments with alloys 5P and 5M.

ALLOY 3M.

Preparation.

The alloy was prepared from high-quality shot nickel, electrolytic copper, redistilled manganese, and a 12 per cent. silicon–copper temper alloy whose only appreciable impurity was 0·06 per cent. iron. Weighed quantities of the constituents were melted together in a Salamander crucible in a gas-fired furnace and cast into a 2-in. steel slab mould previously dressed with a smoke-flame dressing. The ingot was forged and subsequently one half was hot-rolled to $\frac{1}{2}$-in. and the other to $\frac{5}{16}$-in. Finally, the material was reheated to 900° C., maintained for $\frac{1}{2}$-hr., and quenched in cold water. The macrostructure of the rolled material consisted of uniform crystals of small grain-size.

Chemical analysis of drillings from the $\frac{1}{2}$-in. plate gave the following results :

	Per Cent.
Nickel	2·38
Silicon	0·54
Manganese	0·27
Copper (by difference) . .	96·81

Age-Hardening Tests.

The age-hardening survey of alloy 3M was directed in the first plate towards an investigation of the permanence at room temperature of the hardness of the material quenched from 900° C. In preliminary tests on the rolled surface the average hardness initially was 54 and after 17 days was 55 (Brinell hardness, 10/1000/30).

Impressions made periodically during 3 months on a prepared surface at right angles to the rolled face of the $\frac{1}{2}$-in. plate showed that the average hardness of ten specimens tested initially was the same as that in all subsequent tests. The hardness values determined in this way were consistently higher than those measured on the rolled surface, which was covered by a softer skin, roughly 0·01 in. thick, formed during heat-treatment as described by Corson.[2] The irregular variation in hardness of the plate 3M amounted to ± 5 on 63.

Heat-treatment of specimens from the $\frac{1}{2}$-in. plate was carried out in thermostatically controlled furnaces, the specimens being protected against undue oxidation by close wrapping in copper foil. Separate specimens were used for each treatment, as the reheating of partially-aged specimens appears to be undesirable. The specimens reached the desired temperature in approximately 20 minutes and after treatment were quenched in cold water. Three Brinell impressions were then made at room temperature with a 2 mm. ball under a load of 40 kg. applied for 30 seconds on a surface prepared on " 00 " emery paper 0·05–0·1 in. below the previous surface. The hardness values are plotted in Fig. 1.

The ageing study of 3M was later extended to short periods of exposure at temperatures higher than 540° C. Small specimens (20 mm. × 10 mm. × 1 mm.), prepared by rolling the $\frac{5}{16}$ in. plate followed by quenching from 900° C., were dropped into a massive iron container within an electric furnace maintained at the desired temperature, and quenched in water after treatment. In these conditions specimens reached 10° C. below the desired temperature in 35 seconds and that temperature in 60 seconds. The Brinell hardness of these specimens was measured at room temperature on a surface prepared on " 00 " emery paper. Three impressions were made with a 1 mm. ball and a load of 10 kg. applied for 30 seconds. The results are indicated by the broken lines in Fig. 1. Considerable hardening occurs even at temperatures as high as 700° C. provided that the exposure period is appropriately short. This is of considerable interest in the general study of age-hardening phenomena.

The results plotted in Fig. 1 for the short-time treatments at 600° and 650° C. of the 1 mm. specimens agree well with the hardness values obtained on the 12 mm. specimens. At 540° C., however, the hardness of 1 mm. specimens still increases after 44 minutes, whereas the hardness of 12 mm. specimens commences to decrease after about 20–30 minutes. This difference may be ascribed partly to the effect of mass and partly to difference in rate of heating to the ageing temperature, during much of which period some age-hardening would occur.

It will be seen that maximum hardness is reached after the periods of exposure shown in Table II :—

TABLE II.

Temperature to which Material is Reheated, ° C.	Time to Attain Maximum Hardness (Alloy 3M).
250	Exceeds 64 days.
300	,, 64 days.
350	,, 64 days.
400	Approximately 64 days.
450	Between 1 day and 4 days.
500	,, 1½ hrs. and 6 hrs.
540	Approximately 20–30 minutes.
600	,, 5 minutes.
650	,, 3 minutes.
700	Less than 25 seconds.

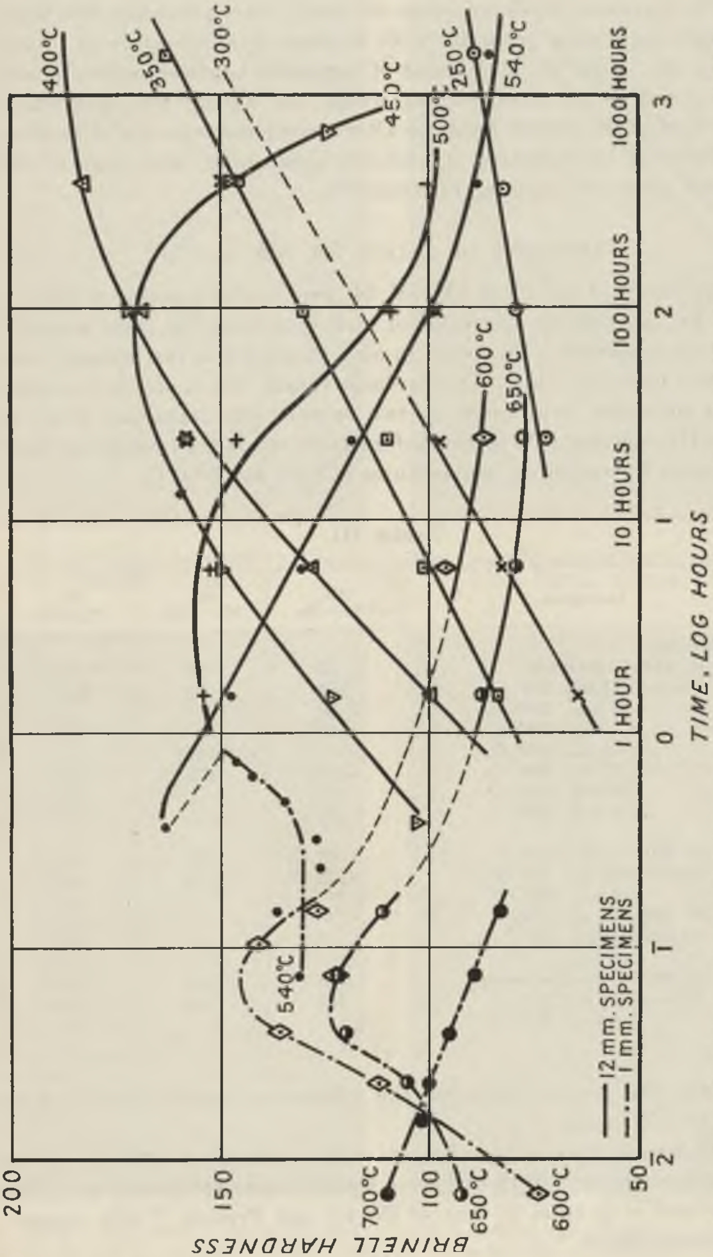

FIG. 1.—Hardness Changes in Nickel–Silicon–Copper Alloy, 3M, containing 3% Ni + Si with 0·3% Mn, Quenched from 900° C. (N.P.L. Investigation.) For details see Tables V and VI.

The maximum hardness values attainable vary gradually with temperature, increasing generally with decrease in temperature as shown in Fig. 16. After the attainment of maximum hardness, softening has been noted at all temperatures where the ageing was sufficiently prolonged. The Brinell hardness after a complete sequence of hardening followed by softening is probably comparable with that of the original quenched material, *i.e.* about 60.

COMPARISON OF ALLOYS 3M, 5M, AND 5P.

Specimens of the alloys 3M, 5M, 5P were heated together at 900° C. for 1 hr., after which specimens of each were cooled in three ways :—(1) water quenched; (2) cooled in air; (3) cooled in the furnace, over a period of about 3 hrs. The hardness values, which are the averages of six to twelve impressions on two or more specimens, are given in Table III, together with further information obtained by reheating these specimens to tempering temperatures of 300° and 500° C.

TABLE III.

Description.	3M, 3% + Mn.	5M, 5% + Mn.	5P, 5% Pure.
Conditions :			
1 hr. 900° C. *quenched*	55	66	79
reheated 1½ hrs. 300° C.	64	82	96
6 hrs. 300° C.	82		91
1 day 300° C.	97		111
½ hr. 500° C.		181	
1½ hrs. 500° C.	158	177	136
6 hrs. 500° C.	152		131
1 day 500° C.	147		112
1 hr. 900° C. *air-cooled*	67	180	182
reheated 1½ hrs. 500° C.	149	170	156
6 hrs. 500° C.			149
1 hr. 1000° C. *air-cooled*			158
reheated 1 hrs. 500° C.			171
1 hr. 900° C. *furnace cooled*	129	116	119
reheated 1½ hrs. 500° C.	137	133	120
6 hrs. 500° C.			118

From the present work and the preliminary results the following have been deduced.

(1) Manganese or other additions such as iron and aluminium appear to aid the retention of the alloys in the soft state by quenching. This experience is parallel to that of Gayler and Preston [12] with copper–aluminium alloys.

FIG. 2.—3M as Quenched from 900° C. Deeply Etched. × 500.

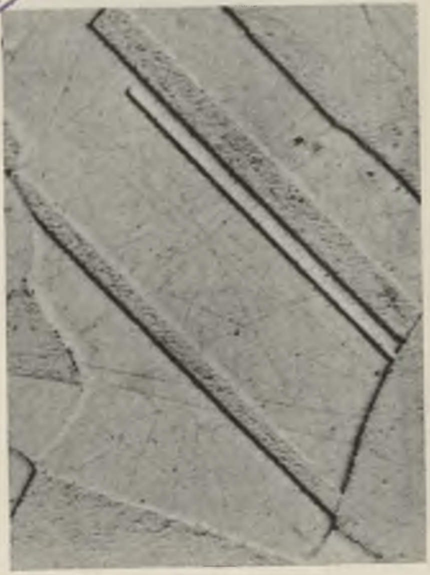

FIG. 3.—3M Quenched 900° C. and Re-Heated 1 Day 450° C. Etched. × 500.

FIG. 4.—3M Quenched 900° C. and Re-Heated 22½ Minutes 540° C. Etched. × 500.

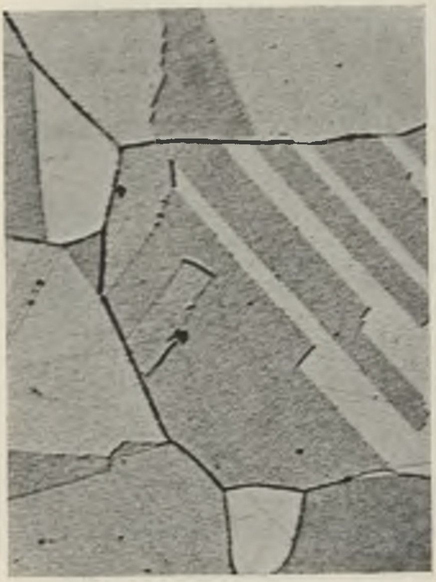

FIG. 5.—3M Quenched 900° C. and Re-Heated 1 Day 540° C. Etched. × 500.

Etched in an Ammoniacal Solution of Ammonium Persulphate.

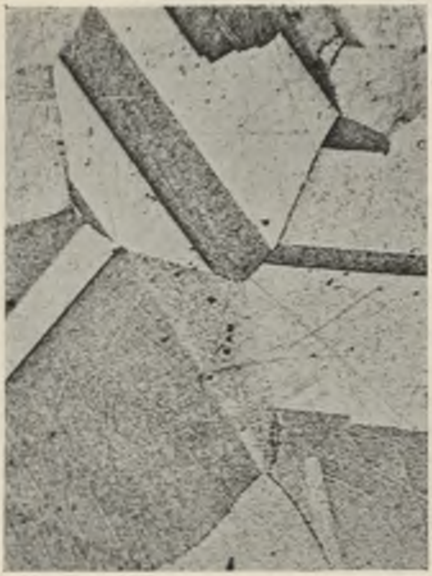

FIG. 6.—3M Quenched 900° C. and Re-Heated 1½ Hrs. 650° C. Etched. × 500.

FIG. 7.—3M Quenched 900° C. and Re-Heated 1 Day 650° C. Etched. × 500.

FIG. 8.—3M Slowly Cooled from 900° C. Etched. × 500.

FIG. 9.—5P Slowly Cooled from 900° C. Etched. × 500.

Etched in an Ammoniacal Solution of Ammonium Persulphate.

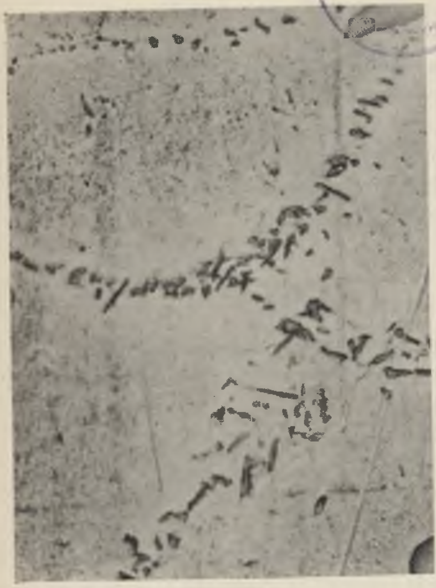

Fig. 10.—5P Slowly Cooled from 900° C. Etched. × 1500.

Fig. 11.—5P Slowly Cooled from 900° C. Etched. × 2000.

Fig. 12.—Alloy S Containing 20% Nickel + Silicon in Atomic Ratio 1 Ni/1 Si, Annealed 1 Week 700° C. and Quenched. Etched. × 150.

Fig. 13.—Alloy Y Containing 50% Nickel + Silicon in Atomic Ratio 2 Ni/1 Si, Annealed 1 Week 700° C. and Quenched. Unetched. × 150.

All except Fig. 13 Etched in an Ammoniacal Solution of Ammonium Persulphate.

(2) Decrease in nickel + silicon content from 5 to 3 per cent. appears to favour the retention of the alloys in the soft state at lower rates of cooling.

(3) Increase in nickel + silicon content from 3 to 5 per cent. increases the rate of attainment of hardness during ageing.

(4) Addition of manganese retards somewhat the hardening during ageing.

MICROSCOPICAL EXAMINATION.

The microstructures of all the specimens of alloys 3M, 5P, and 5M subjected to heat-treatment were examined after etching in an ammoniacal solution of ammonium persulphate.

Alloy 3M when quenched from 900° C. consisted of twinned crystals of a single solid solution. Even after protracted etching, little or no contrast has been observed between adjacent grains in this quenched material, as indicated in Fig. 2 (Plate I). In general, no marked change in microstructure results from tempering the quenched alloy for a shorter time than is necessary to produce the maximum hardness at the selected tempering temperature. On tempering the alloy at 450° C., however, a slight contrast is apparent between the twin-bands after treatment for 1 day, although the maximum hardness is not attained in that period, see Fig. 3 (Plate I).

A marked change which occurs during softening after the attainment of maximum hardness is characterized by the formation of tarnish films, which give rise to colour contrast between adjacent grains and also between the twinned portions of the individual crystals. The contrast increases progressively with the duration of ageing, as is indicated in Figs. 4–7 (Plates I–II).

The changes in microstructure which occur on tempering the other alloys studied, 5P and 5M, are precisely similar to those occurring in alloy 3M.

No resolvable particles of a second phase have been found to occur in tempered specimens, whereas specimens of the alloys slowly cooled from 900° C. over a period of several hrs. clearly exhibit such particles. Fig. 8 (Plate II) shows that in alloy 3M after furnace-cooling from 900° C. a fine shower of small particles is present within the crystals, whilst larger masses have segregated to the grain boundaries. The structure of alloy 5P after similar heat-treatment is shown in Figs. 9, 10, and 11 (Plates II–III). Here the second constituent occurs in three distinct forms, namely, a very fine shower (Fig. 11), larger masses segregated to grain boundaries (Fig. 9), and colonies of particles of comparatively large size which do not lie in or near grain boundaries. One such colony is seen in the large crystal shown at the centre of Fig. 9. The particles within these colonies are sometimes rounded (Fig. 9), but more frequently are plate like (Fig. 10). The colonies appear to originate in the decomposition of a phase stable only at the higher temperatures (as is the β-phase of the silicon–copper system), whilst the fine shower is deposited directly from the main copper-rich solid solution below the decomposition temperature of that phase. Evidence of the existence of a phase which is unstable at lower temperatures has also been put forward by Wilson, Silliman, and Little. In alloy 3M, however, heat-treatment for 10 minutes at 700° C., following a quenching treatment from 900° C., did not result in the separation of a second phase, although some softening took place after hardening.

The particles of a second constituent which occur in the slowly-cooled specimens of alloys 3M, 5P, and 5M are silver-grey in colour, when viewed either by vertical or oblique (dark ground) illumination. In nickel–silicon–copper alloys with higher nickel and silicon contents, a phase of similar appearance was found to occur in increased quantities. Figs. 12 and 13 (Plate III) show two such alloys, *S* and *Y*, the composition of which are :

	S.	*Y.*
Copper, per cent. . . .	80	50
Nickel, ,, . . .	13·8	40·3
Silicon, ,, . . .	6·2	9·7

Both alloys consist of a eutectic together with a primary constituent. In alloy *S* the eutectic consists of a continuous background of the silver-grey phase in which small particles of a copper-rich phase are dispersed. Dendrites of the copper-rich phase are also present. In alloy *Y* the eutectic consists of almost equal proportions of the copper-coloured phase and the silver-grey phase, which also occurs as the primary constituent. In these alloys the copper-rich phase retains the red colour of copper, and it is evident that the silver-grey phase contains the bulk of the nickel and silicon contents of the alloy. As the proportion of the copper-rich phase which occurs in these alloys is in each case much lower than the copper content of the alloy, the silver-grey phase must also contain a large proportion of the copper content. This phase occurs in a higher proportion in alloy *S* than in alloy *Y*, although the nickel + silicon content of alloy *Y* is higher than that of alloy *S*.

It is concluded, therefore, that this constituent is a ternary phase of widely variable composition. This conclusion has been confirmed by the microscopical examination of other alloys containing between 10 and 50 per cent. of nickel + silicon. Corson's suggestion that the phase which separates during the age-hardening of nickel–silicon–

copper alloys is the binary compound Ni_2Si consequently appears to be untenable.

EXAMINATION BY CHEMICAL METHODS.

In conjunction with the X-ray work, which is mentioned later, an attempt was made to obtain by partial chemical solution a concentrate of the phase separating from the alloy 3M on prolonged ageing. On immersion of specimens in a slight excess of aqueous solutions of nitric acid (250 c.c. concentrated acid per litre) an insoluble residue remained, whose weight varied according to the time and temperature of heat-treatment, as is shown in Table IV. At 540° C. little residue resulted from the acid treatment of specimens heat-treated for less than one day, despite the considerable softening (from 163 to 118) which had occurred by this time. The examination of residues confirmed the progressive structural changes during the later stages of ageing, which was indicated under the microscope by the progressive development of differences in response to etching.

TABLE IV.

Heat-Treatment.		Brinell Hardness.	Residue, Per Cent. by Weight of Alloy 3M.
Temperature, ° C.	Time.		
300	1½ hrs.	64	trace
300	6 hrs.	82	trace
300	1 day	97	trace
300	4 days	98	trace
540	22½ minutes	163	0·037
540	1½ hrs.	147	0·033
540	6 hrs.	130	0·073
540	1 day	118	1·51
540	4 days	98	2·42
540	16 days	88	2·29*
540	64 days	85	2·58

* This value is for a small specimen from the centre of the original cube. The percentage residue for the outer part of the same specimen was 2·85.

In this acid treatment it is probable that the nickel and silicon present in the copper-rich solid solution or in a highly-dispersed distribution in the copper-rich phase are dissolved during the solution of copper, whereas the nickel and silicon in the larger particles of second phase formed during tempering are oxidized by the reagent, not dissolved. The residue consisted usually of a mixture of approximately *equimolecular* amounts of NiO and SiO_2. On account of the oxidation of the nickel and silicon, this residue was of little use for the X-ray examination.

X-RAY EXAMINATION OF QUENCHED AND AGED MATERIAL.

Attempts to follow the course of ageing of alloy 3M by observation of changes in the lattice parameter were not successful, as the grain-size of the alloy was rather large for accurate parameter measurements. The total variation in lattice parameter caused by solution of nickel and silicon in copper is very small. The detection of the small amount of a second phase was not possible, even in the slowly cooled alloys, owing to the feeble intensities of the lines.

RÉSUMÉ OF THE EXPERIMENTAL INVESTIGATION OF NICKEL–SILICON–COPPER ALLOYS.

The investigation comprised the survey of the age-hardening of an alloy, 3M, containing 3 per cent. of nickel and silicon with the addition of 0·3 per cent. of manganese, and also included a number of comparison experiments with alloys containing 5 per cent. of nickel and silicon with and without additions of manganese—alloys 5M and 5P, respectively. In each alloy the nickel and silicon are present in the atomic ratio 2 Ni/1 Si. The main conclusions from this study are :

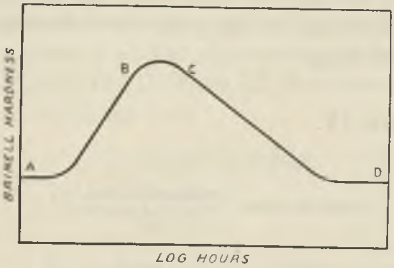

FIG. 14.—Schematic Diagram of Hardness Changes During Age-Hardening.

(1) Alloys containing additions of manganese, iron, &c., may be retained in the soft state by quenching in water from 900° C. Without these additions the alloys are not wholly retained in the soft condition.

(2) The quenched alloys do not change appreciably in their properties at room temperature.

(3) At higher temperatures age-hardening occurs, as is indicated in Fig. 1, which refers to the quenched alloy 3M.

(4) In Fig. 1, whose co-ordinates represent Brinell hardness and a logarithmic time-scale, it will be seen that at such temperatures as 450°–540° C. the ageing curve has the form indicated in Fig. 14. At lower temperatures for the periods of time considered, the curves experimentally determined are of a similar type of the early part of Fig. 14, *i.e.* the portion *AB*, whilst at higher temperatures the curves resemble the latter part, *i.e.* the portion *CD*.

(5) For alloy 3M (3 per cent. nickel + silicon with 0·3 per cent. manganese), complete hardening of the quenched alloy below 400° C.

requires more than 64 days, the rate of change decreasing with decrease in temperature. At higher temperatures, hardening is completed in progressively shorter times (*e.g.* less than 1 minute at 700° C.) and is followed by softening (see p. 290). The hardness after a complete ageing sequence (hardening followed by softening) appears to be comparable to that of quenched material, *i.e.* approximately 60 Brinell.

(7) When the *time* co-ordinates of the maxima of hardness–log. time curves are transferred to a plot of the type employed in Fig. 15, in which the ordinates are a log. time-scale and a scale based on the reciprocals of the temperatures of ageing expressed in degrees absolute (° K.), the points for treatments at 400°, 450°, 500°, and 540° C. lie on or near a straight line. The values for the treatments at 600°, 650°, and 700° C., obtained in somewhat different experimental conditions, are displaced from the straight line in the direction of increased time.

(7) For alloys 5P and 5M results are not inconsistent with a straight line of maximum hardness on a plot of the type employed in Fig. 15. In each instance hardening occurs somewhat more rapidly than in alloy 3M.

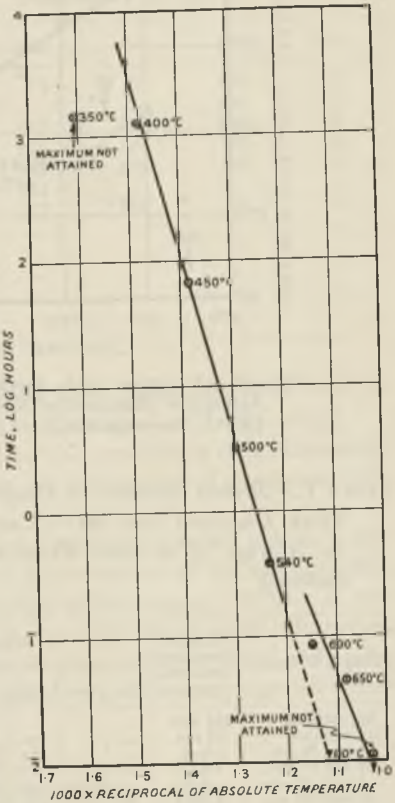

FIG. 15.—Attainment of Maximum Hardness During Ageing of Nickel–Silicon–Copper Alloy, 3M. (N.P.L. Investigation.)

(8) The maximum hardness attained by alloy 3M at a variety of temperatures does not vary greatly with temperature. In general the maximum hardness increases in a more or less linear way with decrease in temperature, as shown in Fig. 16.

(9) Microscopic examination showed that a progressive change in etching properties occurs during ageing and also indicated that the phase formed during ageing is a ternary phase of variable composition.

(10) Chemical separation of residues showed that the progressive change in response to etching is due to the progressive separation of a second phase.

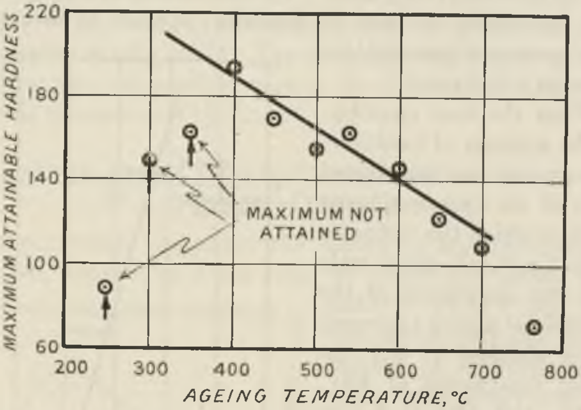

Fig. 16.—Variation with Ageing Temperature of Maximum Attainable Hardness of Nickel–Silicon–Copper Alloy, 3M. (N.P.L. Investigation.)

Table V.—*Brinell Hardness on Cross-Sections of* 3*M Specimens* 12 *mm. Thick, Quenched from* 900° *C. and Reheated. Hardness Values are the Average of at least Three Determinations.* (2 *mm.*/40 *kg.*/30 *seconds.*)

Time in Furnace.	Time at Tempering Temperature.	Tempering Temperature, ° C.										
		15.	250.	300.	350.	400.	450.	500.	515.	540.	600.	650.
42½ minutes	22½ min.	...	...	...	...	...	102	...	...	163	...	...
110 minutes	1½ hrs.	...	...	64	83	99	123	154	150	147	...	87
6 hrs. 20 min.	6 hrs.	...	...	82	101	128	150	152	...	130	96	79
1 day 20 min.	1 day	63	72	97†	110	158	158	146	...	118	87	77
4 days 20 min.	4 days	...	79	98	130	168	172	109	...	98	...	...
16 days 20 min	16 days	63	82*	149	146	182	147	100	...	88	...	...
28 days	28 days	...	...	...	...	...	124	...	...	...	...	...
64 days	64 days	63	89	...	163‡	...	...	...	...	85	...	...

* 15 days 250° C. † 23½ hrs. 305° C. ‡ 63 days 350° C.

Conclusions.

This paper is a report of an experimental investigation into the age-hardening of certain nickel–silicon–copper alloys, the results of which are summarized in a résumé on p. 300, and the Appendix is a consideration of a number of points relating to the age-hardening

TABLE VI.—*Brinell Hardness* (1 *mm.*/10 *Kg.*/30 *seconds*) *of* 3*M Strip* 1 *mm. Thick, Quenched from* 900° *C. and Reheated. Hardness Values are Averages of Three Determinations. Brinell Hardness of Alloy before Use* = 52.

Time in Furnace, Minutes.	Time at Tempering Temperature (approx.).	Temperature of Furnace, ° C.				
		540.	600.	650.	700.	765.
1	25 sec.	...	74	93	110	55
1½	55 sec.	...	...	...	102	51
2	85 sec.	...	112	105	100	52
3	145 sec.	...	136	120	95	54
5	265 sec.	131	122	122	89	53
7	385 sec.	...	141	...	...	...
10	9 min.	136	127	111	83	54
15	14 min.	126	...	...	...	...
20	19 min.	127	...	...	...	...
30	29 min.	134	...	...	...	...
40	39 min.	142	...	...	...	...
45	44 min.	146	...	...	...	...

of nickel–silicon–copper alloys which have been compared with information in the literature relating to other age-hardenable alloys.

Particular attention is directed to the importance of a relationship found between temperature and time of attainment of maximum hardness or maximum resistivity.

The work described in this paper has been carried out as a preliminary to an investigation of the inter-relation of the age-hardening and creep performance of the nickel–silicon–copper alloys. A programme of creep tests is now in progress and should yield information regarding the effect on creep properties of ageing prior to test and ageing during test, and also indicate the effect of continuously-applied tensile stress upon age-hardening.

ACKNOWLEDGMENTS.

The authors desire to thank Dr. C. H. Desch, F.R.S., Superintendent of the Metallurgy Department, The National Physical Laboratory, for his interest during the progress of the work and Mr. C. Wainwright, M.Sc., for carrying out the X-ray examination. They are also indebted to Mr. J. A. G. Smith, late of this Department and now of the Physics Department, The National Physical Laboratory, for his able assistance in the experimental work.

APPENDIX.

OBSERVATIONS ON THE RELATIONSHIP OF TIME, TEMPERATURE, AND CONCENTRATION AS FACTORS IN AGE-HARDENING.

By E. H. BUCKNALL, M.Sc., and C. H. M. JENKINS, D.Sc., A.R.S.M.

In the investigation of the age-hardening of nickel–silicon–copper alloys information was obtained which serves to indicate the relationship of time, temperature, and composition as factors in the age-hardening of these alloys.

In the following discussion these results are compared with the collected experimental data of other workers on the age-hardening of alloys of aluminium, copper, iron, &c., and certain new deductions of a general nature are advanced. As many hundreds of scientific papers deal with age-hardening, it is impossible to refer in this paper to more than a limited proportion. A list of about one hundred age-hardening alloy systems was given by Merica [18] in 1932 in his very complete critical survey of researches on age-hardening.

The first observations of ageing, *i.e.* spontaneous change of properties with time, were concerned with alloys at room temperature. The cases in order of discovery were: (1) secular changes in the magnetic properties of transformer steels [13]; (2) resistance changes in quenched steels [14]; (3) the "improvement" of the aluminium alloys styled "Duralumin" [15]; and (4) the hardening of certain alloys of lead.[16] Merica, Waltenburg, and Scott [17] and Hanson and Gayler [38] showed that the age-hardening of Duralumin is a consequence of a decrease in the solid solubility of alloying elements in aluminium with decrease in temperature, and suggested that age-hardening behaviour may be expected in other systems in which solubility is similarly related to temperature. The work of Sykes [19] on iron–molybdenum alloys and Corson [2] on copper alloys showed that in certain alloys age-hardening may virtually be confined to a range of temperature above the normal. Since then the number of alloys known to harden at elevated temperatures has increased beyond that of alloys in which ageing occurs at room temperature, as may be seen from the data of Merica previously referred to.

For the purpose of comparing the results of experiments on nickel–silicon–copper alloys with other experimental data regarding age-hardening, it is convenient to discuss them under four headings.

A.—RELATION OF THE TIME OF AGEING TO THE HARDNESS. (Composition of alloy and temperature of ageing being fixed.)

It has been shown above that hardness–log. time curves for the nickel–silicon–copper alloy 3M conform to the general type indicated in Fig. 14.

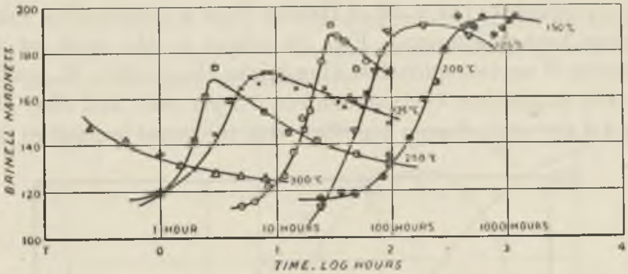

Fig. 17.—Hardness Changes During Ageing of β-Brass, 59·15% Cu. (Hansen.[20])

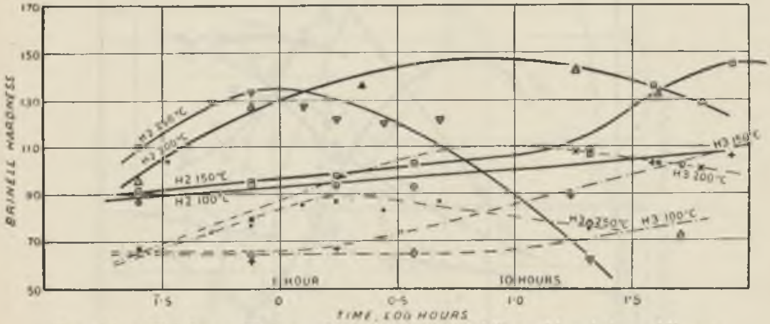

Fig. 18.—Hardness Changes During Ageing of Two Aluminium Alloys. (Gayler and Preston.[21])

Similar plottings have been made from data in the literature relating to a variety of alloys of aluminium, copper, iron, gold, lead, magnesium, nickel, silver, and zinc. In these cases the experimental points fit curves of the type shown in Fig. 14 to within the degree of error after allowing for such local inconsistencies in hardness as are always encountered in age-hardenable alloys. Examples are described below. In the case of certain iron–nickel–chromium alloys previously mentioned the hardness–log. time curves show two distinct peaks. In these alloys, however, the hardening might have occurred from more than one cause.

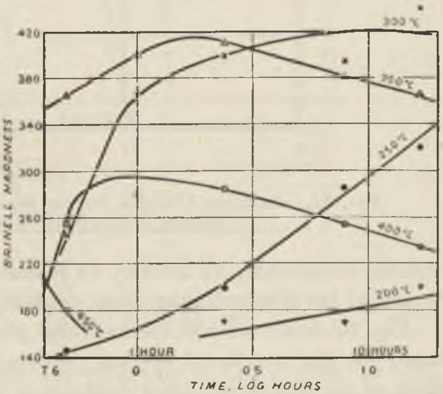

Fig. 19.—Hardness Changes During Ageing of a Beryllium–Copper Alloy. (Dahl.[22])

Fig. 17 relates to the work of Hansen [20] on a β-brass alloy subjected to various heat-treatments. Fig. 18 relates to the work of Gayler and Preston [21] on two quenched aluminium alloys, alloy H_2 containing copper 4·0, magnesium 0·51, and silicon 0·3 per cent. and alloy H_3 containing 4·5 per cent. copper together with the usual impurities in commercial aluminium, whilst Fig. 19 relates to the work of Dahl [22] on a quenched beryllium–copper alloy, containing 2·5 per cent. beryllium.

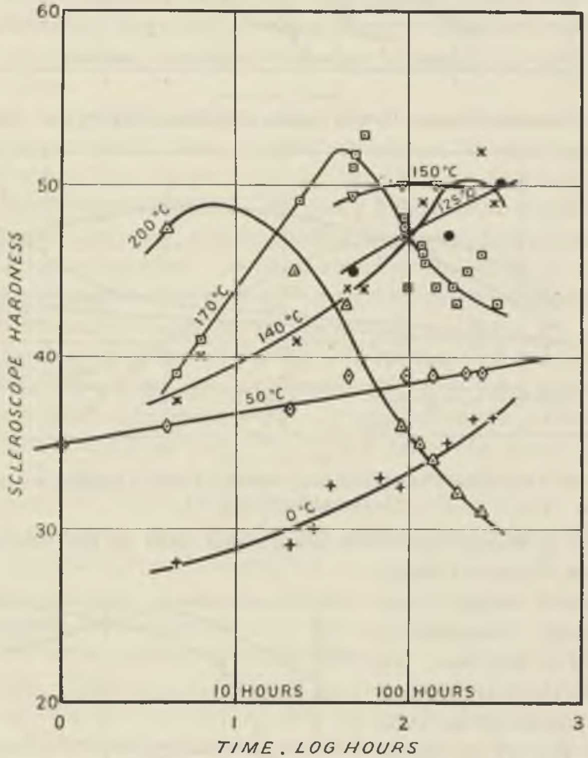

Fig. 20.—Hardness Changes During Ageing of an Aluminium Alloy. (Merica, Waltenberg, and Scott.[17])

Fig. 20 shows scleroscope hardness plotted against log. time, and is based on the results of Merica, Waltenberg, and Scott [17] for rolled sheet of an aluminium alloy containing copper 3·74, magnesium 1·08, iron 0·52, silicon 0·30 per cent.

Fig. 21 shows a series of tensile strength–log. time graphs for the aluminium alloy Lautal, containing 2 per cent. silicon and 4 per cent. copper, based on the results of Bohner.[23]

It will be seen that in each of the cases considered above, the peaks of the curves are translated in the direction of shorter times as the result of increase in ageing temperature.

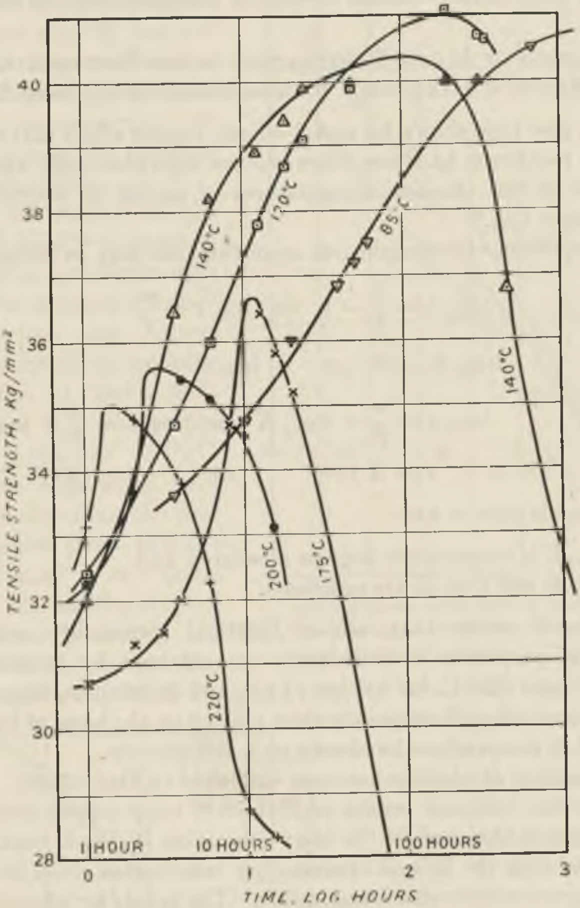

FIG. 21.—Changes in Tensile Strength During Ageing of the Aluminium Alloy "Lautal." (Bohner.[23])

It was found, as a result of the consideration of data for this section, that logarithmic plotting possesses advantages over the direct method of plotting and also over the method favoured by Masing, Dahl, and their co-workers, namely, against a time-scale divided proportionately to the square root of the ageing time. To indicate the trend of experimental results by direct plotting, especially in the early stages of the age-hardening, involves considerable difficulty. Besides affording a reasonable method of condensing the time-scale, the logarithmic method has the advantage—not obtainable in the square root method—of affording geometrically similar curves for a large number of materials.

B.—RELATION OF AGEING TEMPERATURE TO THE TIME OF ATTAINMENT OF MAXIMUM HARDNESS. (Composition of alloy being fixed.)

It has now been shown for nickel–silicon–copper alloys that the times to attain maximum hardness when plotted logarithmically against the reciprocal of the absolute temperatures of ageing lie approximately on a straight line.*

The equation of a straight line upon this plot may be written

$$\log_{10} t = \frac{m}{T} - k \quad \text{or} \quad \log_e t = \frac{m}{T} - c$$

Putting $$-\log_{10} K = k \quad \text{or} \quad -\log_e C = c$$

We have $$\log_{10} t = \frac{m}{T} + \log_{10} K \quad \text{or} \quad \log_e t = \frac{m}{T} + \log_e C$$

i.e. $$t = K\,10^{m/T} \qquad \text{or} \qquad t = Ce^{m/T}$$

Where t is time in hrs.;

T is temperature degrees absolute; and
m and C or K are constants.

Matther[24] states that almost identical (presumbly maximum) mechanical properties of Duralumin are obtained by treatments at 150°, 200°, and 225° C. for 100 hrs., 1 hr., and 10 minutes, respectively. It is of interest that these points when plotted on the basis of log. time–reciprocal of temperature lie closely on a straight line.

This method of plotting has been employed in Figs. 22–28. Fig. 22 relates to the hardness results of Hansen[20] for β-copper–zinc alloys. The five points obtained for the alloy containing 59·15 per cent. copper are derived from the Brinell hardness–log. time curves given in Fig. 17, and lie approximately on a straight line. The points for alloys of other copper contents are taken from Brinell hardness–log. time curves which have not been included here.

Fig. 23 relates to the work of Gayler and Preston,[21] previously described in connection with Fig. 18. At 150°, 200°, and 250° C. the

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* It is of interest to observe that a similar exponential law has been shown by Dushman and Langmuir[36] to apply to diffusion in the solid state. These authors have traced a linear relationship between log D (the diffusivity) and $1/T$ to hold for the diffusion of thorium through tungsten and gold through lead. This point is more fully discussed later (p. 317).

hardness–log. time curves for alloy H_2, reach maxima, within the range of the experimental investigation. These points lie fairly on a straight line. In the case of alloy H_3 it is not clear from the experimental results whether the hardness reaches its maximum at 150° C. within the range of the investigation.

Fig. 24 relates to the work of Dahl,[22] previously described in connection with Fig. 19, in which the Brinell hardness–log. time curves pass through maxima for the treatments at 300°, 350°, and 400° C. whilst the maximum of the 450° C. curve has apparently been passed earlier than the first experimental point and the 250° C. curve is still rising at the end of the experimental investigation.

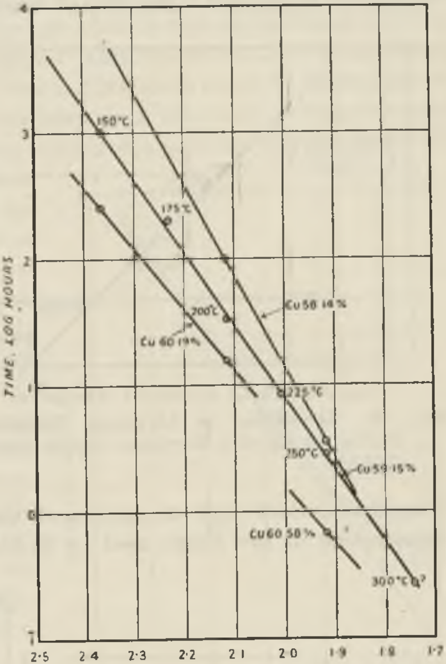

FIG. 22.—Attainment of Maximum Hardness During Ageing of β-Brasses. (Hansen.[20])

Fig. 25 relates to the results of Merica, Waltenberg, and Scott,[17] described above in connection with Fig. 20, in which the scleroscope hardness–log. time curves pass through maxima for the treatments at 140°, 150°, 170°, and 200° C. These points when transferred to Fig. 25 lie fairly on a straight line.

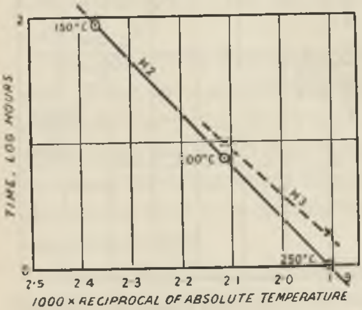

FIG. 23.—Attainment of Maximum Hardness During Ageing of Two Aluminium Alloys. (Gayler and Preston.[21])

Fig. 26 shows the tensile test results of Bohner[23] on Lautal, described above in connection with Fig. 21, in which the curves for treatments at 85°, 120°, 140°, 175°, 200°, and 220° C. pass through maxima within the period of the experimental investigation. These points when transferred to Fig. 26 lie near to a straight line.

Fig. 27 also relates to Lautal and is based on the Brinell hardness results of Meissner.[25] The Brinell hardness–log. time curves, which are not included here, reach maxima for the treatments at 125°, 140°, 150°, 160°, 175°, 200°, and 220° C. As will be seen from Fig. 27, the points for the five lower temperatures lie nearly on a straight line but those at 200° and 220° C. are displaced from the line in the direction of increased time. Comparison of Figs. 26 and 27 indicates that the linear portions of the two curves are not quite coincident. Such lack of agreement may result from differences in composition of the alloys used by Bohner and Meissner or to a real displacement between the maxima of Brinell hardness and tensile strength curves for the ageing of this material.

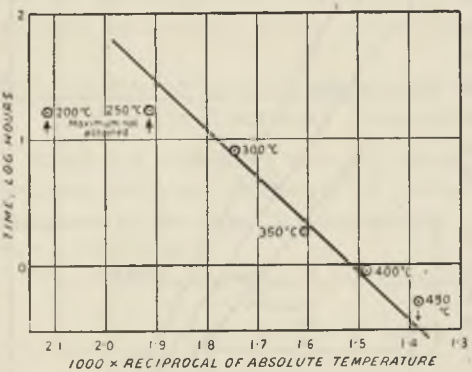

FIG. 24.—Attainment of Maximum Hardness During Ageing of a Beryllium-Copper Alloy. (Dahl.[22])

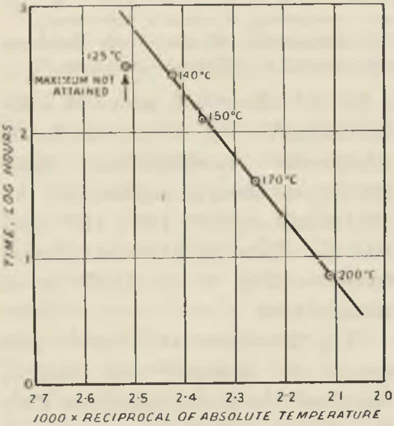

FIG. 25.—Attainment of Maximum Hardness During Ageing of an Aluminium Alloy. (Merica, Waltenberg, and Scott.[17])

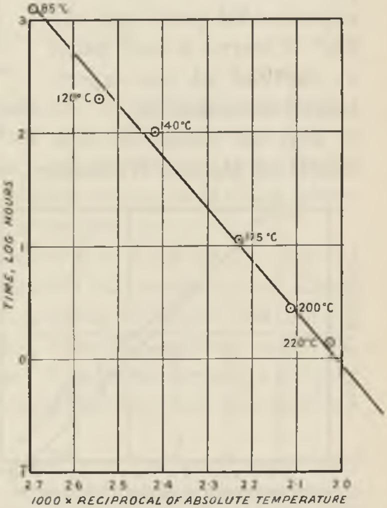

FIG. 26.—Attainment of Maximum Tensile Strength During Ageing of the Aluminium Alloy "Lautal." (Bohner.[23])

It is also interesting in connection with this section to discuss changes in some other physical properties in relation to time and temperature. The electrical resistivity of an alloy which is undergoing transformation from a homogeneous to a duplex state invariably shows an *overall* decrease during the change. In a few instances of age-hardening alloys, there has been shown to be an increase in resistivity during the early stages of ageing to a maximum value and a decrease has then followed. Only in one instance have adequate results been found for the consideration of the effect of temperature on the time of attainment of maximum resistivity, namely, in Hansen's study of the β-copper–zinc alloys.[20] Fig. 28 relates to the alloy containing 59·74 per cent. copper reheated after quenching from 870° C.; here the points representing the time of attainment of maximum resistivity at 150°, 175°, 200°, 225°, 250°, 275°, and 300° C. lie near a straight line on the log. time–reciprocal of absolute temperature plot. In these β-copper–zinc alloys the maxima of resistivity occur consistently earlier at all ageing temperatures than the hardness maxima.

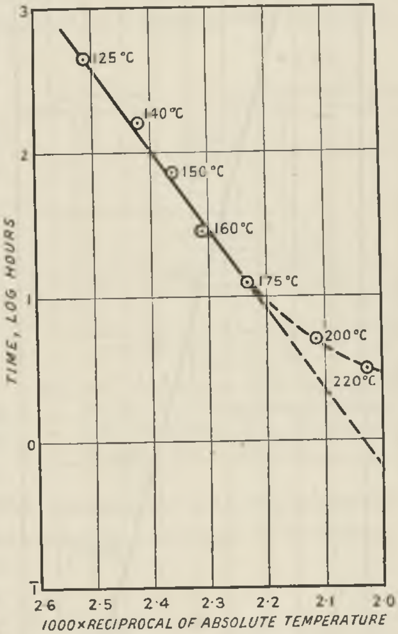

Fig. 27.—Attainment of Maximum Hardness During Ageing of the Aluminum Alloy "Lautal." (Meissner.[25])

Rollason[26] in his study of weld decay in steels of the 18 per cent. chromium, 8 per cent. nickel type, has shown that the time and temperature of heat-treatment necessary to bring about intergranular attack in a cupric reagent are also represented by a straight line on a log. time–reciprocal of absolute temperature plot.

It is also of interest that in the work of Köster[35] on iron alloys containing nitrogen, from which a nitride (possibly Fe_4N) separates during ageing at somewhat elevated temperatures, irrespective of whether the material has previously been quenched or air cooled, the time and temperature of attainment of maximum magnetic remanence are not inconsistent with the logarithmic relation proposed above for the attainment of maximum hardness.

C.—Relation of the Temperature of Ageing to the Maximum Attainable Hardness. (Composition of alloy being fixed.)

The maximum hardness values attained by nickel–silicon–copper alloys increase more or less linearly with decrease in ageing temperature, as is shown in Fig. 16. Figs. 29 and 30 indicate the effect of temperature on the maximum attainable hardness of β-copper–zinc alloys (Hansen [20]) and beryllium–copper alloys (Dahl [22]).

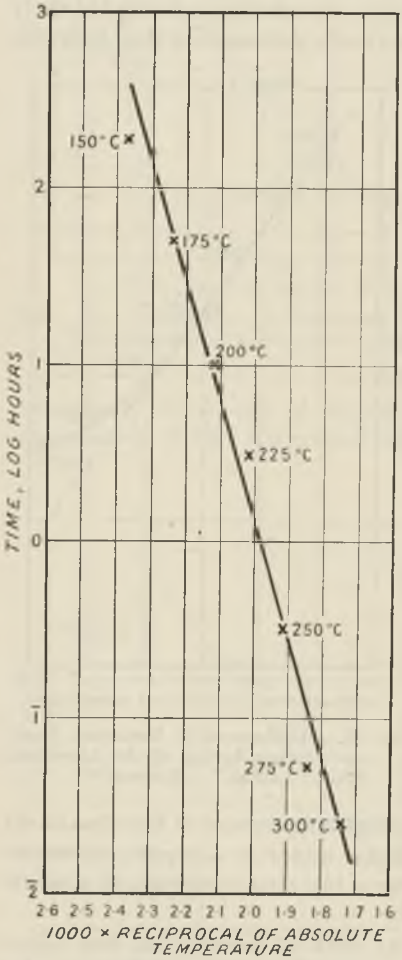

Fig. 28.—Attainment of Maximum Electrical Resistivity During Ageing of β-Brass, 59·74% Cu. (Hansen.[20])

Experimental data given in the literature in general appear to indicate that an increase in maximum attainable hardness usually results from decrease in ageing temperature; thus the degree of hardness attainable is related to the amount of second phase which is precipitable.

A conclusion in the literature that the maximum attainable hardness values are greatest at an intermediate ageing temperature (termed by Meissner [25] the critical ageing temperature) does not appear to be well founded. Such a view may arise from a comparison of the highest hardness values which happen to have been obtained in a series of experiments not continued for a sufficiently long time for the true maximum to be reached at the lower temperatures.

D.—Effect of Composition on Age-Hardening.

It is well known that in a number of instances a variety of different additions render a metal capable of age-hardening, *e.g.* copper is hardenable when alloyed with phosphorus,[27] iron,[28] beryllium,[22, 29] cobalt,[2, 30] or nickel and silicon,[2, 3, 4, 5, 6, 7, 8] &c. A full discussion of the effect of composition on age-hardening is beyond the scope of the present paper. The discussion which follows is limited to alloys which exhibit age-hardening as the result of the "separation" during ageing of identical phases from the same metal. Such alloys may differ in their contents of the components of the separating phase and also in their contents of "auxiliary" alloying elements which are not components of the separating phase, but remain in an unaltered distribution, either in solid solution, or in combination as a permanently separated phase, throughout the ageing. The influence of such variations in composition is considered below with relation to (1) rate of hardening, and (2) attainable hardness.

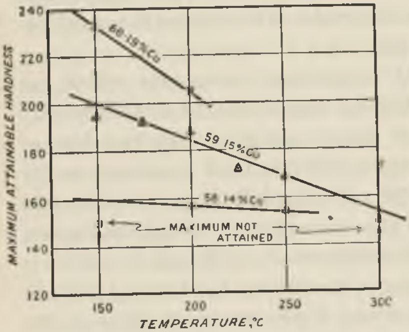

FIG. 29.—Variation with Ageing Temperature of Maximum Attainable Hardness of β-Brass. (Hansen.[20])

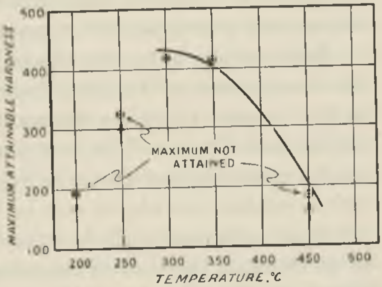

FIG. 30.—Variation with Ageing of Temperature of Maximum Attainable Hardness of a Beryllium–Copper Alloy. (Dahl.[22])

(1) *Rate of Hardening.*

The amount of those alloying metals which form the components of the separating phase has frequently been shown to have an effect on the rate of attainment of hardness, as, for instance, by Smith[29] in the case of beryllium–copper alloys. Alloys containing 2·5 per cent. and more of beryllium attain maximum hardness at 575° F. (300° C.) in 3 hrs. or less, whereas alloys with 0·9–1·7 per cent. beryllium continue to harden after 24 hrs. at 575° F. (300° C.).

Another remarkable example of this effect is afforded by iron–gold alloys. According to data given by Nowack,[31] an alloy containing 15 per cent. iron reaches a maximum hardness in approximately 2 hrs. at 550° C., whereas one containing 20 per cent. iron does so in 2¼ hrs. at 400° C. and in less than 20 minutes at 550° C. On the other hand, the results of Hensel and Larsen[32] for impure titanium–copper alloys indicate that increase in titanium content from 2·58 to 4·74 per cent. has little effect on the time taken to reach a maximum hardness value at 400° or 450° C.

The relationship between the temperature and the time of attainment of maximum hardness, which has been developed in Section *B* (see p. 308), affords a means of considering this effect of composition on rate of hardening in a quantitative manner. In a limited number of cases sufficient data are available for the purpose. For example, from Fig. 22 which relates to β-copper–zinc alloys [20] it is apparent that increase in concentration of the ageing constituent, copper, accelerates the ageing at the lower temperatures but reduces somewhat the accelerating action of increase in temperature.

Information as to the effects of "auxiliary" elements which are not components of the precipitated phase appears to be available only in the instance of copper–aluminium alloys, and even here the data of Gayler and Preston [12] do not permit a fully critical examination by similar means to that shown in Fig. 22. Their work shows that increase in iron content retards, or may even prevent entirely, the age-hardening of copper–aluminium alloys at room temperature, although it has little or no effect on the time of attainment of maximum hardness at 200° C. Silicon, on the other hand, has only a very slight retarding effect on the age-hardening of these alloys at room temperature. When silicon and iron are present together the deleterious effect of the iron is somewhat reduced. The action of manganese additions to nickel–silicon–copper alloys appears to be similar to that of iron in copper–aluminium alloys. It is presumed that these impurities which retard or inhibit age-hardening do so by reducing the rate of diffusion of solute atoms through the solvent lattice. Gayler and Preston also found that as a result of the addition of 0·5 per cent. magnesium to an alloy containing copper 4·04, iron 0·32, and silicon 0·012 per cent. the property of age-hardening at room temperature is restored. The alloy containing magnesium hardens to the same extent as a *pure* 4 per cent. copper–aluminium alloy, but Gayler and Preston consider that different processes are involved in the two cases, some Mg_2Si being precipitated, as well as $CuAl_2$, from the magnesium-bearing alloy.

(2) *Maximum Attainable Hardness.*

In the case of nickel–silicon–copper alloys, increase in alloy content from 3 to 5 per cent. appears to have a slight effect in increasing the hardness attainable at all ageing temperatures.

The data for β-brasses [20] given in Fig. 29 indicate that increase in the concentration of copper, and thus increasing the proportion of α-brass which is capable of separation, markedly increases the attainable hardness, particularly at the lower ageing temperatures. In titanium–copper alloys a similar increase (220–290 V.P.N.) in the hardness attainable at 400°–450° C. accompanies increase of titanium content from 2·58 to 4·74 per cent. (Hensel and Larsen[32]). Nowack's[31] data for iron–gold alloys indicate that increase in iron content from 15 to 20 per cent. increases the Brinell hardness attained at 550° C. from approximately 160 to more than 260.

In copper–aluminium alloys the attainable hardness is probably more markedly affected by auxiliary constituents than by increase in copper content. For example, Gayler and Preston[12] showed that an alloy containing 4·12 per cent. copper with 0·01 per cent. silicon and 0·01 per cent. iron will attain a Brinell hardness of 100 on treatment at 200° C., whereas Kempf and Dean[33] (while discussing the results of Gayler and Preston) indicated that an alloy of higher copper content (5·82 per cent.) but with higher contents of silicon and iron (0·063 per cent. silicon and 0·060 per cent. iron) attains a Brinell hardness of only 90 at the same temperature.

It has been shown in Sections *B* and *C* of this paper that the rate of hardening and the maximum attainable hardness of an alloy vary with the ageing temperature. In addition, as shown in Section *D* (1), the rate of attainment of hardness in a series of alloys exposed at the same temperature is generally affected by variation in the concentration of the components of the separating phase and in the concentration of "auxiliary" alloying elements. In consequence, to understand the effect of composition on "hardenability" it is not sufficient, for purposes of comparison, to expose a series of alloys for one fixed period of time at one temperature. Indeed, even the exposure of a series of alloys for a suitably large number of periods at a *particular* temperature which has been so chosen that within the period of the experiment the hardness of all the alloys increases to a maximum and then decreases, will only result in a correct evaluation of their relative hardenability (and rate of attainment of hardness) at *that* temperature. It is apparent that in tracing the hardenability of a series of alloys at a variety of temperatures the use of the linear relationship between log. time and reciprocal of temperature (developed in Section *B*) will limit the amount of experimental work required.

GENERAL CONSIDERATION OF SECTIONS *A–D*.

It has been shown that the curves connecting either tensile strength or hardness with the logarithm of the time in general conform to the type shown in Fig. 14, namely a curve which rises to a flat maximum and then falls. The maxima of such curves are displaced towards shorter times as a result of increase in ageing temperature. The time values of these maxima lie on or near a straight line on a plot of log. time–reciprocal of absolute temperature. The equation to this line may be written

$$t = Ce^{m/T}$$

Experimental data cited above which relate to the proprietary aluminium alloy Lautal appear to indicate that in this material maximum tensile strength and maximum Brinell hardness are not attained simultaneously.

In an instance where the electrical resistivity passes through a maximum during ageing, the time values corresponding to the peaks of resistivity–time curves appear to be similarly related to temperature. The resistivity maxima appear, however, consistently earlier than the hardness maxima.

The various properties are differently affected by structural constitution: for example, some alloys which exhibit ageing changes in their Brinell hardness do not suffer any marked variation in tensile strength during ageing, an observation which has been explained by Rosenhain.[37] Again, the electrical resistivity of an alloy which is undergoing transformation from a homogeneous to a duplex state invariably shows an *overall* decrease during the change, whereas the Brinell hardness of the equilibrium product does not in general differ markedly from that of the homogeneous alloy.

A consideration of the theories of age-hardening advanced by Merica, Waltenberg, and Scott [17] (later modified by Merica,[18]), by Rosenhain [34] and by Gayler and Preston [12, 21] shows that it is in the main regarded as the result of two changes in the atomic arrangement within the alloy. These changes are: (1) the formation of clusters or " knots " of solute atoms which have moved from the original random positions in the lattice of the solvent; and (2) the formation of discrete particles of the second phase within these " knots " (" crystallization "). The first of these changes is regarded as increasing the hardness and (sometimes) the electrical resistivity, whilst during the second change the hardness and resistivity are decreasing. A continued increase in hardness after the resistivity has begun to decrease indicates that group formation is proceeding at a time when " crystallization " has commenced, thus these opposing processes are in some measure contemporaneous, as has already been put forward by Gayler and Preston. There is no evidence from X-ray spectra that formation of discrete particles of a second phase commences prior to the attainment of maximum hardness, but it is clear that X-ray methods at present employed do not reveal fully the sequence of changes which occur during ageing, although they do indicate parameter changes which accompany the very late stages of ageing.

The first of the processes which occur during age-hardening may be regarded as an instance of diffusion in the solid state. Increase in temperature would consequently be expected to accelerate the rate of formation of groups according to the same law as applied to the effect of temperature on the diffusion coefficient (Dushman and Langmuir). On the theoretical basis outlined above, the progress of group formation will control the progress of the entire process of age-hardening; therefore a logarithmic relationship would be expected to apply between the times and temperatures at which is reached a definite stage in the process, such as attainment of maximum hardness. That such a relationship exists must be regarded as very good evidence of the veracity of the theory.

On the practical side, the relationship between time and temperature is valuable in affording for the first time a means of interpolation and extrapolation from age-hardening results. For example, if it is known that an alloy achieves maximum hardness in approximately 1 hr. at 200° C. and in approximately 10,000 hrs. at 0° C., calculation shows that maximum hardness will be attained at 100° C. in approximately 30 hrs.

In this connection it is interesting to discuss the age-hardening of alloys of the Duralumin type. It is usual to regard such alloys as being fully aged by exposure at room temperature for 3–5 days * and this hardened material to be permanent. Indeed it is even urged that the age-hardening of Duralumin at room temperature differs from the age-hardening of the same material at elevated temperatures inasmuch as softening after hardening occurs at the higher temperatures whereas no such " over-ageing " effect has been observed at room temperature. It is to be regretted that in the literature there does not appear to be any information relating to prolonged exposure of Duralumin at such temperatures as 50° C. These data if available would serve to disclose the existence of any unusual features in the hardening of this material at low temperatures. At the higher temperatures such as 140°–225° C. the log. time–reciprocal of absolute temperature relationship is obeyed by alloys of this type, as has been shown above. No additional con-

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* In Fig. 20, which relates to an alloy of the Duralumin type, there is no evidence of the attainment of maximum hardness within 13 days at any temperature below 125° C. If, on the other hand, the results at 0° C. are directly plotted against time, a curve rising to a flat maximum at about 300 hrs. appears to trace the behaviour; hence the probable origin of the misunderstanding is the consideration of an exponential process on a direct time basis.

stitutional changes are known to occur in Duralumin alloys below 200° C., consequently it appears reasonable to suggest that the hardness --log. time curve at room temperature may be of the form indicated in Fig. 14. Extrapolation from the higher temperatures of the straight line relationship between the reciprocal of absolute temperature and the logarithm of the time indicates that Duralumin should continue to harden over a period of at least a million years at room temperature, before softening sets in. After a few days ageing at room temperature, the rate of hardening is, however, so slow as to escape detection. It is significant also that the supposedly maximum Brinell hardness values obtained for Duralumin alloys by ageing at room temperature are lower than the values obtained by treatment at 150°–200° C., although decrease in temperature generally increases attainable hardness, and, further, the rate of hardening of Duralumin is reduced to a fraction of the usual rate by decrease in temperature from 15° to 0° C. and becomes practically zero at the temperature of carbon dioxide snow. This retardation of the age-hardening of Duralumin by cold storage is used commercially as a method of retaining quenched rivets in a soft condition.

Arising from the above discussion on Duralumin, it is apparent that the steady high hardness values persist probably owing to the slowness of the rate of change of hardness (in the range around the maximum of Fig. 14). In the selection of alloys for service, particularly at elevated temperatures, where stability of hardness is important, the slowness of the ageing should then be the criterion. Such slowly ageing alloys would of course be brought to a suitable hardened state by an appropriately short heat-treatment at a temperature more elevated than the service temperature. In this connection it should be remembered that alloys containing additions of alloying elements which are not themselves components of the precipitated phase generally age more slowly than *pure* alloys of similar content of the hardening constituent.

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THE DETERMINATION OF CERTAIN PHASE BOUNDARIES IN THE SILVER–ZINC THERMAL DIAGRAM BY X-RAY ANALYSIS.*

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I. G. EDMUNDS,‡ M.Sc.

Synopsis.

The phase boundaries in the region extending from the γ- to the ϵ-phase of the silver–zinc thermal diagram, have been determined by X-ray analysis. The crystal parameters are accurate in general to 1 part in 5000; in some of the determinations the accuracy is much higher than this. The results confirm the existence of the phase fields contained in the generally accepted diagram of the system, but they indicate that the positions of the boundaries need readjustment. The $(\gamma) - (\gamma + \delta)$ boundary requires adjustment in the direction of lower silver content, by about 0·5 per cent. silver by weight at the lower temperatures, and by a progressively greater amount in the opposite direction as the temperature is increased. The $(\gamma + \delta) - (\delta)$ boundary needs to be displaced towards the silver end of the diagram through about 4 per cent. in composition, thus reducing the width of the $(\gamma + \delta)$ region to about half its former value. The $(\delta) - (\delta + \epsilon)$ and $(\delta) - (\delta + \eta)$ boundaries are more nearly parallel to the temperature axis than those shown in the thermal diagram published in the International Critical Tables. At the higher temperatures the $(\delta) - (\delta + \eta)$ boundary moves towards the silver end through about 4 per cent. in composition. The $(\delta + \epsilon) - (\epsilon)$ boundary is parallel to that in the accepted diagram, but needs an adjustment of about 1 per cent. towards the silver end of the diagram.

In a previous paper § an account was given of an investigation carried out by X-ray analysis on silver–zinc alloys. Alloys of different compositions ranging from one end of the equilibrium diagram to the other and quenched from 380° C. were studied. The relations between atomic volume and composition were found for all the pure phases excepting the β-phase, which is unstable at ordinary temperature. From these results, the phase boundaries at 380° C. were deduced. The positions of the boundaries were found to be slightly different from those in the thermal diagram due to Carpenter and Whiteley,|| which is reproduced in the International Critical Tables.

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§ Owen and Pickup, *Proc. Roy. Soc.*, 1933, [A], **140**, 344.
|| Carpenter and Whiteley, *Z. Metallkunde*, 1912, **3**, 145.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LVII, 1935. Reference should accordingly be as follows: *J. Inst. Metals*, 1935, **57** (Advance copy).

In the investigation above referred to, the difficulty of producing alloys rich in silver suitable for X-ray examination was overcome by preparing them by interdiffusion. Alloys in this region will be dealt with in a later communication. In this paper attention is directed to alloys at the zinc end of the diagram, ranging from those in the γ-phase to those in the ε-phase.

EXPERIMENTAL PROCEDURE.

The method employed to determine the positions of phase boundaries in a thermal diagram, a description of the precision cameras used, and the corrections to be applied to obtain accurate values of parameters have been described elsewhere.*

Temperatures were measured by means of nickel–Nichrome thermocouples, which were calibrated frequently in the course of the work by the use of pure metals whose melting points were accurately known. At the highest temperatures dealt with, it was estimated that the error in the measurement of temperature was within ± 3° C. The alloys were prepared, by the usual melting process, in the form of ingots weighing from 30 to 40 grm. As the change in parameter with composition in the γ, δ, and ε phases had already been accurately determined, only alloys in the adjacent mixed regions were used for the present investigation.

The compositions of the alloys were determined by estimating the silver content by a method due to Durrant, but since the mean atomic volume of either constituent in a mixed region at any temperature is independent of the composition of the alloy, it was not essential to know the compositions of these alloys accurately. It was, in fact, only necessary to know whether the alloys were in a mixed region, and it was usually possible to state if they were so by an inspection of the X-ray spectra.

HEAT-TREATMENT.

Each ingot was annealed in an evacuated Pyrex glass tube. The procedure adopted was to anneal several ingots in the furnace at the same time, but in separate tubes. No attempt was made to keep the temperature constant, as a fluctuating temperature was considered desirable in that it would probably bring the ingots into a homogeneous state in a shorter time than if the temperature were kept steady. The temperatures of annealing were about 50° C. below the melting points of the alloys.

After lump-annealing, filings were taken from the interior of the ingot; these were lightly rubbed over with a magnet to remove iron

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* Owen and Pickup, *Proc. Roy. Soc.*, 1932, [A], **137**, 397; 1933, **139**, 526.

particles. The filings were then placed in small silica tubes, closed at one end and drawn to a narrow constriction about 1 in. from the open end. Each tube was connected to an oil pump and the filings were gently warmed during the evacuation of the tube to drive off moisture. After pumping out for about 15 minutes, the tube was sealed at the constriction and then placed in the furnace for the annealing operation. During the first part of the annealing period, the temperature generally fluctuated about 10° C. on either side of that required, but was kept steadier towards the end of the period. Fluctuations during the last $\frac{1}{2}$ hr. of the heat-treatment were kept within about 3° C. on either side of the quenching temperature. If the annealing periods were less than 1 hr., the temperature was kept as steady as possible for the whole of the period. When possible the heating current was taken from a battery of large cells, as the mains supply was found to be too unsteady on occasions to enable steady temperatures to be maintained. All the samples were quenched in cold tap-water.

ANALYSIS OF THE PHOTOGRAPHS.

The first step in the analysis was the identification of the reflecting planes corresponding to the line in the precision camera photographs. If the distance between the planes be denoted by d, then $n\lambda = 2d \sin \theta$, where θ is the glancing angle. If r be the radius of the camera and s the corrected arc between two corresponding lines on different sides of the photograph, θ is given by the relation $\pi/2 - \theta = s/8r$ so that $2d = n\lambda \,.\, \sec. (s/8r)$.

To determine which reflecting planes in the crystals gave the various lines, approximate values of the parameters of the structures present which were already known, were taken. For a body-centred cubic crystal $d = a/Q$ where $Q^2 = (h^2 + k^2 + l^2)$ can only have certain even integral values. By substituting the approximate value of a in this equation, the value of Q^2 is found.

The procedure with the hexagonal structures was somewhat different. The distance, d, between the reflecting planes is given by the relation $d/a = \sqrt{4(h^2 + hk + k^2)/3 + l^2/c^2}$ where a is the base side of the hexagonal crystal unit, c the axial ratio, and h, k, and l the Miller indices of the reflecting plane.

The above relation transforms into

$$(h^2 + hk + k^2) = \frac{3}{4}\left(\frac{a^2}{d^2} - \frac{l^2}{c^2}\right)$$

Approximate values of a and c were substituted in this equation and different integral values of l were tried until a value was found which satisfied the equation with h and k also integers.

Having thus identified the planes, it was possible to calculate accurate values for a and c.

We have for one set of planes

$$d_1/a = \sqrt{4(h_1^2 + h_1k_1 + k_1^2)/3 + l_1^2/c^2}.$$

By eliminating a between two such equations we get

$$c^2 = \frac{3}{4}\left[\frac{l_1^2d_1^2 - l_2^2d_2^2}{Q_2^2d_2^2 - Q_1^2d_1^2}\right]$$

where $Q_1^2 = h_1^2 + h_1k_1 + k_1^2$ and $Q_2^2 = h_2^2 + h_2k_2 + k_2^2$.

In the photographs there were many lines which, when combined in different ways, yielded several values of c, the mean of which was taken. For example, in a photograph taken of the δ-phase with nickel radiation, two doublets and one single line were present, being reflections from the planes $10\bar{1}5$, $21\bar{3}2$, $11\bar{2}4$. The eight values of c calculated from the different combinations of planes and wave-lengths are given in Table I.

TABLE I.

Planes and Wave-lengths	$10\bar{1}5\ \alpha_1$ $11\bar{2}4\ \alpha_2$	$10\bar{1}5\ \alpha_2$ $11\bar{2}4\ \alpha_1$	$10\bar{1}5\ \alpha_1$ $11\bar{2}4\ \alpha_1$	$10\bar{1}5\ \alpha_2$ $11\bar{2}4\ \alpha_2$	$21\bar{3}2\ \alpha_1$ $10\bar{1}5\ \alpha_2$	$21\bar{3}2\ \alpha_1$ $10\bar{1}5\ \alpha_1$	$21\bar{3}2\ \alpha_2$ $11\bar{2}4\ \alpha_2$	$21\bar{3}2\ \alpha_1$ $11\bar{2}4\ \alpha_2$
c . .	1·5867	1·5870	1·5866	1·5871	1·5874	1·5873	1·5877	1·5876

The values of the axial ratio obtained by using the same pair of reflecting planes, but different characteristic wavelengths, agree well among themselves. The agreement is better than that between the values obtained with the same characteristic wave-lengths and different reflecting planes. For this reason equal weights were allotted to the means of the values obtained from each pair of planes. The weighted mean value of the axial ratio (c) then becomes 1·5873. Taking this value of c, the next step was to calculate the value of the base-side a. The different lines were again taken which in the case considered gave results shown in Table II.

TABLE II.

Plane . . .	$10\bar{1}5$		$21\bar{3}2$	$11\bar{2}4$	
Wave-length .	NiKα_1	NiKα_2	NiKα_2	NiKα_1	NiKα_2
a	2·8186	2·8187	2·8185	2·8188	2·8188

These give a mean value of 2·8187 A., and so the mean atomic volume calculated from the expression $\sqrt{3}a^2c/4$, is 15·892 A.^{3}.

All the photographs, of which there were about 50, were treated in like manner. The values of the mean atomic volumes thus found for the phases present in the mixed regions, and the accurately determined atomic volume–composition curves previously determined for the adjacent pure phases provided the means of obtaining the compositions at the phase boundaries.

THE PHASE BOUNDARIES.

$(\gamma) - (\gamma + \delta)$ *and* $(\gamma + \delta) - (\delta)$ *Boundaries.*—To determine the positions of these boundaries, the mean atomic volumes of the γ and δ constituents at different temperatures in the $(\gamma + \delta)$ region were found. This region, according to the accepted thermal diagram, extends from 40 to about 49 per cent. silver by weight. A number of alloys was prepared in this range, and on analysis gave the compositions 40·5, 45·0, 47·4, 48·8, and 49·7 per cent. silver by weight. The ingot of alloy 45·0 was cut in two, one portion being annealed at about 600° C. for 20 hrs. and the other annealed at the same temperature for 48 hrs. Photographs of filings prepared from these two specimens and annealed at the same temperature showed both the γ and the δ constituents of the alloy, and on measurement yielded the same values for the mean atomic volumes. This provided evidence that the ingots had received sufficient heat-treatment to bring them to the equilibrium condition. Meanwhile, alloys 47·4, 48·8, 49·7, and 40·5 had been annealed for 155 hrs. Subsequent photographs showed that only two of the alloys, namely, alloys 45·0 and 47·4, were in the $(\gamma + \delta)$ region.

Two other alloys, marked 11 and 12, were therefore prepared. These were lump-annealed at about 600° C. for 240 hrs. Filings from alloy 12 were annealed at 445° C. for 6½ hrs., but only δ lines were registered on the photograph. On analysis the alloy was found to contain 42·4 per cent. silver by weight and, therefore, belonged to the pure δ region. Alloy 11, of which two samples of filings were taken—one sample annealed at 426° C. for 8 hrs., and the other at 570° C. for about 1 hr.—yielded lines corresponding to both the γ and the δ components. This alloy was not analyzed, as it was definitely in the $(\gamma + \delta)$ region.

A systematic investigation was then made of the alloys in the $(\gamma + \delta)$ region; the results are summarized in Tables III and IV. Filings were annealed for periods ranging between 8 hrs. for the lower temperatures (300° C.) and ½ hr. for the higher temperatures (600° C.).

TABLE III.—$(\gamma) - (\gamma + \delta)$ *Boundary.*

Temperature of Annealing, ° C.	Parameter γ Phase, A.	Mean Atomic Volume, A.^{3}.	$(\gamma) - (\gamma + \delta)$ Boundary.	
			Silver, Atomic Per Cent.	Silver, Weight, Per Cent.
608	9·3124	15·530	35·7	47·8
584	9·3135	15·535$_5$	35·9	48·0$_5$
570	9·3146	15·541	36·1$_5$	48·3
529	9·3157	15·547	36·4	48·5
494	9·3161	15·549	36·4	48·6
459	9·3167	15·552	36·5$_5$	48·7
426	9·3165	15·551	36·5	48·7
364	9·3163	15·550	36·5	48·6$_5$
304	9·3155	15·546	36·3	48·4

TABLE IV.—$(\gamma + \delta) - (\delta)$ *Boundary.*

Temperature of Annealing, ° C.	δ-Phase.		Mean Atomic Volume, A.^{3}.	$(\gamma + \delta) - (\delta)$ Boundary.	
	Base Side, A.	Axial Ratio.		Silver, Atomic Per Cent.	Silver, Weight, Per Cent.
608	2·8187	1·5855	15·376	31·6	43·2$_5$
584	2·8187	1·5853	15·374	31·6	43·3
570	2·8186	1·5869	15·388	32·1	43·8$_5$
529	2·8189	1·5875	15·398$_5$	32·6	44·3$_5$
494	2·8193	1·5873	15·403	32·8	44·6
459	2·8190	1·5875	15·400	32·6	44·4
426	2·8192	1·5879	15·406$_5$	32·9	44·7
405	2·8190	1·5875	15·399	32·6	44·4
364	2·8194	1·5873	15·404	33·0	44·6
304	2·8189	1·5871	15·394	32·4	44·1$_5$

$(\delta) - (\delta + \varepsilon)$, $(\delta) - (\delta + \eta)$, and $(\delta + \varepsilon) - (\varepsilon)$ *Boundaries.*—In the $(\delta + \varepsilon)$ region three alloys, whose compositions were 15·6, 9·7, and 5·2 per cent., by weight, were employed to determine the boundaries. The ingots were annealed for 240 hrs. at about 360° C. After the experience gained with alloys in the $(\gamma + \delta)$ region, this was considered sufficient annealing to bring the ingots to a homogeneous state. During the heat-treatment some zinc volatilized and was deposited on the sides of the Pyrex glass containers, but the amount lost was not sufficient to change appreciably the composition of the alloys.

Filings taken from the interior of the ingots were annealed at 314° C., after first being heated at 380° C., and then allowed to cool to the annealing temperature.

It was found necessary to take precision photographs of these alloys with both copper and nickel radiations in order to obtain the required data to calculate the δ and ε parameters. As before, the mean atomic volume for each constituent was calculated for specimens annealed at different temperatures, and the boundary compositions deduced from the mean atomic volume–composition curves of the pure δ and the pure ε regions.

The photographs taken with filings of alloy 5·2 gave only lines reflected from the ε-phase, and these were not quite in the same positions as the lines from the same reflecting planes on photographs of alloys 9·7 and 15·6 annealed at the same temperatures. It was concluded, therefore, that alloy 5·2 was in the pure ε-phase.

The rate of change of the mean atomic volume with composition in the pure ε-region is less than in the pure δ-region. For this reason the $(\delta + \varepsilon) - (\varepsilon)$ boundary could not be determined so accurately as the $(\delta) - (\delta + \varepsilon)$ boundary.

The transformation of the ε-phase to the $(\delta + \eta)$ phase at 300° C. had been confirmed previously by X-ray analysis. The procedure then adopted was to anneal filings at about 400° C. for 1 or 2 hrs. to remove lattice distortion produced by filing, then to cool the filings slowly to 270° C., and to anneal at this temperature for 48 hrs. A further annealing for 24 hrs. showed that the transformation was complete after 48 hrs. The same procedure was adopted in this work. Filings of alloys 15·6, 9·7, and 5·2 were annealed for a short time at about 400° C., and then cooled slowly to the final annealing temperature. One sample of each alloy was annealed at 279° C. for 48 hrs. and another sample at 238° C. for 84 hrs.

Precision photographs were taken of these filings with both nickel and copper radiations. The same reflection lines were obtained from the δ-phase component as in the work on the $(\delta + \varepsilon)$ region. In this case, however, on all but one of the photographs, an η-phase doublet interfered completely with both lines of the δ doublet from the $(11\bar{2}4)$ plane on the photograph taken with nickel radiation. The δ-phase parameters were calculated from the combined data obtained with both the copper and the nickel radiations, except for the photographs taken with alloy 15·6 annealed at 238° C. which gave independent values of the parameter. The $\delta - (\delta + \eta)$ boundary compositions at 279° C. and 238° C. were arrived at in the manner already described for the other boundaries.

Tables V and VI give a summary of the data obtained from the measurements.

DISCUSSION OF RESULTS.

Errors in the present investigation may arise from inaccuracy in the determinations of the temperature of annealing. It is estimated that

TABLE V.—(δ) — (δ + ε) and δ — (δ + η) *Boundaries.*

Temperature of Annealing, ° C.	δ-Phase.		Mean Atomic Volume, A.³.	(δ) — (δ + ε) Boundary.	
	Base Side, A.	Axial Ratio.		Silver, Atomic Per Cent.	Silver, Weight, Per Cent.
408	2·8047	1·5652	14·953	13·5	20·5
379	2·8070	1·5623	14·961	13·8	21·0
343	2·8082	1·5605	14·964	14·0	21·1
314	2·8084	1·5602	14·963	13·8	21·0
				(δ) — (δ + η) Boundary.	
279	2·8095	1·5584	14·965	14·0	21·2
238	2·8094	1·5591	14·969	14·2	21·5

TABLE VI.—(δ + ε) — (ε) *Boundary.*

Temperature of Annealing, ° C.	ε-Phase.		Mean Atomic Volume, A.³.	(δ + ε) — (ε).	
	Base Side, A.	Axial Ratio.		Silver, Atomic Per Cent.	Silver, Weight, Per Cent.
408	2·6989	1·7659	15·033	5·6	9·0
379	2·6936	1·7779	15·045	4·7	$7{\cdot}5_5$
343	2·6877	1·7911	15·058	3·8	6·2

the temperature of annealing could be determined within about ± 3° C. The error in boundary composition from this source will, therefore, be very small in the case of the $(\gamma) - (\gamma + \delta)$, $(\gamma + \delta) - (\delta)$, $(\delta) - (\delta + \varepsilon)$, and $(\delta) - (\delta + \eta)$ boundaries, as these boundaries are nearly parallel to the temperature axis, and a comparatively large change in the temperature of the alloy will produce only a small change in parameter. The possible error in the $(\delta + \varepsilon) - (\varepsilon)$ boundary will be greater, but probably not as great as the error due to inaccuracy in measuring the photographs.

Errors in the determination of parameters are more pronounced in the case of the hexagonal phases. The greatest difference between the values of the $(\gamma) - (\gamma + \delta)$ boundary composition derived from different photographs of the same sample, was 0·24 per cent. silver by weight, corresponding to a difference of 1 in 7000 in the determination of the parameter. Similarly, the greatest variation in the $(\gamma + \delta) - (\delta)$ boundary composition was 0·53 per cent. silver by weight, corresponding to a variation in the determination of the mean atomic volume of 1 in 1500. The values quoted above are the extreme limits; the variations observed were generally well within these limits.

From an examination of the way in which the points determined experimentally are distributed about the $(\gamma) - (\gamma + \delta)$ and the $(\gamma + \delta) - (\delta)$ boundary curves, it is estimated that these boundaries are correct within ± 0·2 and ± 0·3 per cent. silver by weight, respectively. The same accuracy cannot be claimed, however, for the other three boundaries; these are probably correct within ± 0·5 per cent. silver by weight.

Fig. 1 shows how the boundaries in the thermal diagram published in the International Critical Tables should be modified to conform with the present results. The $(\gamma + \delta) - (\delta)$ boundary in this diagram differs from that determined by X-ray analysis by more than 4 per cent. silver by weight, this being far greater than the experimental error. The $(\delta) - (\delta + \eta)$ and $(\delta) - (\delta + \varepsilon)$ boundaries also need modification, the boundaries as determined in this investigation being more nearly parallel to the temperature axis. The $(\gamma) - (\gamma + \delta)$ boundary is changed by about 0·5 per cent. silver by weight, but at the higher temperature it is displaced by a greater amount.

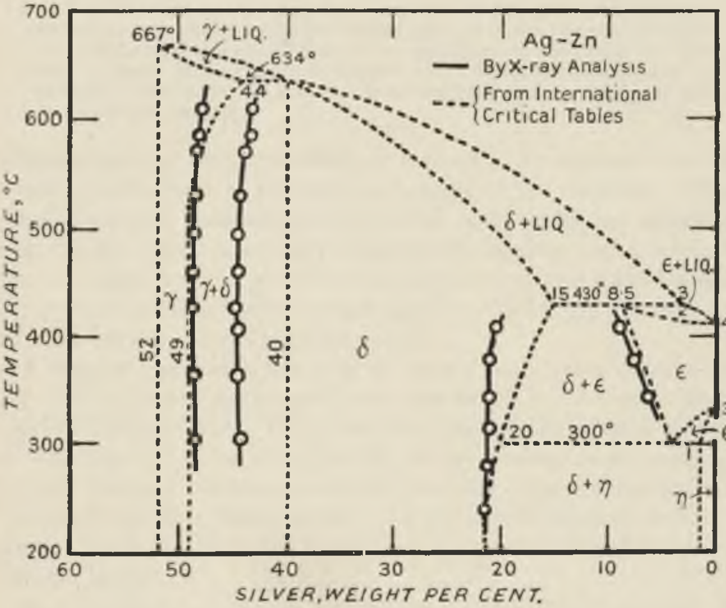

FIG. 1.

The $(\delta + \varepsilon) - (\varepsilon)$ boundary is parallel to that given in the International Critical Tables, but is moved about 0·8 per cent. silver by weight towards the silver-rich end of the diagram. This, however, may be within the experimental error, since the relation between atomic volume and composition in the ε-region was not as accurately determined as in the other pure regions.

In view of these results it will be necessary to redetermine the position of the solidus.

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NOTE ON THE FAILURE OF A GOLD FUSE IN CONTACT WITH NICKEL–CHROMIUM ALLOY.*

By M. C. CAPLAN,† B.Sc., Member.

Synopsis.

The failure of a gold safety fuse to operate at the correct temperature was found to be due to diffusion taking place between the gold link and the nickel–chromium connections at temperatures of 950°–1000° C. An alloy of lower melting point is formed which offers little resistance to oxidation, and finally the gold link becomes disintegrated and converted into a cindery residue.

In designing large electric furnaces, it is usual to incorporate some type of fuse in the circuit to prevent overheating of the elements. Where nickel-chromium elements are employed, gold fuses are sometimes used. These consist essentially of gold links or wires placed inside the furnace, adjacent to the elements and connected so that if the temperature of the element exceeds the melting point of gold, the link fuses and the main furnace current is switched off.

A type of fuse which has been in use for some years consists of a short link of heavy-gauge gold wire connected to two stout 80 : 20 nickel–chromium leads. The latter pass through the furnace wall and are connected in series with the coil of the furnace main contactor. The gold link and leads are protected from the furnace atmosphere by a porcelain sheath. Fuses of this type gave unsatisfactory service in furnaces operating at temperatures as high as 950°–1000° C. for considerable periods.

An examination of several faulty fuses showed that in each case the gold link appeared to be corroded. In one fuse removed from a furnace which had been operated continually at 950°–1000° C., the gold link had disappeared and a black cindery residue was left. This fuse had eventually operated at a temperature below that of the melting point of gold. Spectroscopic analysis of the cindery residue indicated the

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* Manuscript received May 7, 1935.

† Member of the Staff of the Research Laboratories of the General Electric Company, Limited, Wembley.

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presence of gold, nickel, and chromium. Fig. 1 (Plate I) shows another fuse in which one link exhibited signs of diffusion and oxidation. The ends of the gold link were forced into holes drilled in the end of each nickel–chromium wire and held securely by means of a centre-pop. The general disintegration and oxidation of the gold link in contact with the nickel–chromium is shown in Fig. 2. The nickel–chromium was also attacked, and the diffusion of the gold into the nickel–chromium is shown in Fig. 3. It appeared, therefore, that when this type of fuse is held at 950°–1000° C. for a considerable time, diffusion occurs between the gold and nickel–chromium with the production of an alloy of lower melting point than gold. This alloy offers poor resistance to oxidation, and the link becomes slowly disintegrated until only a residue of oxide remains.

In order to confirm these conclusions, several tests were made by heating gold in contact with nickel–chromium at 950°–1000° C., in air and hydrogen. The test-specimens consisted of gold wires plugged into the ends of 80 : 20 nickel–chromium rods. Tests were carried out in hydrogen to reduce the possibility of oxidation, but still retain the conditions of possible diffusion. A short time test in hydrogen for 60 hrs. at 950°–1000° C. showed that diffusion readily took place, especially when the link and the nickel–chromium wire were in intimate contact, as at the centre-pop mark. Fig. 4 shows a test-specimen after heating in air for 250 hrs. at 950°–1000° C. It can be seen that the lower melting point constituent exuded from the hole in the nickel–chromium wire and penetrated at the centre-pop depression where diffusion began. The exuded alloy became oxidized and was similar to the black cindery residues found in the actual failures. A cross-section of the test-piece showed that diffusion had taken place. The alloy produced by this diffusion appears to have little resistance to oxidation at the operating temperature for the fuse. A satisfactory fuse is made if the gold link is replaced by a gold wire which is connected to terminals outside the furnace wall.

FIG. 1.—Gold Link Showing Partial Fusion. × 3.

FIG. 2.—Section of Gold Link and Nickel–Chromium Wire, Showing Disintegration. Unetched. × 10.

FIG. 3.—Section of Nickel–Chromium Wire, Showing Diffusion of Gold. Gold-Rich Phase is Dark. Unetched. × 500.

FIG. 4.—Experimental Test-Piece. 250 Hrs. at 950°–1000° C. in Air. × 5.

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PRODUCTION OF POWDERED ALLOYS OF LOW MELTING POINT.*

By R. W. REES,† B.Sc., Member.

(Communication from the Research Laboratories of the General Electric Company, Limited, Wembley, England.)

Synopsis.

A method is described for producing lead-base alloys in the form of powder. For this purpose advantage is taken of the pasty stage through which the alloys pass during solidification.

Methods of preparing metals in the form of powder may be divided roughly into the following classes :

(*a*) Reduction of the oxide with hydrogen (*e.g.* iron, copper, nickel);
(*b*) Precipitation of the powdered metal from solution (*e.g.* copper by zinc, silver by reducing agents);
(*c*) Distillation (*e.g.* zinc);
(*d*) Mechanical disintegration.

In the case of alloys the methods available are more limited. Certain alloys, such as those of nickel and iron, can be prepared by the reduction of the mixed oxides, or by electrodeposition, but mechanical disintegration is usually the only practical method; this presents considerable difficulty in the case of very ductile alloys. For a particular purpose, an alloy with a melting point not exceeding 180° C. was required in the form of powder, which had to pass a 200-mesh sieve, corresponding to a maximum particle diameter of about 50 μ. The composition of the alloy was unimportant, provided that it could be produced cheaply, and this clearly necessitated the use of lead as the main constituent. Several firms specializing in low melting point alloys were approached, but no simple method for producing such material appeared to be known. One solution of the problem may therefore be worth putting on record.

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Most alloys containing more than 50 per cent. of lead are so ductile that they cannot be powdered by crushing or grinding. Even the comparatively brittle lead-antimony alloys are too soft in this respect, and attempts to induce intercrystalline brittleness by additions of sulphur, &c., were not satisfactory.

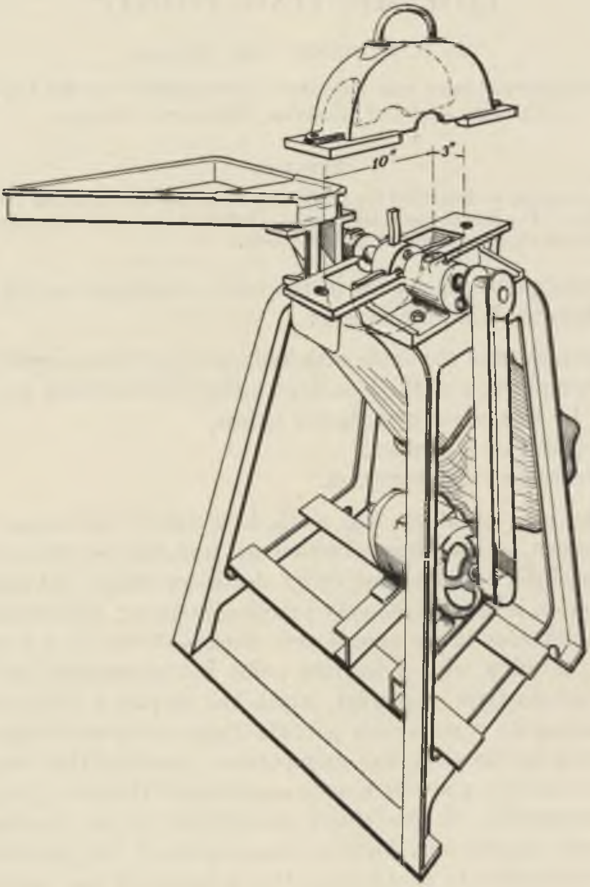

Fig. 1.

Success was finally attained by using alloys having a wide interval between liquidus and solidus, taking advantage of their peculiar properties in this range of temperature. Many lead alloys have a freezing range of 30° C. or more, in which range they have a consistency of wet sand, and can be broken up into coarse powder by simple agitation.

The composition of alloys possessing this property can vary over a wide range, so that a choice of melting point and other properties is possible.

Alloys of the following range of compositions have been successfully treated.

	Per Cent.
Lead	50
Tin	16–20
Cadmium	10–30
Bismuth	0–50
Antimony	0–10

An alloy of lead 50, cadmium 30, and tin 20 per cent., and having a freezing range from 180° to 150° C., was found particularly suitable.

If the molten alloy is poured into a wooden tray and shaken vigorously whilst it solidifies, about 10 per cent. of the material will pass 100 mesh. A finer powder was obtained by pouring the molten metal into an iron mortar, preheated to a temperature about 10° C. below the melting point of the alloy, and grinding vigorously whilst the metal solidified. The addition of a little graphite before grinding prevents the particles from sticking together. The yield by this method was about

40 per cent. through 100 mesh
25 ,, ,, 200 ,,

The method finally adopted was to feed the pasty metal into an impeller-type disintegrator maintained at a temperature about 10° C. below the solidus. The type of mill is shown in Fig. 1. The body of the mill was preheated, but once up to temperature the heat introduced with the hot charge was sufficient to maintain the temperature at the desired value. The shaft carrying the blades was belt-driven at a speed of about 1500 r.p.m. The perforated metal screen is removable, and for this particular purpose one with perforations $\frac{1}{64}$ in. in diameter was found to be the most suitable. With such a screen the yield was:

All through 70 mesh
80 per cent. ,, 100 ,,
30 ,, ,, 200 ,,

The product, which discharged into a bag, was sieved through the appropriate screen, any over-size being returned to the heated hopper.

The output of such a mill is about 2 cwt. of 200-mesh powder per day.

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METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 2 JUNE 1935 Part 6

I.—PROPERTIES OF METALS

(Continued from pp. 197–212.)

***The Annealing of Pure Aluminium and Its Possible Utilization as a Criterion of the Purity of this Metal.** J. Calvet (*Light Metals Research*, 1935, **3**, 368–370).—Translated from *Compt. rend.*, 1935, **200**, 66–68. See *Met. Abs.*, this volume, p. 137.—J. C. C.

***On the Plasticity of Crystals. [Torsion Tests on Polycrystalline Copper and Single Crystals of Copper.]** Pol Duwez (*Phys. Rev.*, 1935, [ii], **47**, 494–501).—A theory of plastic distortion is developed by assuming the existence of the secondary structure postulated by Zwicky. [*Note by Abstractor :* the criticisms of the theory of Zwicky by Buerger and Taylor should be read in this connection.] Gliding in crystals is assumed to take place on the π planes which characterize the secondary lattice at shearing stresses much smaller than those derived from the theory of ideal lattices. This is illustrated by a mechanical model consisting of springs (representing elastic forces) connected by flat plates which glide over one another. The stress–strain curve is obtained as an exponential law involving the torsional modulus, the elastic limit, and the maximum stress that can be applied without producing rupture. The equations are confirmed by the results of torsion experiments on polycrystalline copper, and also on a single crystal.—W. H.-R.

***The Creep Fracture and Fracture of Lead and Lead Alloys.** Herbert F. Moore, Bernard B. Betty, and Curtis W. Dollins (*Univ. Illinois Bull.* No. **272**, 1935, 9–47).—The materials used in this investigation were : commercially pure lead (*A*) ; and alloys thereof with 2% tin (*B*) ; 0·75% antimony (*C*) ; and 0·04% calcium (*D*). In no case is there an absolute limiting tensile stress below which no creep occurs ; at room temperature under a stress of 180 lb./in.^{2} creep occurs at a rate varying from 0·3% per annum for *D* to 0·6% per annum for *A*, and at 65° C. the corresponding figures are 0·6 and 1·4%. Extrapolated from the results of tests over 1000 hrs. the approximate creep at room temperature under 1 year of steady tensile stress is as follows : 200 lb./in.^{2}, (*A*) 0·7, (*B*) 0·6, (*C*) 0·4, (*D*) 0·3% ; 300 lb./in.^{2}, (*A*) 1·6, (*B*) 1·1, (*C*) 0·7, (*D*) 0·4% ; 400 lb./in.^{2}, (*A*) 3·9, (*B*) 1·9, (*C*) 1·0, (*D*) 0·6% ; 500 lb./in.^{2}, (*A*) 5·0, (*B*) 3·2, (*C*) 1·4, (*D*) 0·8%. These figures show that the addition of calcium and antimony has a very marked effect in reducing the creep of lead at high stresses. The lowest stress under which fracture occurs under long continued load is 600 lb./in.^{2} for *A*, *B*, and *C* and 1000 lb./in.^{2} for *D*, the corresponding times to fracture being about 36, 148, 262, and 333 days, respectively. Under reversed flexural stresses of 200 lb./in.^{2} about 10^8 cycles are necessary to produce fracture of (*A*), the weakest of the metals tested. Microscopic examination of lead and its alloys after subjection to long-continued steady loads indicates that there is distortion by rotation of at least the surface crystals, whereas in short time tests distortion occurs by slip within the crystal grains, large-grained metal appearing to resist creep better than fine-grained metal. In creep tests on single crystals distortion occurs along certain definite atomic planes and there appears to be a limiting resolved shearing stress along these planes below which creep is very slow, but above which it occurs rapidly.
—A. R. P.

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* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

Properties and Uses of Lithium. J. Staes (*Rev. Univ. Mines*, 1934, [viii], **10**, 635–637).—S. G.

***Absorption and Adsorption of Hydrogen by Nickel.** J. Smittenberg (*Rec. trav. chim.*, 1934, **53**, 1065–1083).—The absorption and adsorption of hydrogen by nickel at low pressures was studied with a long thin nickel wire. The absorption or solution of hydrogen in solid nickel is proportional to the square root of the pressure, and increases at constant pressure with increasing temperature, obeying the equation: $\log a = A - B/T$. The heat of absorption amounts to − 2·62 kg.-cal. per grm. mol. of hydrogen.—C. E. H.

***The Atomic Heat of Nickel at Liquid Helium Temperatures.** W. H. Keesom and C. W. Clark (*Physica*, 1935, **2**, 230).—[In English.] In this preliminary note, K. and C. state that they have measured the atomic heat, C, of nickel from 1·1° to 20° abs. It appears that as a limiting law at liquid helium temperature, T (1° − 4° abs.), $C = T \times$ const. The contribution to the atomic heat attributable to a variation of magnetization with temperature is, theoretically, proportional to $T^{3/2}$. The experimental values are largely in excess of this amount, and follow another law. The atomic heats of nickel are many times larger than the values deduced from Sommerfeld's formula based on the existence of free electrons. These larger values may be associated with an abnormally small value of the limiting electronic energy. —J. S. G. T.

***A New Method for Determining Thermionic Work-Function of Metals, and Its Application to Nickel.** Gerald W. Fox and Robert M. Bowie (*Proc. Iowa Acad. Sci.*, 1933, **40**, 154).—See *J. Inst. Metals*, 1933, **53**, 690.—S. G.

***Platinum–Helium Compound Probably as Large as Colloidal Particles.** Horacio Damianovich (*Anales soc. cient. Santa Fe*, 1934, **6**, 17–19; *C. Abs.*, 1935, **29**, 2814).—Failure to obtain photomicrographs of individual particles of the platinum–helium compound leads to the belief that they may be of colloidal size. Calculations indicate that Pt_5He is the first compound of the series of possibilities likely to give molecules of colloidal size.—S. G.

***Microstructure of Platinum Subjected to the Action of Helium, Oxygen, and Hydrogen under the Influence of the Electric Discharge.** Horacio Damianovich (*Anales soc. cient. Santa Fe*, 1934, **6**, 20–22; *C. Abs.*, 1935, **29**, 2814).—Photomicrographs of platinum surfaces subjected to electric discharges in atmospheres of hydrogen and helium are reproduced. Very curiously different protuberances appear in each case. These phenomena will be investigated in different conditions.—S. G.

The Thermal Expansion of Silver, Quartz, and Bismuth by X-Ray Measurements. A. H. Jay (*Z. Krist.*, 1934, **89**, 282–285).—A summary of work published elsewhere (cf. Jay, *Proc. Roy. Soc.*, 1933, [A], **142**, 237; and 1934, [A], **143**, 465 (*Met. Abs.*, 1934, **1**, 113)).—W. H.-R.

***The Thermionic Properties of Tantalum.** Alvin B. Cardwell (*Phys. Rev.*, 1935, [ii], **47**, 628–630).—Prolonged outgassing of tantalum at 2200° K. produced an apparently stable condition (cf. Cardwell, *ibid.*, 1931, [ii], **38**, 2041), and a final stable condition was only obtained at 2500° K. For the final condition, the constants of the Richardson equation are $b = 47{,}560°$ K., $h = 4{\cdot}10$ v., $A = 37{\cdot}2$ amp./cm.^{2} degree^2. Comparison with previous results shows that the value of the photoelectric work-function determined by Fowler's method agrees with the value of the thermionic work-function of the same surface, regardless of whether the surface is completely outgassed or not.—W. H.-R.

***Electrical Resistances and Volume Changes up to 20,000 Kg./cm.^{2} [Tellurium, Lithium, Sodium, Potassium].** P. W. Bridgman (*Proc. Nat. Acad. Sci.*, 1935, **21**, 109–113).—The resistance of tellurium, and the pressure–volume–temperature relations of lithium, sodium, and potassium have been studied at pressures up to 20,000 kg./cm.^{2}. Measurements of the volume changes of these alkali metals revealed a serious error in the results previously published. On increasing the pressure from 2000 to 20,000 kg./cm.^{2}, the mean coeffs. of linear expansion (0°–95°) of lithium, sodium, and potassium decreased from 0·0000515 to 0·0000273, 0·0000622 to 0·0000233, and 0·0000670 to 0·0000125, respectively.—C. E. H.

***The Elastic Properties of Single and Multiple Tin Crystals.** W. Boas (*Helv. Phys. Acta*, 1934, **7**, 878–883; *Sci. Abs.*, 1935, [A], **38**, 236).—[In German.] The dependence on orientation of the moduli of elasticity and torsion of the crystal of tin is described. The method employed was that given by Huber and Schmid (*Met. Abs.*, this volume, p. 208). By summation of average values over the whole region of orientation the moduli of the quasi-isotropic multiple crystal are calculated, and comparison is made with experiment.—S. G.

***New Method of Preparing Pure Vanadium.** André Morette (*Compt. rend.*, 1935, **200**, 1110–1112).—Vanadium tetrachloride, obtained by the action of chlorine at 500°–600° C. on cast vanadium and free from oxychlorides, is passed with a current of pure hydrogen over pure magnesium filings in a magnesia boat, the temperature being increased progressively in 2½ hrs. to 700° C. On cooling, a grey powder containing 99·3% of vanadium is obtained. Alternatively, vanadium dichloride, obtained by the action of hydrogen on the tetrachloride at 750°–800° C., is reduced by magnesium (2 parts of dichloride to 1 of magnesium filings) by heating in a magnesium boat *in vacuo*, in argon, or in pure hydrogen at 700° C. for 1–2½ hrs. A grey powder containing 98·9–99·5% of vanadium results after cooling, washing, and cold-drying the product. The metal thus prepared burns with brilliant sparks when thrown into a Bunsen burner flame. It reacts violently with concentrated nitric acid, giving, after dessication, a substance possessing the characteristics of vanadium anhydride; it is soluble in hydrofluoric acid and is unattacked by hydrochloric acid.—J. H. W.

***Work in the Charlottenburg Cryoscopic Laboratory on Superconductivity and on the Hydrogen Isotope [Vanadium; Molybdenum].** W. Meissner (*Helv. Phys. Acta*, 1933, **6**, 414–418; *C. Abs.*, 1935, **29**, 2413).—Vanadium and molybdenum become superconducting at 4·3° and 1·1° K., respectively. Arsenic–lead alloys become superconducting at the transition point of lead. —S. G.

***The Exact Measurement of the Specific Heats of Solid Substances at High Temperatures. VI.—The Specific Heats of Vanadium, Niobium, Tantalum, and Molybdenum.** F. M. Jaeger and W. A. Veenstra (*Rec. trav. chim.*, 1934, **53**, 677–687).—See also *Met. Abs.*, 1934, **1**, 227. The specific heats of these 4 metals were determined at various temperatures up to about 1550° C., by the method previously described (*ibid.*, 1932, **51**, 2). The exactness and reproducibility of the measurements proved to be 0·1–0·2% of the values indicated. From the results, equations connecting specific and atomic heats with temperature were developed for the various metals, and thus values were calculated for temperatures from 0° to 1600° C., at 100° C. intervals. In the case of niobium, specific heats at constant volume were also calculated.—C. E. H.

***Mosaic Zinc Crystals.** E. P. T. Tyndall and H. K. Schilling (*Proc. Iowa Acad. Sci.*, 1933, **40**, 156; *C. Abs.*, 1935, **29**, 2415).—Crystals of a distinctly mosaic type (that is, a group of polycrystals with almost identical orientations) were grown with great frequency during 1931 and 1932.—S. G.

***Resistivity of Mosaic Zinc Crystals.** W. J. Poppy (*Proc. Iowa Acad. Sci.*, 1933, **40**, 156; *C. Abs.*, 1935, **29**, 2415).—See also *Met. Abs.*, this volume, pp. 5 and 46. Zinc mosaics depart from the resistivity–orientation relation characteristic of a true single crystal. They show marked increases in resistivity after strain with a decline to the original, or lower values, on annealing.—S. G.

Elasticity of Zinc Crystals. A. W. Hanson (*Proc. Iowa Acad. Sci.*, 1933, **40**, 156; *C. Abs.*, 1935, **29**, 2415).—See also *J. Inst. Metals*, 1933, **53**, 692 and

Met. Abs., 1934, **1**, 228. The apparatus for the determination of elastic constants was improved. Incomplete tests seem to show that crystals with distinct mosaic structure differ only slightly, if at all, in elastic properties from true single crystals.—S. G.

***On the Effect of Slight Impurities on the Elastic Constants, Particularly the Compressibility of Zinc.** P. W. Bridgman (*Phys. Rev.*, 1935, [ii], **47**, 393–397). —Cf. following abstract. Single crystals of zinc were prepared from 3 sources of exceedingly pure metal, and their linear compressibilities for different orientations measured by B.'s method (*Proc. Amer. Acad. Sci.*, 1923, **58**, 166). No difference within the experimental error could be correlated with the source of the metal. This is in marked contrast to the conclusions of Hanson (*Phys. Rev.*, 1934, [ii], **45**, 324) who calculated the elastic constants and compressibilities from the results of bending and torsion experiments. Some of B.'s specimens were made from the same blocks of metal used by Hanson, and it is concluded that the differences found by the latter are due to internal strains. The following improved values are found for the compressibility of zinc: 90° orientation, $-\Delta l/l_0 = 1{\cdot}57 \times 10^{-7} p - 0{\cdot}75 \times 10^{-12} p^2$, 0° orientation, $-\Delta l/l_0 = 13{\cdot}50 \times 10^{-7} p - 7{\cdot}68 \times 10^{-12} p^2$, volume compression, $-\Delta V/V_0 = 16{\cdot}64 \times 10^{-7} p - 9{\cdot}62 \times 10^{-12} p^2$, at 30° C., p in kg./cm.^{2}.—W. H.-R.

***Note on the Probable Values of the Elastic Constants of the Zinc Crystal.** E. P. T. Tyndall (*Phys. Rev.*, 1935, [ii], **47**, (5), 398–399).—The work of Bridgman (preceding abstract) is accepted as disproving the conclusion of Hanson (*Phys. Rev.*, 1934, [ii], **45**, 324) that the elastic constants and compressibilities of zinc crystals are markedly affected by minute traces of impurities. One set of Hanson's measurements is, however, not only self-consistent, but also in good agreement with Bridgman's compressibility data, and the following values for the elastic constants are considered to be the most probable: $s_{11} = 7{\cdot}70$, $s_{12} = 0{\cdot}83$, $s_{13} = -6{\cdot}93$, $s_{33} = 27{\cdot}66$, $s_{44} = 24{\cdot}40$, all $\times 10^{-13}$ cm.^{2}/dyne.—W. H.-R.

Factors Influencing Creep. R. W. Carson (*Machinist* (*Eur. Edn.*), 1935, **79**, 261–263).—The various factors influencing creep are reviewed, and it is suggested that creep at normal temperature is closely related to high-temperature creep, although the controlling factors are different. Copper alloys have more creep than nickel or Monel metal, but age-hardening alloys are an important exception to this generalization.—J. H. W.

***Transparency of Thin Metallic Films in the Ultraviolet.** H. Harold Hartzler (*J. Opt. Soc. Amer.*, 1934, **24**, 339–341).—Measurement of transmission of light of different wave-lengths was made on metallic films of varying thicknesses by means of the vacuum prism spectrograph (Cario and Schmidt-Ott). The metals copper, silver, gold, magnesium, tin, lead, arsenic, antimony, and bismuth were deposited on thin films of celluloid by evaporation in a vacuum tube. The individual numerical results are given. Zinc and cadmium failed to give suitable films; the films were porous and fern-like in structure. Poor films were also given by the alkaline earth metals and those of the iron group. —R. G.

***Action of Nitrogen on the Metals. Electrical Discharges at Low Pressures.** G. Berraz (*Anales soc. cient. Santa Fe*, 1933, **5**, 54–56; *C. Abs.*, 1935, **29**, 2861). —Cathodic sputtering of silver in nitrogen at reduced pressure resulted in fixation of very little nitrogen, and it is doubtful whether any NAg_3 was formed. Similar results were obtained with gold. Lead gave an easily pulverizable deposit which gave NH_3 in moist air: it is probably N_2Pb_3, which reacts as follows: $N_2Pb_3 + 3H_2O = 2NH_3 + 3PbO$.—S. G.

Anodic Passivation [of Metals]. W. J. Shutt (*Trans. Faraday Soc.*, 1935, **31**, 636–637).—A reply to Armstrong and Butler's criticism of Shutt and Walton's conclusions on the mechanism of the passivation of gold in chloride solutions (cf. *Met. Abs.*, this volume, p. 3).—A. R. P.

The Effect of Slow Electrons on Metal Surfaces. J. B. Philipson (*Proc. Iowa Acad. Sci.*, 1933, **40**, 150–151; *C. Abs.*, 1935, **29**, 2452).—The impact of electrons on a metal surface alters the chemical properties of the surface in such a way that certain subsequent chemical treatments will make the exposed portions visibly different from the unexposed portions.—S. G.

***The Influence of Cold-Work on the Thermal Conductivity of Metals.** G. Tammann and W. Boehme (*Ann. Physik*, 1935, [v], **22**, 500–506).—The thermal conductivity of metal wires drawn to 98% reduction is less than that of similar wires in the annealed state by the following amounts: silver 5·8, copper 1·6, iron 3·2, nickel 5·4, aluminium 0, 77 : 23 silver–zinc alloy 22, 72 : 28 brass 22%. These values correspond almost exactly with the increase in electrical resistance, and the curves showing change in electrical and thermal resistance with annealing temperature are also similar. The thermal conductivity of rolled sheets of iron, nickel, silver, copper, and aluminium shows no anisotropy.—v. G.

***Asymmetric [Electrical] Conductivity of an Electrode System comprising Metal–Salt Layer–Adsorbed Alkali Metal.** J. H. de Boer and W. Ch. van Geel (*Physica*, 1935, **2**, 309–320).—[In German.] A silver–calcium fluoride–cæsium rectifier is investigated.—J. S. G. T.

***Asymmetric [Electrical] Conductivity of the Combination Metal-Blocking Layer–Salt Layer–Adsorbed Alkali Metal.** W. Ch. van Geel and J. H. de Boer (*Physica*, 1935, **2**, 321–327).—[In German.] See also preceding abstract.
—J. S. G. T.

***Thermo[electric] Force and [Electrical] Resistance.** L. Nordheim and C. J. Gorter (*Physica*, 1935, **2**, 383–390).—[In German.] Any perturbation introduced into the atomic system of a metal will give rise to an increased electrical resistance and to a change in its thermoelectric power. In certain conditions a parallelism between such changes is to be anticipated. Theoretical formulæ relating to these two physical quantities are reviewed briefly and the effects of perturbations as shown by solid solutions, ferromagnetic materials, cold-worked metals, and liquid metals are briefly discussed both theoretically and with reference to experimental results. Parallelism between the two phenomena apparently exists in some cases, but the observations require considerable amplification. Such data when available promise to extend very considerably our knowledge of the metallic state.—J. S. G. T.

***The Superconductivity of Thin Films.** E. F. Burton, J. O. Wilhelm, and A. D. Misener (*Trans. Roy. Soc. Canada*, 1934, [iii], **28**, Sect. III, 65–79).—Experiments were carried out on thin films of tin, deposited on wires of a non-superconducting metal. It was found that the superconducting point was approximately the same whether the tin was deposited on Constantan, nickel, steel, phosphor–bronze, or manganese. The method of application of the tin (wiping, hot-dipping, or electrodeposition) was also without important effect. With decreasing thickness of the tin layer, the films become superconducting at lower temperatures, and are more sensitive to current strength. When the film of tin is covered by an electrodeposited layer of copper or nickel, the superconducting point is depressed considerably. It appears that a definite thickness of metal and a free surface are necessary for superconductivity.—C. E. H.

***Effective Permeability of Superconductors.** F. G. A. Tarr and J. O. Wilhelm (*Trans. Roy. Soc. Canada*, 1934, [iii], **28**, Sect. III, 61–63).—Describes an experiment on a block tin tube, verifying the findings of W. Meissner and R. Ochsenfeld (see *Met. Abs.*, 1934, **1**, 289), that on lowering the temperature of a superconductor, its permeability becomes zero below the transition point.
—C. E. H.

***The Course of the Penetration of a Transverse Magnetic Field into a Superconductor.** W. J. de Haas and J. M. Casimir-Jonker (*Physica*, 1934, **1**, 291–296; *Comm. K. Onnes Lab. Leiden*, No. **229d**).—[In German.] Bismuth at liquid helium temperatures shows marked resistance changes in a magnetic field; it was used as indicator for the field strength inside a tin single crystal at or near the superconducting transition point. A cylindrical single-crystal tin wire (7 mm. in diameter, 8 mm. long) was provided with 3 parallel glass capillaries, one in the axis, 2 others 1 mm. under the skin of the wire. Inside the capillaries bismuth wires, 1–2 cm. long, with copper potential and current leads were introduced. The tin cylinder was cooled below the transition point without magnetic field, a transverse field was then applied and increased in strength until the superconductivity of the tin was again destroyed. During the latter period the bismuth resistance was measured repeatedly. Up to a threshold value for the external field the bismuth resistance did not change; the threshold value was higher for the central wire than for the outside ones. The curve of bismuth resistance (changing with local field strength) *versus* the external field strength for the enclosed wires is entirely different from the normal one for bismuth. The sudden increase above the threshold value extends to a value above the normal curve and is followed by a gradual approach of the latter. It is concluded that the external magnetic field induces persistent currents which compensate the field strength inside the superconductor. From a certain field strength on the surface superconductivity is destroyed, the persistent currents disappear and this destruction gradually penetrates into the tin metal with increasing field strength, the interval between the initial and total destruction being 3 gauss. Above 32 gauss, the value for complete destruction, the bismuth resistance returns to normal. For a longitudinal field the resistance changes of the 3 bismuth wires are all identical and simultaneous; the curve has the same character as above. On cooling a tin wire in a constant field it was observed that the field disappears from the superconductor near the outer bismuth wires, the central bismuth wire showed a field increase at the transition point.—S. G.

***Superconduction and Diamagnetism.** F. and H. London (*Physica*, 1935, **2**, 341–354).—[In German.] Contrary to the usual conception that an electric current in a superconductor cannot exist without the coexistence of a magnetic field, the super-current is here conceived as a kind of diamagnetic volume current, and is maintained by a magnetic field which can be generated by the current itself. The mathematical analysis of the phenomenon is developed along these lines and is extended to the case where both superconducting and normal electrons are present.—J. S. G. T.

†**Electronic Structure of Metals.** J. C. Slater (*Rev. Modern Physics*, 1934, **6**, 209–280).—The first usable electronic model of the electron was that of Lorentz. It conceived a metal as consisting of empty space containing hard spherical atoms, between which the electrons moved subject to 2 forces only, *viz.* any external applied electric fields and forces of elastic collision with atoms. This model, characterized by a beautiful simplicity, requires modification in the light of present-day knowledge of atomic structure, and Lorentz's theory of the metal state has been superseded by the extremely complicated present-day theories. Here, the modern mathematical theory of the metallic state is presented. The subjects discussed comprise (1) Fermi statistics and free electrons, and (2) the wave mechanical theory. The treatment throughout is mathematical. A *bibliography* of 118 references is appended.—J. S. G. T.

Quantitative Calculation of the Proper Functions of Electrons in Metals. H. Bethe (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 18–23; *C. Abs.*, 1935, **29**, 2833).—Only qualitative explanations of the energy levels of metal electrons and physical properties of metals can be given by theory. This is because of the rigid requirements made by either a free-electron theory or by an atomic proper function (valency force) theory. Free electrons in the alkali metals, the cohesion of metals and the absorption of light by metals are discussed.
—S. G.

The Limits of the Elementary Theory of Electrons in Metals. L. Nordheim (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 3–17; *C. Abs.*, 1935, **29**, 2834).—A general discussion of the hypothesis of free electrons and of free paths of electrons in metals.—S. G.

The Statistical Basis of the Electron Theory of Metals. R. Peierls (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 24–30; *C. Abs.*, 1935, **29**, 2834).—Assumptions must be made in the statistical treatment of the electron theory of metals which are not fulfilled for metals at high temperatures. This case can be treated by using other simplifications which give good results.—S. G.

Basis of the Electron Theory of Metals and the Method of the Self-Consistent Field. Léon Brillouin (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 33–46; *C. Abs.*, 1935, **29**, 2835).—Methods employing hypothetical assumptions of free electrons and periodic potential are compared with self-consistent field methods. A table is given showing the results of several theories.—S. G.

Surface Waves in the Electron Theory of Metals. A. W. Maue (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 68–71).—See *Met. Abs.*, this volume, p. 94.—S. G.

Application of the Electron Theory of Metals to the Study of Alloys. H. Jones (*Helv. Phys. Acta*, 1934, **7**, Suppt. II, 84–87; *C. Abs.*, 1935, **29**, 2835).—The physical properties of bismuth and its alloys are considered from the point of view of Brillouin zones. The magnetic susceptibilities are calculated and compared with experimental values.—S. G.

***The Liquid State.** W. H. Rodebush (*Phys. Rev.*, 1935, [ii], **47**, 513).—A note. Analogies between the electrons in a metal and the molecules in a liquid are pointed out. Superheating of a solid above its melting point does not occur because the heat of activation for fusion is small, and presumably no greater than the heat of fusion, but with transition points superheating is possible, because a heat of activation essentially equal to the heat of vaporization is required.—W. H.-R.

***Hall Coefficients of Alkali Metals [Electron Theory of Metals].** Clarence Zener (*Phys. Rev.*, 1935, [ii], **47**, (8), 636).—A note. Recent values for the Hall coeff. show good agreement with theory for sodium, fair agreement for potassium and cæsium, and a poor agreement for lithium. The theoretical implications are discussed.—W. H.-R.

II.—PROPERTIES OF ALLOYS

(Continued from pp. 212–219.)

***Contraction of Aluminium and Its Alloys on Solidification.—I.** L. Losana (*Alluminio*, 1934, **3**, 321–327; *C. Abs.*, 1935, **29**, 2133).—The changes in volume of aluminium and some of its alloys have been measured by the hydrostatic balance method (cf. *Gazz. chim. ital.*, 1923, **53**, 89–94). The contraction in volume on solidification, which is 6% for pure aluminium, is reduced to 5·95 and 5·6%, respectively, by the addition of 1 and 2% iron. Similarly, additions of 0·7, 1·4, and 1·6% silicon reduce the contraction to 5·8, 5·2, and 4·6%. Further addition reduces the contraction in proportion, up to 20% silicon, the limit studied. Addition of 1, 2, 5, and 7% copper reduces the contraction to 5·8, 5·4, 4·3, and 3·6%, respectively. Further addition of copper produces very little change.—S. G.

***Transformations in Iron–Aluminium Alloys.** C. Sykes and H. Evans (*Iron Steel Inst. Advance Copy*, **1935**, 1–23).—In conditions of slow cooling, atomic rearrangement ("ordering") occurs in alloys of the approximate composition Fe_3Al (13·9% of aluminium). The heat evolution due to this process starts at about 560° C. and continues over a considerable range of temperature, probably down to 200°–250° C., depending on the rate of cooling. The critical temperature can be obtained from the measurement of the resistivity of samples quenched from various temperatures and, so obtained, is in good agreement with the results of thermal methods. The magnetic change points of alloys containing 11–17% of aluminium were determined, from which it appears that the ordering process can in certain cases affect the magnetization-temperature curve.—J. H. W.

***On the Low Temperature Diffusion of Solid Aluminium into Iron.** Leo G. Hall (*Phys. Rev.*, 1935, [ii], **47**, 418–419).—A note. Aluminium will diffuse into steel or cast iron at 300° C. provided that both surfaces are clean, and sufficient pressure exists to ensure full contact of the surfaces. Penetration without substantial pressure has not been observed below the melting point of aluminium. The rate of diffusion is a direct function of the pressure, whilst the pressure necessary to produce a given rate of penetration decreases with increase of temperature. When a bar of iron is immersed in molten aluminium, the aluminium diffuses upward at the rate of 1–2 cm./day, and some iron dissolves in the aluminium. Some properties of iron impregnated with aluminium are described briefly.—W. H.-R.

***The Alloys Formed by the Aluminium–Magnesium Solid Solution.** G. Chaudron and R. Dandres (*Compt. rend.*, 1935, **200**, 1324–1326).—The variation of the mechanical properties of the aluminium–magnesium alloys (containing up to 15% of magnesium) in sheet form, as a function of the magnesium content, has been investigated. The breaking load increases regularly, but the elongation decreases rapidly from 55 to 32% at 2% of magnesium, and thereafter remains approximately constant or slightly increases up to the limit of the solid solution. Certain impurities have the same effect as small quantities of magnesium in considerably modifying the deformability of pure aluminium. For instance, 0·15% of silicon largely increases the resistance and diminishes the elongation, and similar effects are caused by 0·45 and 0·1% of manganese. The sum of the breaking load and the elongation of these alloys is practically constant for the same magnesium content. The mechanical properties of the solid solution are not altered by 1% of zinc or cadmium, which crystallize in the same system as magnesium. Annealing experiments showed that the Al_3Mg_2 crystals cause a considerable diminution of the elongation without appreciably raising the breaking load. Metallographically, the precipitation of the β-crystals is seen at first between the grains, and then within them. These alloys have, after annealing, a more electro-negative potential than the β-crystals.—J. H. W.

***The Variation of the Mechanical Properties of an Aluminium–Magnesium Alloy as a Function of the Purity.** Henri Fournier (*Compt. rend.*, 1935, **200**, 1398–1400).—The effect on the mechanical properties of cast aluminium–magnesium alloys of various refining fluxes and gases used in melting has been investigated. Chlorine was eliminated by the addition of fluorides. The alloys, of commercial purity, were treated as follows: (1) addition of salt fluxes; (*a*) sodium fluosilicate, (*b*) mixtures of fluxes, as that of the chloride and cryolite type: $BaCl_2$ 35, KCl 23, NaCl 18, $CaCl_2$ 17, and $AlNa_3F_6$ 7%; (2) chlorides of metals susceptible to reduction by alloying; (*a*) manganese chloride, (*b*) molybdenum chloride, (*c*) titanium chloride; (3) gas treatments, (*a*) dry nitrogen, (*b*) nitrogen followed by chlorine and nitrogen; (4) addition of metals more electro-positive than aluminium–sodium. The treatments were given at a temperature of 750° C., and the alloy cast at 730°–750° C. into either dry sand or chill moulds. The breaking load, apparent elastic limit, limit of proportional elasticity, and the modulus of elasticity were measured. The properties with these alloys were inferior to those of alloys made with pure metals, and were maximum in sand castings after using a flux, such as cryolite or titanium chloride. In the case of several melts, lower values were found for the limit of proportional elasticity and the modulus of elasticity than have been elsewhere recorded, but in other cases, normal values were obtained. Further experiments are necessary to explain this fact.—J. H. W.

***The Aluminium-Rich Alloys of the Ternary System Aluminium–Tin–Manganese.** A. Schück (*Light Metals Research*, 1935, **3**, 384–401).—Translated from *Z. Metallkunde*, 1935, **27**, 11–18; see *Met. Abs.*, this volume, pp. 50, 147.—J. C. C.

†The Fatigue-Strength of Cast Light Metals. W. Linicus and E. Scheuer (*Light Metals Research*, 1935, **3**, 365–367).—Translated from *Metallwirtschaft*, 1934, **13**, 829–836, 849–855. See *Met. Abs.*, this volume, p. 95.—J. C. C.

Aluminium Alloys. W. C. Devereux (*Machinery* (*Lond.*), 1935, **46**, 7–11, 140–143).—Read before the Scottish Local Section of the Institute of Metals and the Coventry Branch of the Royal Aeronautical Society. Comparative tests on various alloys cast in " R.R." and B.S.I. type moulds illustrate that the feeding methods employed affect the properties of different alloys in different ways. The importance of investigating methods of feeding, running, and chilling for each individual casting is emphasized. Heat-treatment is not recommended for intricate and large castings. For impact-testing cast levers, a machine is described which delivers a series of blows, the tup being raised between each until fracture occurs. By this means, the advantage of low modulus of elasticity in absorbing shock is taken into account, and material with high elastic limit shows up the best. Over-fluxing light alloys may give large grain-size. Defects arising in wrought material, particularly those due to the growth of large crystals, are discussed, and reference made to the effect of heat-treatment after cold-working.—J. C. C.

†Advances and Researches in the Field of Light Metals. —— (*Metallwirtschaft*, 1935, **14**, 192–194).—A review of the literature.—v. G.

***The Hall Effect and Some Other Physical Constants of Alloys. IV.—The Bismuth–Cadmium Series of Alloys.** S. Gabe and E. J. Evans (*Phil. Mag.*, 1935, [vii], **19**, 773–787).—The electrical resistivity at 0° C., and its temperature coeff. over the range 0°–100° C., the density, thermoelectric power relative to copper, Hall effect, and the specific heats of carefully annealed alloys (18) of the bismuth–cadmium series have been determined over the complete range of compositions. The density (d), specific heat (s), resistivity (ρ), and thermoelectric power (P), of an alloy containing χ% of bismuth are given by the following equations: $d = 8{\cdot}64 + 1{\cdot}16\chi 10^{-2}$; $s = 0{\cdot}0559 - 2{\cdot}58\chi 10^{-4}$; $\rho = 6{\cdot}83 + 0{\cdot}168\chi + 0{\cdot}00270\chi^2 + 56{\cdot}2\chi^6 10^{-12}$; $P = 1{\cdot}701 - 0{\cdot}130\chi - 0{\cdot}00380\chi^2 - 15{\cdot}1\chi^7 10^{-14}$. The resistivities decrease on annealing the alloys, the change being greatest for the alloy containing 14·9% by weight of bismuth. The bismuth–cadmium alloys exhibit no reversal of sign over the range of magnetic field strengths 3096–8424 oerstedt, contrary to what is found to occur in the bismuth–tin and bismuth–lead series of alloys. The Hall coeff. of all the bismuth–cadmium alloys examined are negative, and diminish as the magnetic field strength is increased. A large negative value of the Hall coeff. corresponds with a high resistivity. The thermoelectric power–composition curve follows the general trend of the Hall coeff. composition curve.—J. S. G. T.

Cadmium–Silver Bearing Metal on New Pontiacs [Motor Cars]. —— (*Amer. Metal Market*, 1935, **42**, (28), 2).—A short note. The engine bearings are made of a silver–copper–cadmium alloy (cadmium 87·5, silver 2·25, copper 0·25%) having a melting point of 610° F. (321° C.) and a Brinell hardness of 40 at room temperature and 16·5 at 310° F. (154° C.). A chill-cast section, $\frac{1}{4}$ in. thick, withstands 135° cold bend without cracking and at 400° F. (204° C.) can be bent flat on itself without cracking. The tensile strength is approximately 22,000 lb./in.². The alloy shows low frictional characteristics comparable to tin-base Babbitt and is non-scoring to steel shafts. Owing to its higher melting point and greater hardness at operating temperatures, the life of bearings of this alloy is several times that of tin-base Babbitt bearings.
—I. M.

***The Beta Transformation in Copper Alloys.** I. Obinata (*Kinzoku*, 1934, **4**, 289–291, 333–335).—[In Japanese.] In the binary systems copper–zinc, copper–tin, and copper–aluminium there is a $\beta \longrightarrow \beta_1$ transformation, and in the β-phase there is a eutectic transformation resembling the A_1 transformation in steel. During this transformation, a metastable intermediate phase is formed. In the case of the copper–zinc system the β-phase is stable at room temperature and there is no eutectic transformation; below room temperature, however, this eutectic transformation may take place.—S. G.

***The Ternary System Copper–Silver–Cadmium.** L. Losana and C. Goria (*Industria chimica*, 1934, **9**, 1603–1615; *C. Abs.*, 1935, **29**, 2061).—The composition and cooling curves of the system copper–silver–cadmium were studied completely, and the results of studies of several of the binary systems were combined. The equilibrium diagram is very complex. Several useful alloys are indicated: (*a*) cadmium 81, silver 12, copper 7%, melting at 490°–505° C.; (*b*) cadmium 57, silver 6·5, copper 36·5%, melting at 535°–550° C.; (*c*) cadmium 39, silver 40·5, copper 20·5%, melting at 670° C. These alloys are resistant to oxidation, but are fragile, especially (*c*). They are useful for fusible safety plugs, &c.—S. G.

***High-Tin Bronze.** C. H. Tonamy (*Kinzoku*, 1934, **4**, 401–402).—[In Japanese.] Even in heat-treated gun-metal a tensile strength of 20 tons/in.^{2} is obtainable; when high-strength copper alloys are required, therefore, heat-treated high-tin bronze is recommended in place of manganese–brass and "aluminium–bronze." Three specimens, containing 20, 22, and 24% tin, respectively, held at 650° C. for $1\frac{1}{2}$ hr. and then quenched in water, had the following tensile strengths and elongations, respectively: 26·21 tons/in.^{2}, 12·5%; 26·80 tons/in.^{2}, 3·0%; 25·00 tons/in.^{2}, 2·0%.—S. G.

†Studies on Cast Red Brass for the Establishment of a Basic Classification of Non-Ferrous Ingot Metals for Specification Purposes. C. M. Saeger, Jr. (*Proc. Inst. Brit. Found.*, 1933–1934, **27**, 268–304; discussion, 304–317).—American Exchange Paper. See *Met. Abs.*, 1934, **1**, 382, 491.—S. G.

Non-Metallic Inclusions in Ferro Alloys. B. Matuschka (*Iron Steel Inst. Advance Copy*, **1935**, 1–8).—The structure and physico-chemical behaviour of the slag inclusions in liquid and solid steel are considered in general terms and the nature, occurrence, and behaviour of non-metallic inclusions in ferro-alloys with tungsten, chromium, nickel, molybdenum, cobalt, vanadium, manganese, silicon, aluminium, and copper are described.—J. H. W.

†Lead Bearing Metals: Present Position of Their Technique and the Knowledge of Their Applications. Fr. Witte (*Z.V.d.I.*, 1935, **79**, 98–100).—The characteristic properties of lead-base bearing metals are described and their future development is discussed with especial reference to the attempts which are being made to improve their stability by addition of heavy metals.—K. S.

New Alloy Melts at Temperature of 116° F. —— (*Amer. Metal Market*, 1935, **42**, (88), 5).—A brief note. The discovery of a new low-melting point alloy is announced by Professor S. J. French of Colgate University, U.S.A.; its composition is not given. Since its melting point is only slightly above that of the human body, it may find use in making finger print and surgical moulds.—I. M.

The Nature of the Diffusion of Mercury on Tin. T. Alty and A. R. Clark (*Trans. Faraday Soc.*, 1935, **31**, 648–659).—The diffusion of mercury in tin consists of a rapid surface diffusion accompanied by a much slower volume diffusion. A detailed study of the surface process shows it to be a true diffusion in that it obeys an ordinary diffusion equation. The variation of the rate of diffusion with the temperature obeys the same law as that of an adsorbed film, and the energy of activation of the mobile atoms on a pure tin surface is 1920 grm.-cal./grm.-atom. The rate of diffusion in water is greater and that in oil slower than in air; at 60° C. the rate in water is 1·081, and at 15·3° C. 1·076 times that in air, whilst at 60° C. the rate in light liquid petroleum is 0·77 times that in air. The diffusion of mercury on a surface of a tin amalgam containing 8 atomic-% mercury decreases with rise in temperature, and the energy of activation of the mobile atoms on the amalgam surface is — 328 grm.-cal./grm.-atom.—A. R. P.

***X-Ray and Hardness Tests on Nickel-Rich Nickel–Tin Alloys.** Eric R. Jette and Erich Fetz (*Metallwirtschaft*, 1935, **14**, 165–168).—The alloys with 0–33% tin were melted in a vacuum furnace, then homogenized, powdered, annealed at various temperatures, quenched, and examined by X-rays. The results gave the following values for the solubility of tin in nickel: 500° C. 1·9; 700° C. 8·8; 900° C. 17·7; and 1100° C. 19·8%. Consequently these alloys are capable of being precipitation-hardened, the 10% alloy to a Brinell hardness of 290 and the 20% alloy to a hardness of 490.—v. G.

***On a Further Investigation of the Equilibrium Diagram of the Nickel–Zinc System.** Kanzi Tamura and Atomi Ôsawa (*Sci. Rep. Tohôku Imp. Univ.*, 1935, [i], **23**, 794–815).—[In English.] See *Met. Abs.*, this volume, p. 216.—S. G.

***On the Glow-Electric Effect of Palladium–Silver Alloys Saturated with Hydrogen.** J. Schniedermann (*Ann. Physik*, 1935, [v], **22**, 425–442).—Adsorption of hydrogen increases the electron emission of all palladium–silver alloys, the effect being at a minimum at 40% silver as is the case with all other properties.—v. G.

***Solidification Diagrams of Alloys Formed by Two Alkali Metals: The Potassium–Rubidium Alloys.** E. Rinck (*Compt. rend.*, 1935, **200**, 1205–1206).—A continuation of the work done on the alloys of sodium with potassium, rubidium, and cæsium (see *Met. Abs.*, this volume, p. 54). Potassium and rubidium are completely miscible in the solid state. The liquidus and solidus are very close, and show a flat minimum at 32·8° C., corresponding exactly to K + 2 Rb. Microexamination showed that these 2 metals form a single series of solid solutions.—J. H. W.

Are Not Liquid Sodium Amalgams Colloidal? R. M. Joshi (*Indian J. Research*, 1934, **9**, 153–159; *C. Abs.*, 1935 **29**, 2814).—The probability that colloidal system is present is greater than Bent (*J. Inst. Metals*, 1933, **53**, 493) admits.—S. G.

***Magnetoresistance of Liquid Sodium–Potassium Alloy.** J. E. Armstrong (*Phys. Rev.*, 1935, [ii], **47**, 391–392).—Cf. *Met. Abs.*, this volume, p. 218. The effect of a magnetic field on the resistance of a liquid sodium–potassium alloy containing approximately 35% of sodium has been studied for field-strengths up to 16,000 gauss. A definite magnetoresistance effect exists apart from any secondary effects due to motions in the liquid. A longitudinal magnetic field produces a larger effect than a transverse field, although, in non-ferromagnetic crystalline solids, the converse is true. Above 2000 gauss there is a linear relation between the magnetoresistance (dR/R) and the field-strength.—W. H.-R.

†**Alloys—Old and New.** (Sir) H. C. H. Carpenter (*Iron Steel Inst. Advance Copy*, **1935**, 1–19).—Presidential Address. The various meanings of the term "alloy" are explained, and the history of the development of alloys from the earliest times is briefly set out. In relating the properties of an alloy with its previous treatment, it is necessary to consider (1) its composition, (2) its constitution, (3) its structure, and (4) its condition. These factors, as well as the properties and treatment, are so inter-related that they cannot be considered entirely independently. Composition varies greatly in importance with the properties, and is determined chiefly by the electric, magnetic, and chemical properties required of the alloy. The constitution and structure are determined more by the mechanical properties desired, and their study is based on the equilibrium diagram, the 4 principal types of which are here classified, and the structure characteristic of each is described. The trans-

formations in solid alloys are explained with examples of the gold–copper, aluminium–iron, and magnesium–silicon systems, and the hypotheses put forward to account for age-hardening are critically reviewed.—J. H. W.

***On the Rate of Precipitation-Hardening [of Alloys].** Erich Söhnchen (*Metallwirtschaft*, 1935, **14**, 205–208).—The effect of addition of other elements, of variations in grain-size and degree of deformation, and of magnetic fields on the rate of precipitation-hardening of various alloys has been determined, and the results are discussed with reference to the literature. Magnetic fields have no influence on aluminium or magnesium alloys.—v. G.

Progress in Metals. Albert J. Dornblatt (*Heat-Treating and Forging*, 1935, **21**, 129–131).—The composition of a number of alloys for various applications in transportation equipment and the specific properties required in each case are tabulated.—J. H. W.

"Iso-Elastic." A New Alloy for Springs. —— (*Amer. Metal Market*, 1934, **41**, (225), 5).—A brief note. The alloy is intended for use in measuring apparatus, and conforms to Hooke's law under widely varying conditions. It is a modification of Elinvar, but the composition is not given.—I. M.

On Ferromagnetic Alloys and Their Conformity to Laws. A. Kussmann (*Chem.-Zeit.*, 1935, **59**, 285–287).—Recent work on the relation between constitution and magnetic properties is reviewed with special reference to the stress theory of the magnetization curve and to the development and uses of new magnetic alloys with high nickel or cobalt contents.—A. R. P.

***Curves of Fusion of Solid Solutions Accompanied by the Formation of a Chemical Combination.** A. Mlodziejowski (*Physica*, 1935, **2**, 159–168).—[In French.] M. has already derived an expression for the radius of curvature of a curve of fusion of a binary system at the melting point, for the case of binary systems forming a single liquid phase which on solidifying yields only crystals not containing the components in solid solution (*Arch. Néer.*, **1931**, III, A, 196). Here the analysis is extended to the case where a solid solution is formed.—J. S. G. T.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

(Continued from pp. 220–226.)

***Metallographic Films.** E. O. Bernhardt and H. I. Wiester (*Z.V.d.I.*, 1935, **79**, 7–11).—The apparatus, technique, uses, and results of filming the changes which take place in the structure of metals at high temperatures, *e.g.* the process of recrystallization, are described.—K. S.

***Microstructure of Aluminium and Its Alloys.** H. Nishimura (*Kinzoku*, 1934, **4**, 179–184, 321–326).—[In Japanese.] The microstructures of the aluminium–copper, aluminium–silicon, aluminium–magnesium, aluminium–zinc–copper, and aluminium–silicon–copper alloys were investigated. A new equilibrium diagram is put forward for the aluminium–copper system.—S. G.

Affinity in the Hume-Rothery Phases. U. Dehlinger (*Metallwirtschaft*, 1935, **14**, 145–149).—The principles of the Hume-Rothery rule for the formation of intercrystalline phases are discussed on thermodynamical considerations. —v. G.

The Structure of Metallic Coatings, Films, and Surfaces. Introductory Paper. Cecil H. Desch (*Faraday Soc. Advance Copy*, **1935**, Mar., 2 pp.).—A brief outline of recent work on the study of metal surfaces is followed by a brief survey of the field covered by the papers presented at the general discussion on the structure of metallic coatings, films, and surfaces (see following abstracts).—A. R. P.

***Factors Influencing the Formation and Structure of Hot-Dipped Tin Coatings.** Edward J. Daniels (*Faraday Soc. Advance Copy,* **1935,** Mar., 5 pp.; and *Tech. Publ. Internat. Tin Res. Development Council,* 1935, [A], (**17**), 1–10).—Theories of the mechanism of the formation of hot-dipped coatings are reviewed and it is suggested that the prime factor in wetting is the attraction between the solid and liquid metals, the affinity between the two metals resulting generally in the formation of an intermetallic compound or solid solution at the interface; many examples of these phenomena are discussed, and in the case of tin coatings on copper and iron the effects of additions of various metals on the nature of the intermediate layer are described. The action of fluxes in promoting union of the liquid and solid metals is briefly outlined, and it is shown that hydrogen can act as a true flux in the tinning of copper since it reduces the oxides of both metals below 300° C. and thus provides clean surfaces. Steel cleaned with emery can also be tinned by immersion in molten tin containing only 0·05% phosphorus without the use of any flux. Addition of 0·04% cobalt or 0·1% of nickel to tin entirely prevents rippling of the coating on steel, and addition of more than 3·7% silver or 1·1% copper to tin has the same effect on coatings on copper; it is suggested that deposition of tiny crystals of an intermetallic compound, *e.g.* Ni_3Sn_2, Cu_6Sn_5, or Ag_3Sn, evenly over the surface of the coated metal, acts as a "grit" in the molten metal, preventing the movements which, when unimpeded, produce ripples. If the tinning temperature is too low the "grit" crystals become too large and the coating is pimply, but if the temperature is too high rippling occurs since the "grit" is dissolved in the hot metal. Bright, unrippled coatings can also be obtained by a suitable quenching operation. —A. R. P.

***Determination of the Phase Structure of Metallic Protective Coatings by Anodic Dissolution.** A. Glazunov (*Faraday Soc. Advance Copy,* **1935,** Mar., 3 pp.).—The thickness of zinc coatings and of the various intermediate layers on galvanized iron may be determined by anodic dissolution of the coating in a saturated solution of zinc sulphate. If d is the thickness of the layer, e the electrochemical equivalent, I the current intensity, t the time, η the sp. gr. of the metal, and s the area, then $d = e \,.\, I \,.\, t/\eta \,.\, s$. If the voltage of the cell is plotted against the time a graph will be obtained consisting of one or more horizontal sections connected by sloping lines. Since each phase of constant composition has its own potential which remains constant during its dissolution, and since the potential changes regularly during the dissolution of a solid solution, from the lengths of the individual potential values (horizontal positions in the graph) and of the intervals between them the thickness of the various layers and their composition can be determined with the aid of the above equation if the course of the potential curves of the binary system in question is known. Thus galvanized coatings have been shown to contain Zn_3Fe and probably also $ZnFe_3$.—A. R. P.

†The Determination of the Structure of Electrodeposits by Metallurgical Methods. D. J. Macnaughtan and A. W. Hothersall (*Faraday Soc. Advance Copy,* **1935,** Mar., 6 pp.).—Recent work on the determination of the structure of electrodeposits of nickel, chromium, and other metals by micrographic methods and by physical tests, especially hardness determinations, is described and critically reviewed, photomicrographs of nickel deposits made under various conditions are shown and discussed and the effect of annealing on the crystal structure is briefly outlined.—A. R. P.

†The Effects of Film Formation on the Structure of Electrodeposited Metallic Coatings. E. Liebreich (*Faraday Soc. Advance Copy,* **1935,** Mar., 3 pp.).—Modern theories of the mechanism of the electrodeposition of metals, with especial reference to the effect of film formation on the structure of chromium deposits are reviewed.—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 (*Faraday Soc. Advance Copy*, **1935**, Mar., 7 pp.).—From experiments on nickel- and chromium-plating and from a review of the published results of other investigators it is concluded that the structure of electrodeposits may be influenced by the crystal structure of the cathode but also depends on the rate of formation (N_c) of crystal nuclei and on their rate of growth (V_c) which are functions of the concentration of the electrolyte in contact with the cathode, the current density, and the temperature. Crystalline continuity between the deposit and the cathode requires the absence of surface films on the cathode and of the hardened amorphous layer produced by polishing. If N_c is large, *e.g.* in fine-grained deposits, compared with the number (n) of crystals per unit area of cathode, the effect of the surface of the latter is small since n is negligible compared with N_c, whereas if N_c is very small the nature of the cathode surface determines the grain-size of the deposits. In general the grain-size decreases with increase in N_c and increases with increase of V_c. The effect of various conditions on the nature of nickel and chromium plates is shown in a series of 23 photomicrographs.—A. R. P.

***Influence of the Basis Metal on the Structure of Electrodeposits.** A. W. Hothersall (*Faraday Soc. Advance Copy*, **1935**, Mar., 5 pp.).—Examination of the structure of deposits of copper on cold-rolled copper, annealed silver, and nickel, and cast 98 : 2, 90 : 10, 70 : 30, 60 : 40, and 54 : 46 brasses, of tin on cast tin, cast 1% antimony–tin alloy, and annealed copper, and of nickel on annealed nickel and iron, and filed electrodeposits of nickel (micrographs of all are reproduced) shows that continuation of a basis metal structure in an electrodeposit is possible when both belong to the same crystal system and the lattice parameters vary by from, *e.g.*, $-$ 2·4 to $+$ 12·5%, and when both belong to different systems. Thus tetragonal tin continues the microstructure of face-centred cubic copper, and copper continues the structure of body-centred cubic brass. Distortion of the lattice by cold-work or by the introduction of an element in solid solution does not restrict continuation of microstructure during electrodeposition of another metal. It is unlikely, therefore, that co-deposition of hydrogen in solid solution has any effect on the grain-size of electrodeposits. The high degree of adhesion obtainable with electrodeposited coatings is probably associated with their ability to continue the crystal lattice of the basis metal even if only to a limited thickness.—A. R. P.

†Electrode Potentials and the Form of Electrodeposited Metals. Samuel Glasstone (*Faraday Soc. Advance Copy*, **1935**, Mar., 3 pp.).—From a critical analysis of recent work on the deposition of silver from cyanide baths, and of zinc and nickel from sulphate baths, it is concluded that there must be some connection between the form of an electrodeposited metal and the potential at the cathode during deposition, but that the relation is difficult to determine exactly owing to the effect of numerous other factors, some of which work in opposite directions.—A. R. P.

***Factors Affecting the Structure and Grain-Size of Electrodeposited Cadmium.** S. Wernick (*Faraday Soc. Advance Copy*, **1935**, Mar., 4 pp.).—In neutral potassium cadmicyanide baths the grain-size of the deposits becomes finer as the cadmium content is increased from 8 to 40 grm./litre, but owing to the absence of free cyanide the anode tends to darken and become " foul." Addition of free cyanide to a bath with 30 grm./litre of cadmium gradually improves the nature of the deposit until with 100% excess cyanide a white, compact, and very fine-grained deposit is obtained; with a larger excess of cyanide considerable gassing occurs at the cathode. The presence of 1–2% of free alkali hydroxide in the bath increases the conductivity, has a restraining influence on the anode dissolution, and materially assists in maintaining the colour and uniformity of the deposit. In a bath containing cadmium 30 grm./litre, free cyanide 100%, and caustic soda 15 grm./litre increase in current density from 10 to 15 amp./ft.^{2} causes the original white deposit to become greyer and more crystalline, while at 30 amp./ft.^{2} the deposits are "burnt," and at 40 amp./ft.^{2} dark, nodular, and large-grained, all of these defects being, however, overcome by stirring the electrolyte. Increase in temperature above 30°–35° C. increases the crystal size of the deposits and makes them loose, granular, and poorly adherent. In sulphate electrolytes the deposit is finer the higher the p_H up to about 6·6, good fine-grained plates being obtained from M-cadmium sulphate solutions buffered to p_H 5·5–6·6 by addition of boric acid 30, and sodium chloride 5·85 grm./litre, and operated at 35–40 amp./ft.^{2} with stirring; the plates are, however, not so fine-grained as those obtained from cyanide baths, although they can readily be buffed to a good colour. Increase in temperature from 22° to 50° C. reduces the crystal size but darkens the deposit, but a further increase to 80° C. makes the deposit more crystalline, but whiter. Addition of 0·04% dextrin, or better 0·1–0·2% gelatin, reduces the grain-size to that obtainable in cyanide baths.—A. R. P.

***Structure and Properties of Nickel Deposited at High Current Densities.** William Blum and Charles Kasper (*Faraday Soc. Advance Copy,* **1935,** Mar., 5 pp.).—The tensile strength, elongation, hardness, and structure of nickel deposits obtained at 100° C. with current densities of 22–45 amp./dm.^{2} in $4N$-nickel solutions of p_H 1–2 have been determined, and the results are shown in a table and in a series of photomicrographs. Deposits from chloride solutions have a fine-grained structure and are relatively smooth, strong, hard, and brittle, whereas those from sulphate solutions under the same conditions are rough, coarse-grained, soft, and ductile. In mixed solutions in which at least 25% of the nickel is present as chloride the deposits are similar to those obtained from pure chloride solutions. Change in p_H from 1 to 2 has no effect in chloride solutions, but in sulphate solutions an increase in p_H increases the hardness and reduces the ductility. Boric acid additions slightly soften deposits made from sulphate baths but have no effect on those made from chloride baths. The cathode efficiency is higher in chloride than in sulphate baths, especially at the higher current densities.—A. R. P.

***The Crystallization of Thin Metallic Films.** E. N. da C. Andrade (*Faraday Soc. Advance Copy,* **1935,** Mar., 4 pp.).—The nature of thin gold and silver films produced by cathodic sputtering has been investigated and their behaviour on heating *in vacuo* examined by optical methods with light- and dark-field illumination and with polarized light. In films about 50 atoms thick silver begins to crystallize at 250°–280° C. and gold at about 400° C.; at these temperatures the eye can detect no change, but under the microscope spherulitic crystals of about 1 μ can be distinguished. As the temperature is increased the number and size of the spherulites increases, and eventually they coalesce to true crystals of the ordinary form. The nature of the original sputtered films cannot be definitely established by microscopic examination, but if they are crystalline the size of the crystals is beyond the resolving power of the microscope. Whilst it is possible that the spherulites are the end products of a process of gathering together of minute sub-microscopic crystals and not the result of an association of un-ordered atoms, it appears to be more likely that the original film is amorphous and the spherulites are formed by the motion of the surface layer to the depth of a few atoms with the production of a spherulitic aggregate which later grows in size and crystallizes.
—A. R. P.

***Optical Research on Evaporated Metal Layers.** L. S. Ornstein (*Faraday Soc. Advance Copy,* **1935,** Mar., 10 pp.).—Optical research on metallic films produced by evaporation from tungsten filaments *in vacuo* gives valuable information on the structure of the metal in thin layers and on the effect of various reagents thereon. The mathematical and experimental bases of the procedure are explained in detail and some results obtained with antimony, tin, silver, gold, and copper are described. The mechanism of the condensation of the metal vapour on a cooled glass plate appears to be as follows: at first small crystalline nuclei are formed by condensation of the monatomic vapour at various random points, and these then act as centres of condensation for the growth of small crystals. A method of determining the reflectivity of tungsten as a function of the temperature is summarized and its mathematical basis is explained.—A. R. P.

The Validity of Drude's Optical Method of Investigating Transparent Films on Metals. Leif Tronstad (*Faraday Soc. Advance Copy*, **1935**, Mar., 4 pp.).—The theoretical principles of Drude's method are explained mathematically and possible sources of error in applying it to the investigation of thin oxide and other films on metals are discussed at some length, together with possible ways of overcoming them.—A. R. P.

***The Thickness of the Amorphous Layer on Polished Metals [Gold].** H. G. Hopkins (*Faraday Soc. Advance Copy*, **1935**, Mar., 3 pp.).—Examination of the polished layer on gold by the electron diffraction method, after removing various thicknesses of the metal by cathodic sputtering, has shown that the amorphous Beilby layer has a thickness of about 30 A. and that there is a gradual increase in crystal size below the polished surface.—A. R. P.

***The Structure of Polished Metal Surfaces.** C. S. Lees (*Faraday Soc. Advance Copy*, **1935**, Mar., 3 pp.).—Polished surfaces of gold and copper have been examined by electron diffraction after electrolytic etching to remove various thicknesses. The results show that the Beilby layer produced by polishing is separated from the unoriented polycrystalline interior of the metal by a thin layer of oriented crystals and the thicknesses of these 2 layers have been measured. The orientation of the intermediate layer is probably due to deformation of the crystals by compression, but the actual surface layer, which is 20–40 A. thick, is shown to be either a pseudo-liquid or to consist of minute unoriented crystals smaller than 15 A.—A. R. P.

***Differences in the Structure of Electrodeposited Metallic Coatings Shown by X-Ray Diffraction.** W. A. Wood (*Faraday Soc. Advance Copy*, **1935**, Mar., 3 pp.).—The lines in the X-ray spectrum of a metal are of 3 types: in the first they are broken and spotted, in the second continuous and sharply resolved, and in the third broad and diffuse; these correspond roughly with grain-sizes greater than 10^{-3} cm., between 10^{-3} and 10^{-4} cm., and finer than 10^{-5} cm., respectively. Annealed metals and electrodeposits of copper and similar metals give the first type, most commercial metals give the second type, and strain-hardened metals and alloys of the interstitial solid solution class the third type. Since electrodeposited nickel and chromium coatings belong to the third type they are abnormal, chromium coatings in particular giving extremely diffuse lines, corresponding with grain-sizes of $8–19 \times 10^{-7}$ cm. This abnormality is the more pronounced since cold-working of the compact metal, *e.g.* nickel, never produces a spectrum of the third type, and it is concluded, therefore, that the subnormal grain-size of electrodeposited nickel and chromium is due to the presence of very high stresses which inhibit grain-growth, and are probably caused by the presence of occluded atoms of hydrogen or oxygen. Lattice distortion is also present in nickel deposits, and is to some extent the cause of line broadening; its presence is clearly demonstrated by a weakening of the high order reflections relative to the earlier orders, thus the (311) and (420) lines which are especially strong in spectra of the normal metal photographed with copper K_a radiation are abnormally weak in the spectra of electrodeposits. Another characteristic of electrodeposited coatings is the tendency for the grains to grow with a given crystallographic axis in a preferred direction; thus in very lustrous chromium deposits made at 50° C.

with current densities of 25–500 milliamp./cm.^{2}, the (200) line is absent and the (211) line very strong, whereas in dull deposits made at 15° C. the intensity ratio of these lines is normal. Attention is also drawn to a relation between the line-broadening and the hardness of the deposits of chromium and nickel. —A. R. P.

Electron Diffraction and Surface Structure. G. I. Finch, A. G. Quarrell, and H. Wilman (*Faraday Soc. Advance Copy*, **1935**, Mar., 14 pp.).—A description is given of types of precision electron-diffraction cameras and of the auxiliary apparatus, of the technique of their operation, and of various methods of preparing specimens for examination. This is followed by a mathematical explanation of the electron diffraction by reflection from a crystal face and by transmission through single crystals and polycrystalline aggregates. Finally some applications of the process to the study of metal films and surfaces are described. A *bibliography* of 27 references is appended.—A. R. P.

Inner Potentials of Crystals and the Electron Diffraction. W. E. Laschkarew (*Faraday Soc. Advance Copy*, **1935**, Mar., 7 pp.).—The subject is discussed theoretically and mathematically on the basis of results obtained by numerous investigators, chiefly on non-metallic substances.—A. R. P.

***X-Ray Investigations on α-Tin Bronzes.** T. Isawa and I. Obinata (*Metallwirtschaft*, 1935, **14**, 185–188).—Cf. *Met. Abs.*, this volume, p. 56. X-ray examination of bronzes with up to 18% tin which had been homogenized by rolling, annealing, and quenching from various temperatures gave the following values for the solid solubility of tin in copper: at 200°–400° C., 13·9; 500° C. 15·5; 525° C. 16·0; 600° C. 15·7; 700° C. 15·2, and 780° C. 14·1%. The solubility line thus has a point of inflection at the eutectoid temperature (525° C.).—v. G.

***Texture of Rolled α-Brass.** V. I. Iveronova and G. S. Zhdanow (*Tech. Physics U.S.S.R.*, 1934, **1**, 64–79).—[In German.] See *Met. Abs.*, this volume, p. 100.—S. G.

***The Crystal Structures of $LaSn_3$ and $LaPb_3$.** A. Rossi (*Gazz. chim. ital.*, 1934, **64**, 832).—Two corrections to a previous paper (see *Met. Abs.*, 1934, **1**, 299).—S. G.

***The Theoretical Constitution of Metallic Lithium.** Frederick Seitz (*Phys. Rev.*, 1935, [ii], **47**, 400–412).—Theoretical. The modern electron theory of metallic crystals is further developed for metallic lithium, and a better agreement between the calculated and observed values of the lattice constant and binding energy is obtained.—W. H.-R.

On the Space-Lattice of Berthollides. A. Glazunov (*Coll. trav. chim. Tchécoslov.*, 1935, **7**, 76–83).—From a discussion of the nature of various intermetallic compounds the name " berthollides " is adopted for chemical compounds having their own space-lattice in which the atoms are distributed statistically, and the name " daltonides " for those in the lattice of which the atoms are arranged regularly according to a definite law. Intermetallic phases intermediate between these two types are stated to be of a certain " degree of berthollidicity."—A. R. P.

†Description of the Binding Forces in Molecules and Crystal Lattices on Quantum Theory. F. Hund (*Internat. Conference Physics*, **1934**, (II), 36–45).—The nature of the binding forces in matter is discussed. Among matters briefly treated are included: why is sodium a metal and chlorine a gas though both are monovalent?; how are the transition elements arsenic, antimony, silicon, selenium, and tellurium to be classified?—J. S. G. T.

***About the History of Load of Deformed Crystals [X-Ray Method for the Examination of Slip-Bands].** Wolfgang F. Berg (*Z. Krist.*, 1934, **89**, 286–294).—An X-ray method for the examination of slip-bands is described, and is applied in detail to the examination of slip-bands on cleavage faces of rock-salt.—W. H.-R.

†**Shear-Hardening and Recrystallization of Aluminium Single Crystals, with an Appendix on "Transformation-Hardening."** W. G. Burgers (*Internat. Conference Physics*, **1934**, (II), 139–160).—An extensive series of investigations on the deformation and recrystallization of aluminium crystals is reviewed. Transformation-hardening occurs on transition of a solid metal from one phase to another. In such a process the specimen may become harder, unlike a strained test-piece, which becomes annealed on recrystallization. —J. S. G. T.

†**Plasticity, Crystallographic and Non-Crystallographic.** E. Schmid (*Internat. Conference Physics*, **1934**, (II), 161–170).—Experimental data relating to crystal plasticity are reviewed. Among the subjects discussed are: Cauchy's relations for the elasticity of crystals, typical cases of crystal and non-crystallographic plasticity.—J. S. G. T.

[**Discussion on**] **Plasticity and Strain-Hardening in Crystals.** —— (*Internat. Conference Physics*, **1934**, (II), 171–183).—Discussion following the reading of papers by Burgers and by Schmid (see preceding abstracts).—J. S. G. T.

†**Experimental Evidences of Group Phenomena in the Solid Metallic State.** Alexander Goetz (*Internat. Conference Physics*, **1934**, (II), 62–71).—Experiments affording evidence of the existence of a higher structural periodicity than the primary crystal lattice in the solid metallic state are critically reviewed. The word "group" is taken to mean an agglomeration of a limited number of molecules in crystalline array; inside the group the stability of a molecule is different from what it is outside, and the size of the group is a physical constant of the type of crystal considered. Thus a group structure neither accepts nor rejects the "secondary structure" discussed by Zwicky. Evidence for the existence of groups comprise: etch figures on the cleavage planes of bismuth, phenomena occurring at the transition from solid to liquid, the behaviour of crystals formed partly within and partly without a magnetic field, the distribution of the last traces of impurities, and comparison of the coeff. of thermal expansion as measured macroscopically and by X-ray methods. A *bibliography* of 31 references is appended.—J. S. G. T.

†**Group Phenomena in Metallic Crystals.** Alexander Goetz (*Z. Krist.*, 1934, **89**, 310–326).—See preceding abstract.—W. H.-R.

†**The Cause of the Low Value of Mechanical Strength.** A. Joffé (*Internat. Conference Physics*, **1934**, (II), 72–76).—Experimental values of the mechanical strength of materials are usually many thousand times lower than those to be anticipated from the theory of crystal lattices. Amorphous substances exhibit similar discrepancies. Two kinds of rupture are distinguished, *viz.* plastic rupture, in which there is a reduction of area at some point before fracture occurs, and brittle rupture. The influence of plastic deformation on mechanical strength is discussed. Brittleness occurs if the elastic limit, increased either by previous plastic deformation or by reduction of temperature, reaches the value of the practical tensile strength. Two types of explanation have been advanced to account for this, *viz.* internal faults and surface crevices. Experimental results with rock-salt are described, and it is concluded that practical weakness is due essentially to sharp discontinuities present on the surface.—J. S. G. T.

†**The Mechanism of Brittle Rupture.** A. Joffé (*Internat. Conference Physics*, **1934**, (II), 77–80).—Experimental evidence indicating that the weakness in tension of materials such as quartz and glass is due to superficial irregularities is reviewed. It is shown that dissolving away a layer from the surface of a glass rod has the same effect on tensile strength as drawing it down in a gas-flame. Irregularities distributed throughout the volume of the material affect the strength of the material only when they reach the surface. —J. S. G. T.

†**The Rupture of Plastic Crystals.** E. Orowan (*Internat. Conference Physics*, **1934**, (II), 81–92).—Sensitive processes start from nuclei, *e.g.* rupture can be initiated at Griffith's cracks. The sensitivity depends on two circumstances, *viz.* the intensity of the external influence necessary to start growth from the nuclei may depend on the size or quality of the nuclei, and the whole process may be initiated by one or a few nuclei. An important difficulty of the crack propagation theory has hitherto been the enormous crack lengths required by the Griffith's formula for explaining the tensile strength of plastic crystals. Besides the statical notch-effect discussed by Griffith, there exists, however, the possibility of the development of cracks due to plastic slip. The necessity of assuming the existence of unduly large crack lengths can thus be avoided, and the crack propagation theory of rupture can then be considered satisfactory. Proofs are given that no secondary or block structure theory of tensile strength is possible.—J. S. G. T.

†**The Structure-Sensitive Properties of Rock-Salt.** Adolf Smekal (*Internat. Conference Physics*, **1934**, (II), 93–109).—A structure-sensitive property is one which has different values for different specimens of the same crystal, the actual states of a crystal being of a characteristic metastability. The observed metastability of an actual crystal for small changes of temperature indicates that the crystal preserves the state in which crystallization occurred. In the formation of crystals, growth, in general, takes place tangentially to certain definite planes; the molecular character of the growth produces gaps and local variations in orientation; the presence of impurities leads to the incorporation of foreign atoms. These are all characterized as primary flaws, and are statistically distributed along the principal planes of growth. Secondary flaws result from alteration of primary flaws or are produced by mechanical or thermal treatment of crystals. They may attain much greater size than primary flaws. The relations to be anticipated between flaws and structure-sensitive properties are discussed. The second section of the paper deals with experimental results relating to the structure-sensitive properties of rock-salt.—J. S. G. T.

[Discussion on] The Deviations of Real Crystals from the Ideal Lattice Structure. —— (*Internat. Conference Physics*, **1934**, (II), 109–135).—A discussion following the reading of papers by Ewald and Renninger, Goetz, Joffé, Orowan and Smekal (see preceding abstracts).—J. S. G. T.

†**The Intensities of X-Ray Spectra and the Imperfections of Crystals.** R. W. James (*Z. Krist.*, 1934, **89**, 295–309).—A review of the evidence for perfection in the structure of actual crystals given by a quantitative study of the intensity with which they reflect X-rays.—W. H.-R.

***The Thomas–Fermi Method for Metals.** J. C. Slater and H. M. Krutter (*Phys. Rev.*, 1935, [ii], **47**, 559–568).—Theoretical. The Thomas–Fermi method is applied to solid metals in its simple form, and in a more correct manner introducing the effect of exchange. It is concluded that neither method gives results of sufficient accuracy to use for investigating the energy in the neighbourhood of equilibrium. On the other hand, the potential field, momentum distribution, and other features may be of value as first approximations in more accurate treatments of metals.—W. H.-R.

IV.—CORROSION

(Continued from pp. 226–231.)

On a Rapid Method of Testing the Corrosion-Resistance of Aluminium and Aluminium Alloys. H. Carlsohn and W. Voigt (*Chem. Fabrik*, 1935, **8**, 126–127).—The metal is coated with an oxide film, *e.g.* by the M.B.V. process, and a scratch through this film is made with a sharp point. The resistance of the exposed metal to corrosion is then measured by the time required to produce a reaction with a filter paper impregnated with a morin or sodium alizarinsulphonate indicator dissolved in the corrosive medium, *e.g.* 3% sodium chloride solution.—A. R. P.

***Corrosion of Aluminium in the Brewing Industry.—I.** Marc H. van Laer (*Ann. zymol.*, 1933, [ii], **1,** 201–213; *C. Abs.*, 1935, **29,** 2293).—Cf. *Met. Abs.*, 1934, **1,** 240. Corrosion tests were carried out on a number of samples of aluminium (new metal) subjected to various heat-treatments, and also on samples procured from aluminium brewing equipment which had been more or less corroded in service. The Mylius test (loss in weight in mg./dm.^{2} on exposure to the action of an oxidizing saline solution) is better suited to the evaluation of the resistance to corrosion likely to be encountered in the brewing industry than either the temperature increase or gas evolved in treating with hydrochloric acid. Of the samples taken from equipment, 4 were of decidedly inferior quality, but the equipment from which they were procured was not so badly corroded as some made from metal that withstood the corrosion tests much better; in all cases the greater corrosion occurred in equipment (tanks) encased in concrete and having some copper parts. This shows the importance of having aluminium electrically insulated and out of contact with other metals.—S. G.

***Corrosion of Aluminium in the Brewing Industry.** R. de Wilde (*Ann. zymol.*, 1934, [ii], **1,** 365–387; *C. Abs.*, 1935, **29,** 2294).—Further tests were carried out on the previously-used (see preceding abstract) aluminium samples (annealed, quarter-hard, semi-hard, cold-hardened): corrosion potentials of aluminium in a suitable electrolyte were determined by measuring the decrease in potential of each electrode separately relatively to a comparison electrode (saturated Hg_2Cl_2); the variation in the potential of aluminium, and also the current intensity, during the course of fermentation were measured by determining directly the difference in potential of 2 aluminium electrodes. The results are given in detail and discussed. The conclusions are as follow: In an aluminium fermentation tank, if differences in structure exist in different parts of the metal, in certain unfavourable conditions (imperfect insulation, presence of a copper coil) severe local corrosion can take place, as the differences in potential which are set up in time result in the formation of primary cells. It is impossible to assign a definite potential to a given sample of aluminium, as it becomes less noble in time owing to the increasing activity of aluminium as corrosion progresses. The current intensities with aluminium–copper electrodes were approximately 2000 times greater than those with 2 aluminium electrodes. Cold-hardened aluminium is particularly sensitive to electrochemical corrosion; a well-annealed metal containing at least 99·6% aluminium should be used. Aluminium tanks should be well insulated, *e.g.* bare tanks mounted on porcelain insulators should be used.—S. G.

The Effect of Sulphur on Aluminium Cars. —— (*Railway Mech. Eng.*, 1934, **108,** 83–84).—Aluminium hopper cars used for transporting high-sulphur coal have given satisfactory service for 2 years. They show no appreciable corrosion, although steel often fails very rapidly under the same conditions.—C. E. H.

***The Interpretation of the Negative Difference Effect [in Aluminium and Magnesium].** W. O. Kroenig and V. N. Uspenskaja (*Korrosion u. Metallschutz*, 1935, **11,** 10–16).—The negative difference effect is the name given to the phenomenon observed when an aluminium electrode is short-circuited with a platinum cathode in dilute hydrochloric acid; instead of a reduction in the volume of hydrogen evolved at the aluminium surface, there is an increase. Experiments are described which show that the effect is due to the presence of an oxide film on the metal; the more complete is this film the greater is the effect, and the complete removal of the film, *e.g.* by amalgamation or by replacement of the acid solution by sodium hydroxide, renders the effect positive. Magnesium and aluminium alloys behave similarly to aluminium. The effect is attributed to breakdown of the oxide film by the intensification of the formation of ions by contact with the more noble metal. —A. R. P.

***X-Ray Examination of the Mechanism of Corrosion of Solid Solutions [Copper–Gold].** L. Graf (*Korrosion u. Metallschutz,* 1935, **11**, 34–42).—X-ray examination of the surfaces of various copper–gold alloys after corrosion with strong and weak oxidizing agents shows that if the ionization potential of the ions in the corrosive medium suffices to ionize the more noble atoms rendered unstable by the break-up of the solid solution lattice, the resistance limit of the alloy in that medium will lie at 50 atomic-%, the newly ionized atoms of the more noble metal being then re-precipitated on the surface to form a protective film which prevents further attack of the medium. If the latter is not powerful enough to ionize the unstable noble atoms the resistance limit in that medium will lie at 25 atomic-% of the noble metal. —A. R. P.

The Improvement of Drainage and Water Pipes by the Use of Lead Alloys. Kenneth Gray (*Munic. Eng. Sanit. Record*, 1935, **95**, 105–107; *C. Abs.*, 1935, **29**, 2493).—Some old lead pipes laid down about the first century A.D. to bring water to the old Roman baths at Chester were remarkably well preserved after nearly 2000 years underground. Modern pipes sometimes fail after a few years' use. The purity of the old pipe, determined spectroscopically, was no greater than that of good commercial lead now available. Weak acids produce a sort of intercrystalline cracking or penetration in modern pipe. The scouring lines in extruded pipe due to die and core are considered to be starting points for corrosion. Oxide inclusions from the skin on the bath of the extruding machine are also causes of corrosion. The old Roman pipe was cast. The use of alloying constituents to improve corrosion-resistance is discussed.—S. G.

***The Dissolution of Magnesium in Aqueous Salt Solutions.** L. Whitby (*Trans. Faraday Soc.*, 1935, **31**, 638–648).—The rate of dissolution of magnesium that has been exposed to air for periods up to 3 weeks has been measured in N, $0{\cdot}01N$, and $0{\cdot}001N$-solutions of sodium sulphate and sodium chloride; the results show that the film of hydroxide formed by atmospheric corrosion has no protective action in any of the solutions tested. In N-sodium chloride the presence of the 3-weeks' film actually increases the rate of corrosion, but this is not the case in the corresponding sulphate solution since the film is almost completely dissolved thereby owing to the higher solubility of magnesium hydroxide in N-sodium sulphate solutions. The increase in the rate of corrosion of magnesium by increasing the concentration of dissolved salt is comparable with the increase in the solubility of magnesium hydroxide in the solutions, but the position of the maximum rate of dissolution depends on the composition of the metal and on the time of immersion. The curves obtained under various conditions provide additional evidence in favour of the theory of primary preferential hydroxyl ion discharge. Dissolution/time curves for the rate of dissolution of magnesium in $0{\cdot}01$–$4N$-lithium, sodium and potassium chloride solutions are given.—A. R. P.

Colouring of Cheese by Tin-Foil. J. Gangl and F. Becker (*Milchwirtschaft. Forsch.*, 1933, **15**, 281–293; *C. Abs.*, 1934, **28**, 2803).—Pasteurized cheese of sufficient acidity ($p_H < 5{\cdot}0$), if a suitable oxidizing medium is present, will dissolve tin from tin-foil whether it is pure or contains antimony or lead. The black stain on such a cheese is due to finely divided antimony or lead, the grey stain to tin. A method is described for determining antimony in tin-foil.—S. G.

***Corrosion Tests on Galvanized Iron.** A. L. Savvateev (*Trans. State Inst. Applied Chem.* (*U.S.S.R.*), 1934, (**21**), 67–69; *C. Abs.*, 1935, **29**, 2495).—[In

Russian.] Iron plates, galvanized under various conditions, were placed in water saturated with oxygen, and the time of appearance of corrosion noted. With zinc coatings of 0·0044 grm. or more zinc per cm.^{2}, rust appeared after 5 days. With lighter coatings (0·0012 grm. zinc per cm.^{2}) resistance to corrosion depended on the method of electrolytic deposition of the zinc. The resistance was greater for coatings deposited slowly and at low current densities.—S. G.

Examples of Corrosion from Practice, Their Causes and Prevention [Zinc Sheet; Lead Pipe]. Karl Mandl (*Mitt. tech. Versuchsamt.*, 1934, **23**, 41–46).—The development of local pits and perforations in a zinc sheet covering the parapet of a brick wall was traced to the presence of condensed moisture which dissolved sodium sulphate from the mortar used and this solution then acted as an electrolyte, the lead inclusions (0·91%) in the zinc acting as anodes; the trouble was stopped by providing free aeration between the zinc and the bricks. A case of corrosion of lead pipes by the free lime in the mortar of a new wall against which they were laid is also described.—A. R. P.

The Corrosion of Metals Covered by Electrolytic Deposits. J. Liger (*Galvano*, **1935**, (35), 16–18).—Conclusion of a serial article; for previous parts see *Met. Abs.*, this volume, p. 162. The merits and fields of application of silver, nickel, chromium, cadmium, and zinc coatings are considered. Silver is the only one recommended for coating articles of copper and copper alloys to be used in contact with food. Nickel can give good protection against atmospheric influences and against acids and alkalis, but there is too strong a tendency to-day to cheapen the work at the expense of quality. When appearance is secondary, steel is preferably coated with zinc or cadmium. —C. E. H.

Photoelectric Fatigue and Oxidation. J. S. Hunter (*Phil. Mag.*, 1935, [vii], **19**, 958–964).—The progress of the superficial oxidation of copper, silver, bismuth, and nickel is discussed by means of results obtained by photoelectric measurements. The results suggest that when a clean metallic surface is exposed to air there is an instantaneous adsorption of gas by the surface. The rate at which oxygen from the air is adsorbed by the surface governs the subsequent time interval before true oxidation of the surface commences. In the case of iron this interval appears to be very small; in the case of copper, silver, bismuth, and nickel the interval is relatively large at ordinary temperatures. The subsequent rate of oxidation depends on the rate of condensation on the oxide/oxygen surface.—J. S. G. T.

***The Corrosive Actions of Different Cooling Brines on Combined Metals.** W. Mohr and R. Kramer (*Molkerei-Zeit.* (*Hildesheim*), 1934, **48**, 2160–2162, 2184–2187; *C. Abs.*, 1935, **29**, 2136).—Experiments are reported involving the selection of refrigerants which do not attack metals and alloys, and the selection of metals and alloys resistant to all brines. The brines studied were those previously used (*Met. Abs.*, 1934, **1**, 586) and in addition Reinhartin, 22° (Bé) and Frietin, 22°. Tests were carried out by immersing metals in brines and noting loss in weight and surface corrosion. When two different metals are in contact and immersed in a brine, galvanic action greatly increases the corrosion. Common metals undergo a marked electrolytic corrosion when used with noble metals. The measurable electric current generated is a criterion of the galvanic corrosion. Corrosion is proportional to brine temperature. Air, owing to its oxygen content, increases corrosion markedly, *e.g.* when the brine is stirred. Corrosion is increased about 100% when the concentration of Reinhartin is changed from 28° (Bé) to 22°. Frigisol, 22°, causes corrosion in increasing order in V2A steel, aluminium, tinned copper, brass, cast iron, copper, iron, and zinced iron. A calcium chloride brine causes more corrosion in an aluminium and copper combination than in aluminium alone. In a stirred Frigisol brine, 22°, a nickel and aluminium combination produces an electric current smaller (less than 0·1 milliamp.) and more constant than that produced by a nickel and zinc combination (0·2–0·6 milliamp.) or a copper and iron combination (0·06–0·5 milliamp.). Corrosion at the cathode is usually negligible; that at the anode is relatively great. Lead is especially susceptible to galvanic corrosion. Chromium–copper undergoes little galvanic corrosion; electrolytic chromium–copper undergoes none. Nickel is very resistant; it is corroded slightly in Frigodur, Kühlsoleen, and Frietin. V2A steel is better than nickel. In a nickel and V2A steel combination the steel acts as the anode and is decomposed slightly by only one brine, Frigodur. Nicorros, like nickel, is very resistant. Copper and its alloys are slightly corroded and the surface may become coated or coloured. Tin, tinned copper, tinned brass, iron, and cast iron are similar in resistance and are less resistant than copper and its alloys. Lead is still less resistant. Soldered tin is more resistant than lead. Aluminium is more resistant than iron; it becomes porous, however, in all brines, and its volume loss is similar to that of lead. Zinc and zinced-iron are non-resistant. Addition of chromate to Reinhartin greatly reduces its corrosive action; it is one of the best brines. Molkereisole is very non-corrosive; Frigisol is slightly more corrosive. Chromate-free Reinhartin, 28°, and special Kühlsoleen, 20°, are intermediate. Chromate-free Reinhartin, 22°, and Eisol, 22°, are more corrosive. The most corrosive brines are magnesium chloride, Frigodur, calcium chloride, sodium chloride, Thermolyt, Kühlsoleen, and Frietin, all 22° Bé.—S. G.

***Corrosion Phenomena in Sugar House Evaporators.—II.** M. Garino (*Industria saccarifera italiana*, 1935, **28**, 1–11; *C. Abs.*, 1935, **29**, 2380).—See also *Met. Abs.*, this volume, p. 227. Juices sampled from the individual evaporators were tested for the presence of iron, and the % of chlorine, and the temperatures of the juices were determined. The temperature–percentage of chlorine curves, representing actual operations, define the conditions of freedom from corrosion, danger from corrosion, and definite corrosion. Other factors are involved which do not disturb materially the criteria, except the scaling of the evaporator tubes, in which case the temperature and % of chlorine at the surface of the tubes are not those of the juice. When the scale contains more than 2% Fe_2O_3 there is corrosion. Photographs are given of 18 corroded tubes.—S. G.

***Alkaline Corrosion of Metals in the Production of Dyes.** Z. N. Suirkin (*Anilinokrasochnaya Prom.*, 1934, **4**, 570–573; *C. Abs.*, 1935, **29**, 2494).—[In Russian.] Cf. Suirkin and Smirenskii, *Met. Abs.*, 1934, **1**, 500. Tabulated results are given of the preliminary tests of corrosion of various grades of cast iron, steel, and copper alloys in the laboratory production of β-$C_{10}H_7OH$ and PhOH by alkaline fusion of the respective sulphonic acids.—S. G.

Corrosion of Petrol Containers. —— (*Oel u. Kohle*, 1935, **11**, 259–260).—In referring to a statement by M. P. Graempe, to the effect that fuels containing alcohol exert marked corrosive action on metallic containers, it is stated that the phenomena described might equally be due to the presence of sulphur compounds or of minute traces of copper. The sulphur compounds found in petrol and benzole are known to attack lead rapidly, whilst the porosity of most galvanized zinc coatings renders this material unsuitable. The experience of a commercial undertaking employing over 600 large vehicles is quoted in support of the non-corrosive character of alcohol–petrol mixtures. —P. M. C. R.

Testing Cracked Petrols for Corrosion. P. A. Sentzov and L. F. Chadaeva (*Groznenskii Neftyanik*, 1934, **4**, (6/7), 37–40; *C. Abs.*, 1935, **29**, 2719).—[In Russian.] Elementary sulphur is the most corrosive form of sulphur. Hydrogen sulphide and mercaptans are also corrosive, although to a lesser extent; they are the basic substances for the formation of elementary sulphur. Sulphides and disulphides are but little active and may be considered as non-corrosive sulphur ingredients. Thiophenes are not corrosive. Treatment with sulphuric acid yields non-corrosive petrols. Preliminary treatment of the oil with sodium hydroxide makes it non-corrosive and prevents the corrosion of equipment.—S. G.

***Elimination of Corrosive Substances from Cracked Petrols.** L. Sel'skii (*Groznenskii Neftyanik*, 1934, **4**, (8), 45–49; *C. Abs.*, 1935, **29**, 2719).—[In Russian.] The corrosion of distilling apparatus was prevented by introducing a sodium hydroxide solution into the pipe-line used for the pressure distillate; the sodium hydroxide was recycled until spent. The use of a solution of calcium hydroxide on refinery scale is accompanied by the formation of emulsions, while satisfactory results could not be obtained with NH_3.—S. G.

A Method for an Accelerated Determination of the Corrosive Properties of Cracked Petrol. L. A. Aleksandrov (*Groznenskii Neftyanik*, 1934, **4**, (5), 52–53; *C. Abs.*, 1935, **29**, 2719).—[In Russian.] A. recommends carrying out the copper-strip test for cracked petrols at 150° C. for 15 minutes, using a flask with a reflux condenser on an oil-bath. These conditions are equivalent to 3 hrs. at 100° C., the loss of light fractions being insignificant.—S. G.

V.—PROTECTION

(Other than Electrodeposition.)

(Continued from pp. 231–234.)

Considerations on the Possibility of the Protection of Metals from Corrosion. M. Straumanis (*Korrosion u. Metallschutz*, 1935, **11**, 49–53).—The possibility of reducing the rate of corrosion of a metal by alloying it with a small quantity of another metal is discussed with reference to the earlier work of S. on the effects of small additions of cadmium or mercury on the rate of dissolution of pure zinc and alloys of zinc with small amounts of other metals in dilute acids. These results show that protection from corrosion is afforded by alloying a metal (*A*) with another (*B*) which forms a complete series of solid solutions or definite compounds with the impurities present, which has a higher overvoltage than *A* and which is only slightly miscible with *A* in the solid state; the alloy must be cooled sufficiently rapidly to ensure even distribution of *B* throughout *A*.—A. R. P.

†**On the Applications of Oxide Films on Aluminium.** W. Birett (*Metallwirtschaft*, 1935, **14**, 188–190).—The properties of oxide films on aluminium produced by the Eloxal process are described, and the various uses of the coated metal in the chemical industry, in electrotechnology, and for architectural purposes are enumerated.—v. G.

The Anodic Coating of Aluminium. Harold K. Work (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (4), 32–35, 37–39).—A review of recent American patent literature on anodic oxidation of aluminium.—A. R. P.

†**Surface Ennoblement of Aluminium and Its Alloys.** G. Elssner (*Chem.-Zeit.*, 1935, **59**, 213–215, 235–237).—Recent work on the plating of aluminium and on the production of protective oxide films on the surface is described at some length and the value of the coatings is discussed.—A. R. P.

Tarnish-Resistant Films on Silver. K. Assmann (*Chem.-Zeit.*, 1935, **59**, 217).—The tarnishing of standard silver articles on exposure to the air may be prevented by immersing them for about 5 minutes in a 10% solution of potassium dichromate whereby the metal becomes coated with a thin practically invisible film of silver chromate, which in no way, however, detracts from the display value of the articles.—A. R. P.

How Effective is a Cadmium Coating? J. S. Hoffman and L. J. George (*Steel*, 1934, **94**, (18), 23–25).—The minimum useful thickness of a cadmium coating on steel is 0·0002 in., but for outdoor conditions at least 0·0004 in. is needed. The thickness is determined by a stripping test, which is described without disclosing the composition of the stripping solution.—C. E. H.

The Homogeneous Coating of Apparatus with Lead. —— (*Illust. Zeit. Blechindustrie*, 1935, **64**, 298–299).—To produce a non-porous, homogeneous coating of lead on metallic and other objects, the surface must be cleaned with wire brushes or by sand-blasting, and the object pickled, thoroughly rinsed, dipped in a concentrated solution of zinc ammonium chloride, and at once transferred to the lead plating bath, which is maintained at 350° C. with a surface flux of borax or zinc ammonium chloride. The intermediate bath secures satisfactory adhesion. Modifications of the treatment are described for objects of exceptional size. A lead-base alloy containing 15% of tin is satisfactory for many purposes, but its melting point is comparatively low. The strength of lead coatings may be increased by the addition of aluminium and arsenic in the respective proportions of 5 and 0·03%.
—P. M. C. R.

Factors Influencing the Formation and Structure of Hot-Dipped Tin Coatings. See p. 285.

†**On Electrolytic Tinning.** See p. 301.

***Protecting Ferrous Materials from Corrosion by Electrodeposits of Zinc and Cadmium.** F. Pietrafesa (*Metallurgia italiana*, 1934, **26**, 937–948; *C. Abs.*, 1935, **29**, 2136).—The resistance of cadmium- and zinc-plated iron to the corrosive action of a spray of 20% salt solution has been determined. Cadmium gives better protection, as its corrosion product tends to prevent further action. Thus, the rate of corrosion is directly proportional to the time of exposure for zinc, and to the cube root of the time for cadmium. The minimum thickness of plating required for protection against the action of salt-spray for 60 days is 0·0075 and 0·015 mm., respectively, for cadmium and zinc. Cadmium is best deposited from alkaline baths, and zinc from acid baths.—S. G.

Materials and Methods Used to Protect Galvanized Iron. I.—Painting. Wallace G. Imhoff (*Amer. Metal Market*, 1934, **41**, (220), 6, 8).—Adhesion of paint to newly galvanized iron is ensured by sandblasting the surface; the best primer coat appears to be a paint containing a 4 : 1 mixture of zinc dust and zinc oxide as pigment.—A. R. P.

Materials and Methods Used to Protect Galvanized Iron.—II. Wallace G. Imhoff (*Amer. Metal Market*, 1934, **41**, (229), 6, 8).—The formation of " white rust " on galvanized iron may be prevented by dipping the metal in a solution of chromic acid or potassium dichromate, or both. Various lacquer and similar coatings of a proprietary nature can also be used.—A. R. P.

Adjustment, Refinement, and Co-ordination as Factors in Lengthening the Life of Hot-Dip Galvanizing Pots. Wallace G. Imhoff (*Amer. Metal Market*, 1934, **40**, (169), 3, 8; (183), 3, 6; (185), 3, 4).—A detailed description of the hot-dip galvanizing process is given, with practical hints on the operation of the pot to obtain the best results and longest life.—A. R. P.

Mechanical Galvanizing. I.—Mechanical Galvanizing of Sheets. A. Forny (*Galvano*, **1935**, (36), 24–27).—In this process the weight of coating can be reduced to 350 grm./m.^{2} on both sides, as compared with 1200 grm. in hand-dipping. A sketch of a complete installation for pickling, washing, and galvanizing is given, together with data on the consumption of acid, flux, zinc, and fuel. The sheets are fed into the galvanizing bath through a flux box, being then gripped by a pair of rolls entirely submerged in the zinc, and ejected from another pair of rolls partially submerged at the surface. To obtain a good spangle a little tin should be added, but aluminium is detrimental in this process.—C. E. H.

Mechanical Galvanizing. II.—The Mechanical Galvanizing of Sheets by the Dry Process. A. Forny (*Galvano*, **1935**, (37), 25–28).—A semi-automatic plant dealing with 300 sheets per hr. is described. The sheets are pickled in a pickling machine, rinsed, immersed in zinc chloride, and passed on a conveyor through a drying oven. As they emerge from the oven they are dropped vertically into the zinc bath, over which a hood is arranged to carry off the fumes produced. They are withdrawn from the other side of the bath by mechanically operated pincers, and allowed to cool. No flux cover is used for the zinc bath. The coating is of good quality, but more dross is produced than in the wet process.—C. E. H.

Zinc-Coated Wire by a New Process. —— (*Amer. Metal Market*, 1934, **40**, (173), 3).—A brief note. Zinc is deposited on the wire, directly from a zinc-bearing ore, by an electrolytic process. The coating obtained is more adherent and will not crack or chip.—I. M.

Electro-Galvanizing. See p. 301.

New Method of Galvanizing Affords Uniform Coating. J. L. Schueler (*Steel*, 1934, **95**, (9), 40–41).—The usual type of wiper for removing the excess coating from wire is replaced by a coating regulator of unspecified design. The galvanized wire after passing through this regulator is subjected to a flame, which smooths and evenly distributes the coating, and also seals up pores.—C. E. H.

Chemistry of Using Glycerin as Flux Conditioner in Hot Galvanizing. Wallace G. Imhoff (*Steel*, 1934, **94**, (21), 23–25).—Glycerin provides a medium for supplying and holding water in the flux. This is essential, as a perfectly dry flux is ineffective. It also keeps the flux light and puffy, thus adequately removing moisture from articles during immersion, and preventing explosions. —C. E. H.

A Review of the Developments in Cleaning, Pickling, Fluxing, and Hot-Dip Galvanizing for 1934. Wallace G. Imhoff (*Amer. Metal Market*, 1935, **42**, (9), 3, 8; (12), 3, 5).—A brief review of the journal and patent literature for 1934, with notes on the more outstanding advances made.—A. R. P.

Protection of Steel Structures from Rusting by Means of Zinc Coatings. Hans M. Forstner (*Chem.-Zeit.*, 1935, **59**, 293–295).—A review of recent work, with a *bibliography* containing 41 references to articles on the dipping, plating, and spraying processes, and to methods of testing the efficiency of the coatings. —A. R. P.

Increasing the Efficiency of Resistances. —— (*AEG. Mitt.*, **1935**, (4), 161–162).—A brief account of the improved performance and durability of resistance wire which has been coated with a glaze containing a mixture of nickel and chromium oxides as one of its ingredients.—P. M. C. R.

Anti-Corrosive Paints Made from Coal-Tar or Coal-Tar Oil with and without Pigmentation with Aluminium. Luc Choupin (*Peintures, pigments, vernis*, 1935, **12**, 38–39; *C. Abs.*, 1935, **29**, 3177).—Protective paints (so-called Vernicolors), which have desirable physical properties and unusual resistance to chemical agents, and which can be applied to various surfaces, can be prepared from various coal-tar fractions by mixing with suitable solvents and bituminous resins either with or without addition of metallic aluminium pigment.—S. G.

VI.—ELECTRODEPOSITION

(Continued from pp. 235–238.)

***Electrolytic Deposition of Cadmium.** Antonio Ríus and Luis Quintero (*Anales soc. españ. fís. quím.*, 1934, **32**, 1077–1089; *C. Abs.*, 1935, **29**, 2858).—The composition of the bath is cadmium oxide 39·4, potassium cyanide 128·2, sodium sulphate 50·0, and nickel sulphate 1·0. Cathodic deposits from this bath are dull, but addition of small quantities of soap (Lipofor), licorice, or saponin give brilliant deposits at a current density of 2 amp./dm.^{2}. Anodic current density has an influence on cathodic brilliance in dilute baths. With commercial baths containing 4–5% cadmium, no such influence is observed. In conditions which give brilliant cathodic deposits, the anode becomes brilliant.—S. G.

***Factors Affecting the Structure and Grain-Size of Electrodeposited Cadmium.** See p. 286.

***Cadmium–Zinc Alloy Plating from Acid Sulphate Solutions.** Colin G. Fink and C. B. F. Young (*Electrochem. Soc. Preprint*, **1935**, 133–156).—The factors affecting the composition of the deposit obtained from slightly acid baths containing zinc and cadmium sulphates have been investigated. To obtain an alloy plate the ratio of zinc to cadmium in the bath must be about 70 : 2·5 using a cadmium anode. The cadmium content of the deposit is increased by rotation of the cathode or circulation of the electrolyte and by increasing the temperature, while the zinc content of the deposit is increased by increasing the cathode current density, by increasing the acidity, and by addition of salts such as aluminium sulphate, or organic compounds such as caffeine. The most satisfactory plating baths contain zinc 55–75, cadmium 5–30, hydrated aluminium sulphate 15–20 grm./litre, caffeine or gelatin 3–6 mg./litre, and sufficient free sulphuric acid to give p_H 4; the best operating conditions are 25° C. and 1–2 amp./dm.^{2}. Corrosion tests by intermittent immersion in 20% sodium chloride solution showed that the 50 : 50 alloy is the most resistant, followed by pure zinc.—A. R. P.

***Studies in the Theory of Chromium Electrodeposition.** Raymond R. Rogers (*Electrochem. Soc. Preprint*, **1935**, 1–22).—A systematic investigation of the range of electrolyte compositions within which bright chromium plates may be obtained has been made and the results are shown in a ternary diagram: $Na–SO_4–CrO_4$. The results show that there appears to be a definite acidity range within which chromium deposits may be obtained; at low sulphate concentrations this varies between that of pure chromic acid and that of a very slightly acid solution of sodium dichromate, whilst at high sulphate concentrations more chromic acid is required to obtain a bright deposit since sodium sulphate tends to increase the p_H. As the acidity of the bath is increased the current density must be increased to obtain a good deposit, and with a given composition of the bath each current density requires a definite temperature range. Examination of the deposits formed from various solutions as the current density is increased indicates that at low current densities in acid solutions chromous hydroxide is deposited, and at high current densities a frosted deposit containing much hydrogen. From these and other observations it is concluded that to obtain good chromium deposits the p_H of the liquid film adjacent to the cathode must be high enough to cause precipitation of chromous hydroxide, the concentration of the atomic hydrogen at the cathode must be great enough to reduce this hydroxide, and the rate of the first reaction must be smaller than that of the second.—A. R. P.

Influence of Bath Concentration on Chromium Hardness. R. J. Piersol (*Metal Cleaning and Finishing*, 1935, **7**, 73–76; *C. Abs.*, 1935, **29**, 2857).—Experimental results indicate that the most efficient chromic acid concentration for hard chromium plating is 250 grm./litre when the bath is operated with a sulphate content of 2·5 grm./litre and equilibrium value of Cr^{III} as maintained with lead anodes, at a temperature of 46° C. Such a concentration also gives the most rapid rate of deposition for a given current density. —S. G.

Black Chromium Plating. Heinz Endrass (*Chem.-Zeit.*, 1935, **59**, 338).—The black chromium plate produced by the method described by Pollack (*Met. Abs.*, this volume, p. 105) contains only 70–80% of metallic chromium, the remainder being an oxide of uncertain composition. To produce these coatings it is not necessary to keep the temperature of the bath below 15° C.;

good black deposits can be obtained at 30° C. under the correct current conditions.—A. R. P.

***Copper Plating of Iron at High Current Densities.** N. P. Lapin, V. N. Kharlamov, and G. S. Goniev (*Trans. State Inst. Applied Chem.* (*U.S.S.R.*), 1934, (**21**), 46–56; *C. Abs.*, 1935, **29**, 2455).—[In Russian.] Thick copper coatings were obtained on iron samples from a copper acetate bath at an anode density of 5 amp./dm.^{2}. A higher current density resulted in a coarse, crystalline deposit. In corrosion tests carried out by placing in sodium chloride and acetic acid solutions hot-tinned iron plates covered with copper coatings 0·02, 0·03, and 0·04 mm. thick, the copper coating had to be at least 0·04 mm. thick to protect the iron against corrosion. Iron samples coated with copper were placed in an acid copper cell containing 250 grm. copper sulphate and 75 grm. sulphuric acid per litre of water, with mechanical stirring. Fine crystalline copper deposits were obtained at 5–18 amp./dm.^{2}. The addition of 1 grm./litre of phenol–sulphonic acid solution improved the appearance of the deposit. Experiments were also carried out with univalent copper salts such as $CuCl + NaCl$, $CuCl + HCl$, $CuCN + NaCN$, but with little success. Experiments on the deposition of thick copper coatings (0·15 mm.) from a Hull and Blum cell, on top of a cyanide copper flash coat, gave adherent, but coarsely crystalline, deposits.—S. G.

The Electrodeposition of Copper, Nickel, and Zinc Alloys from Cyanide Solutions. II.—Discussion of the Results in I. Charles L. Faust and Geo. H. Montillon (*Electrochem. Soc. Preprint*, **1935**, Mar., 299–315).—From a critical discussion of the results previously obtained (*Met. Abs.*, 1934, **1**, 308) it appears that the relative rate of ion diffusion has not such a large effect on the relative concentration of the metal ions at the cathode as has the degree of ionization of the complex ions. Increasing the temperature of the cyanide solutions increases the degree of dissociation of the complex metallocyanide ions to a maximum at 25° C. for the zincicyanide, at 50° C. for the nickelocyanide, and at above 70° C. for the cupricyanide ion. Increase in current density has a much larger effect on the composition of the alloy plate at low than at high temperatures.—A. R. P.

Gold Plating Baths of Gold Fulminate. M. Vaudroz (*Galvano*, **1935**, (35), 28–29).—A typical bath contains gold fulminate 8, sodium phosphate 7·5, sodium cyanide 15 grm., and water 1 litre. The advantage of converting the gold into this form and then dissolving in cyanide, rather than converting the *aqua regia* solution of gold direct to cyanide, is that in the former case undesirable alkali salts can be eliminated. The chemistry of the fulminate and its production are described.—C. E. H.

Are Angled Electrodes of Advantage in [Nickel] Electroplating Baths? Eugen Werner (*Oberflächentechnik*, 1935, **12**, 1).—The advantages and disadvantages of angled nickel anodes over flat and cylindrical anodes are discussed. The latter type of anode has a smaller tendency to form nickel peroxide, and gives a better distribution of the current; angled anodes corrode just as rapidly as other types in the middle and leave a much larger and less usable residue. Although a higher current density can be used with angled anodes the composition of the solution limits this. The causes of pitting and of the production of rough and cracked deposits is discussed at some length; addition of 0·1 oz. of sodium chloride per gall. is much more effective in preventing pitting and rough deposits than is the addition of hydrogen peroxide, sodium perborate, or nitrates.—A. R. P.

***Structure and Properties of Nickel Deposited at High-Current Densities.** See p. 287.

Control in Nickel Plating. E. E. Halls (*Machinist* (*Eur. Edn.*), 1935, **79**, 189–190E).—The regular control of nickel plating in order to obtain a regular product is discussed.—J. H. W.

Ductility and Adhesion of Nickel Deposits. F. P. Romanoff (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (4), 8–15; discussion, 15–20).—Essentially the same as the paper presented at the Spring Meeting of the Electrochemical Society (see *Met. Abs.*, 1934, **1**, 308).—A. R. P.

Automobile Bumpers are Polished, Plated, and Buffed Rapidly. John M. Bonbright (*Steel*, 1934, **95**, (10), 23–25).—An illustrated description of the nickel and chromium plating of bumpers at the Chevrolet plant.—C. E. H.

Nickel and Chromium Plating of Sheet Zinc and Zinc-Base Die-Castings. B. Trautmann (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 119–120).—After electrolytic degreasing in trisodium phosphate solution the metal is plated with copper for 15 minutes at 0·3–0·4 amp./dm.^{2} and 3·4 v. in a bath containing copper acetate 20, sodium carbonate crystals 20, sodium bisulphite 20, and potassium cyanide 20 grm./litre. The best nickel-plating solution contains nickel sulphate 75, sodium sulphate 75–100, ammonium chloride 15–23, and boric acid 75 grm./litre; this bath gives soft deposits free from hydrogen, which can readily be chromium-plated in the usual bath.—A. R. P.

Electroplating with Rhodium and Rhenium. H. Anderssen (*Chem.-Zeit.*, 1935, **59**, 375–376).—Brief notes on recent work, especially that of Fink and his collaborators.—A. R. P.

†On Electrolytic Tinning. Max Schlötter (*Metallwirtschaft*, 1935, **14**, 247–250).—Wire and sheet metal can be electrolytically tinned by a process devised by S. No details are given, but the method is claimed to be as economical as the hot-dipping process and to yield coatings with satisfactory mechanical properties.—v. G.

***Comparative Study of Various Electro-Galvanizing Solutions and of the Properties of the Zinc Coatings Obtained.** N. P. Lapin, E. T. Vil'yamovich, and M. V. Dmitrieva (*Trans. State Inst. Applied Chem.* (*U.S.S.R.*), 1934, **(21)**, 56–67; *C. Abs.*, 1935, **29**, 2456).—[In Russian.] The following bath compositions were compared: (1) $ZnSO_4 \cdot 7H_2O$ 200 grm., $Na_2SO_4 \cdot 10H_2O$ 70 grm., $KAl(SO_4)_2 \cdot 12H_2O$ 30 grm., H_2O 1 litre; (2) $ZnSO_4 \cdot 7H_2O$ 3%, H_3BO_3 1%, $KAl(SO_4)_2$ 2%, $Na_2S_2O_8$ 0·1%, $Na_2SO_4 \cdot 10H_2O$ 1–2%; (3) $ZnSO_4 \cdot 7H_2O$ 360 grm., NH_4Cl 30 grm., $NaOAc \cdot 3H_2O$ 120 grm., H_2O 1 litre; (4) ZnO 45 grm., NaCN 75 grm., NaOH 15 grm., H_2O 1 litre; (5) $ZnSO_4 \cdot 7H_2O$ 250 grm., $MgSO_4 \cdot 7H_2O$ 45 grm., H_3BO_3 45 grm., H_2O 1 litre, plus a little licorice root extract. Samples of roof sheet iron, carefully cleaned and dipped in 5–7% sulphuric acid, were placed in these various baths, and a zinc coat obtained in conditions of room temperature and a current density of 1 amp./dm.^{2}. A comparison of results was made on the basis of ease of operation, rate of solution of zinc coat in a hydrochloric acid solution, mechanical adhesion of deposit and micrographic analysis. Cell (4) had better dispersing ability and gave better and thicker coatings on articles of irregular shape. Cell (1) gave almost as good results. Results with cell (2) are comparable with those with (1), but difficulties are encountered in (2) owing to fine control of acidity. With cell (5) the coating was uneven, and special precautions were required in cleaning the surface to be coated. The best results were obtained from (4) and also from (5) on a sample with a zinc undercoat from a cyanide bath. —S. G.

Improved Coating Applied to Wire by Electrogalvanizing. —— (*Steel*, 1934, **95**, (26), 22–24).—An illustrated description of a plant for the continuous electrodeposition of zinc on steel wire. The process is capable of giving coatings two or three times as thick as those obtained by hot-dipping. A high current density of 700–1400 amp./ft.^{2} is employed.—C. E. H.

Zinc Plating. James Higgins (*Monthly Rev. Amer. Electroplaters' Soc.*, 1935, **22**, (4), 58–59).—Smooth bright deposits of zinc having a high resistance to the salt-spray test can be obtained by plating at 15 amp./ft.^{2} for 15 minutes at 40°–45° C. in a bath containing zinc 5, sodium cyanide 17·5–18·5, and sodium hydroxide 5 oz./gall. with 1% of corn syrup as a brightener. The best anodes consist of an alloy of zinc with aluminium 2 and mercury 0·5%.—A. R. P.

Symposium on Structure of Metallic Coatings. See pp. 284–289.

The Adherence and the Causes of Non-Adherence of Electrolytic Deposits. Vittorio P. Sacchi (*Galvano*, **1935**, (33), 20–25; (35), 19–25; (36), 20–23).—After describing the mechanism of adhesion, the author discusses the causes of non-adherence under the following headings: (1) preparation of the basis metal—degreasing, pickling, rinsing, gas occlusion; (2) properties of the basis metal—position in the electrochemical series, passivity, structure, heat-treatment; (3) properties of the electrolyte and of the deposit—electrochemical and ionic properties, current density, temperature, concentration and agitation of the solution, and the corresponding structure of the deposit; (4) effects of thermal expansion. Both theoretical and practical aspects are considered.—C. E. H.

The Adhesion of Electrodeposits. M. de Kay Thompson (*Metal Cleaning and Finishing*, 1935, **7**, 83–85).—General discussion.—S. G.

Some Further Principles of Electrochemistry Applied to Electrodeposition. IV.—Ostwald's Law of Dilution. V.—Mixed Electrolytes. VI.—Coulometers. VII.—Complex Salts. Samuel Field (*Met. Ind.* (*Lond.*), 1934, **45**, 473–475; 1935, **46**, 103–104, 199–200, 389–390).—(V.—) The conductance of acid copper solutions and the method of calculating the throwing power are discussed. (VI.—) The use of gas, copper, and silver coulometers for the measurement of the current used in electrodeposition is described, and the use of lead and mercury for coulometers and the substitution of a solution of silver perchlorate for silver nitrate in silver coulometers are discussed. (VII.—) The meaning and significance of transport numbers, their use in the study of complex salts and in particular of the double cyanides are discussed.—J. H. W.

VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY

(Other than Electrodeposition.)

(Continued from pp. 238–241.)

***The Cathodic Film in the Electrolytic Reduction of Aqueous Chromic Acid Solutions.** Erich Müller [with Donald W. Light] (*Faraday Soc. Advance Copy*, **1935**, Mar., 5 pp.).—Very pure chromic acid solutions are not reduced at smooth platinum cathodes but reduction occurs up to quite high current densities at carbon cathodes; in the first case addition of SO_4 ions to the electrolyte causes reduction to take place at the cathode, but only at a much higher potential than the normal. These facts have been investigated by means of cathodic potential curves and oscillograms, and on the basis of the results obtained a theoretical explanation of the phenomena is put forward. —A. R. P.

***Sodium Discharge Potential at the Mercury Cathode.** W. W. Stender, M. M. Stroganov, and P. B. Zhivotinsky (*Electrochem. Soc. Preprint*, **1935**, 23–33).—The sodium discharge potentials at amalgam cathodes varies from 0·1 to 0·15 v. at current densities from 2·88 to 30 amp./dm.^{2} in 4·28 *N*-sodium chloride solutions at 15°–70° C.; the sodium content of the cathodes varies under these conditions from 0·02 to 0·4%. During electrolysis at high cathode current densities and when the sodium concentration in the amalgam is high, a hard crystalline amalgam forms on the surface and a sudden rise in the cathode potential occurs which may be sufficient for hydrogen to discharge. —A. R. P.

IX.—ANALYSIS

(Continued from pp. 241–245.)

Nephelometry in the Metal Industry. Julius Grant (*Met. Ind.* (*Lond.*), 1935, **46**, 457, 459).—A brief description is given of nephelometry and, in particular, of the use of the photoelectric cell in measuring turbidity. The applications of this method of analysis are described for the determination of Ag, Zn, As, Al, Hg, Mg, Pb, and Cu.—J. H. W.

The Analysis of Elektron. Ivo Ubaldini and Giuseppina Mirri (*Industria chimica*, 1934, **9**, 1476–1480; *C. Abs.*, 1935, **29**, 2114).—The methods for determining Zn, Al, Sn, Si, Cu, and Pb, as they occur in Elektron, are reviewed, and the best methods noted.—S. G.

Rapid Determination of Nickel and Chlorides in Nickel Plating Solutions. Walter R. Meyer (*Met. Ind.* (*N.Y.*), 1934, **32**, 306–307).—To 10 c.c. of the filtered solution in a 250 c.c. flask, add 50 c.c. of a solution containing 40 grm. KI, 35 c.c. of concentrated NH_4OH, and 50 grm. $Na_4P_2O_7$ per litre and titrate with approximately 6% KCN solution containing 0·34% $AgNO_3$, until no turbidity remains. Standardize the KCN solution against solutions containing known quantities of Ni which have been treated in the same way. To determine Cl_2, take another 10 c.c. of solution, add 50 c.c. of 0·2% $Na_2CrO_4 \cdot 10H_2O$ and titrate with 0·1*N* $AgNO_3$ to a buff colour.—S. G.

†**The Analysis of Plating Solutions and Deposits.** Walter R. Meyer (*Metal Cleaning and Finishing*, 1935, **7**, 61–64, 68; *C. Abs.*, 1935, **29**, 2884).—A critical review of recently developed methods of analysis of Sn (Thompson, *Met. Abs.*, 1934, **1**, 389), Cu (Hamburger, *Zeit. deut. Buchdrucker*, 1932, **44**, 523–524; Wick, *Met. Abs.*, 1934, **1**, 430), Ag (Lochmann, *Met. Abs.*, 1934, **1**, 356), Ni (Meyer, preceding abstract), Cd (Halls, *Met. Abs.*, 1934, **1**, 307), and Zn plating solutions. The latter can be determined nephelometrically by precipitating with $K_4Fe(CN)_6$ after removal of Fe and Cu, according to the method of Grant (*Met. Abs.*, 1934, **1**, 356). A p_H of 2·3 should be maintained. This method has been used also for Ag, Ca, P, and As. The drop test (Clarke, *Analyst*, 1934, **59**, 525–528; Glazunov and Křivohlavý, *Met. Abs.*, 1934, **1**, 430; Millot, *Met. Abs.*, 1934, **1**, 507), Preece test (Groesbeck and Waldrup, *Met. Abs.*, 1934, **1**, 427), electrical methods, and stripping methods (Glazunov, *Met. Abs.*, 1934, **1**, 428) of determining the thickness of electrodeposits are described.—S. G.

***Determination of Sulphuric Acid in Chromium Plating Baths.** M. Günthel (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 139–142).—Methods recently proposed for the determination of the SO_4'' content of Cr-plating baths have been critically examined and shown to give erratic results when the solution tested contains impurities such as $Fe^{\cdots}$ salts derived from the plating operation. Satisfactory results (± 2·5% of the actual SO_4'' content) are obtained only by removing the impurities before reducing the CrO_3 to $Cr^{\cdots}$ salt. The best procedure comprises treating 25 c.c. of the plating solution with 2–5 c.c. of HCl, and a few drops of HNO_3 to oxidize the $Fe^{\cdot\cdot}$ to $Fe^{\cdots}$, heating to boiling, adding Na_2CO_3 until a faint opalescence appears, then 2–3 drops of HCl, diluting to 150 c.c., adding Na_2HPO_4 solution until no further precipitate forms, boiling for 5 minutes, and just neutralizing with Na_2CO_3. After filtration, the clear solution is boiled with HCl and HCHO or C_2H_5OH, and kept overnight at 100° C. on the hot plate, treated with the requisite amount of boiling $BaCl_2$ solution, set aside for 4–6 hrs., and filtered. The $BaSO_4$ is washed with warm 0·01*N*-HCl, then with hot H_2O, ignited, and weighed. This procedure obviates loss of SO_4'' in basic sulphates and absorption of other metals by the $BaSO_4$.—A. R. P.

***Qualitative Detection of Bismuth with Sulphur-Containing Organic Compounds.—IV.** J. V. Dubsky, Arn. Okáč, and J. Trtílek (*Z. anal. Chem.*, 1935, **100**, 408–419).—The reactions of Bi with numerous complex organic compounds containing S are described.—A. R. P.

Potentiometric Estimation of Copper with Sodium Sulphide. C. Prasad and J. B. Jha (*J. Indian Chem. Soc.*, 1935, **12**, 1–3).—The estimation of Cu as $CuSO_4$ in $NaC_2H_3O_2 \cdot C_2H_4O_2$ buffers can be made potentiometrically with Na_2S without adding free acid. The best p_H range is 3–5.—R. G.

***A Volumetric Determination of Lead in Alloys Containing Zinc, Copper, and Antimony.** N. A. Tananaeff (*Z. anal. Chem.*, 1935, **100**, 394–396).—The alloy is dissolved by boiling with concentrated H_2SO_4, and the $PbSO_4$ collected in the usual way, washed free from acid with C_2H_5OH and converted into $PbCO_3$ by boiling with a measured volume of $0{\cdot}1N$-Na_2CO_3. The precipitate is filtered off and washed with hot H_2O, the excess of Na_2CO_3 in the filtrate being determined by titration with $0{\cdot}1N$-H_2SO_4 or HCl, and the remainder calculated to Pb.—A. R. P.

A Rapid Determination of Lead on Lead-Coated Iron. Erich Kasper and Paul Slawik (*Chem.-Zeit.*, 1935, **59**, 308).—A strip of the metal is degreased by washing with C_2H_5OH and after drying it is weighed and immersed in a warm 5% solution of NaOH containing 0·5 grm. of Na_2O_2. The solution is slowly heated to boiling to dissolve the Pb coating and any Sn which was used to tin the Fe before applying the Pb. The loss in weight of the strip gives the sum of the Sn and Pb. The solution is rendered strongly acid with HCl, the Sn^{IV} reduced with Fe filings, and the Sn^{II} titrated with $0{\cdot}1N$-I.
—A. R. P.

***Rapid Quantitative Spectroscopic Determination of Metals. I.—Estimation of Lithium.** A. P. Snessarew (*J. prakt. Chem.*, 1934, **141**, 327–330).—A definite amount of a solution of the material to be analyzed is taken on a Pt spiral and dried, and the spiral is then introduced into a flame. The flame is observed through a spectroscope to determine whether the characteristic Li lines are visible. The solution is diluted until this is no longer the case. It has been determined that the Li lines cease to be visible when the solution taken contains less than 0·0000010728 grm./c.c. of Li, so the Li content of the original material can be calculated from the dilution. The chief advantage of the method is that other metals need not be separated from the solution.
—C. E. H.

Manganese Determination on Chrome–Cobalt Alloys and Ferrocobalt Stellites and Cobalt High-Speed Steels. H. A. Kar (*Chemist-Analyst*, 1935, **24**, (2), 6–7).—The sample is dissolved in a suitable acid or acid mixture, any insoluble residue being collected, ignited, fused with Na_2O_2, and added to the main solution, which is then treated with an excess of ZnO emulsion and made up to a definite volume in a graduated flask. Half the solution is then filtered through a dry paper and poured into an excess of NH_4OH sufficient to dissolve the $Zn(OH)_2$ first precipitated; on boiling with $(NH_4)_2S_2O_8$ the Mn is precipitated as MnO_2 whilst the Co remains in solution as a $Co^{\cdots}$ ammine. The precipitate is collected, washed, and dissolved in HNO_3 and $NaNO_2$ and the Mn determined by the bismuthate method.—A. R. P.

***On the Question of the Deposition of Manganese at the Mercury Cathode.** Victoria M. Zvenigorodskaya (*Z. anal. Chem.*, 1935, **100**, 267–271).—In sulphate solutions containing an excess of N_2H_4,H_2SO_4, Mn is deposited only incompletely at a Ag cathode and hence Mn interferes in the separation method based on the deposition of Fe, Cr, Zn, Cd, &c., on a Hg cathode since it contaminates both the deposit and the solution.—A. R. P.

***The Quantitative Determination of Thorium with Picrolonic Acid.** Friedrich Hecht and Walter Ehrmann (*Z. anal. Chem.*, 1935, **100**, 87–98).—From a hot, solution of $Th(NO_3)_4$, made slightly acid by CH_3COOH and free from Na, K, and NH_4 salts, Th is quantitatively precipitated as crystalline hydrated $Th(C_{10}H_7N_4O_5)_4$ by addition of 0·01*N*-picrolonic acid. The precipitate after drying at 105° C. contains 17·82% Th.—A. R. P.

***The Quantitative Determination of Thorium with 8-Hydroxyquinoline.** Friedrich Hecht and Walter Ehrmann (*Z. anal. Chem.*, 1935, **100**, 98–103).—The precipitation is made in a boiling neutral nitrate solution of the metal containing 2·5% of $CH_3{\cdot}CO_2H$, the red crystals of $Th(C_9H_6ON)_4,C_9H_7ON$ being collected and dried at 105° C.; they contain 24·347% Th.—A. R. P.

***The Determination of Small Quantities of Tellurium in Lead.** E. Kröner (*Chem.-Zeit.*, 1935, **59**, 248).—The Pb (20 grm.) is dissolved by boiling with 1 : 1 HNO_3, a little Br being added at the end of the reaction to oxidize any oxides of N. The solution is evaporated until crystallization commences, cooled, diluted to 500 c.c., and titrated with 0·02*N*-$KMnO_4$ (1 c.c. = 0·00102 grm. Te).—A. R. P.

Rapid Determination of Tin, Copper, and Antimony in Babbitt Metal. I. V. Tananaev (*Zhurnal Prikladnoi Khimii* (*J. Applied Chem.*), 1934, **7**, 223–228; *C. Abs.*, 1935, **29**, 2474, and (abstract) *Chim. et Ind.*, 1934, **32**, 585–586).—[In Russian.] Digest 1 grm. of the alloy with 35 c.c. of concentrated HCl and a little $KClO_3$. Make up to exactly 100 c.c. and use 20 c.c. for the determination of Cu. Shake with Bi–Hg at about 50° C. until all the Cu^{++} is reduced to Cu^+ in an atmosphere of CO_2. Add a crystal of $KBrO_3$, and as soon as the colour is gone filter rapidly and titrate with $K_2Cr_2O_7$ to an end point with diphenylamine. In another aliquot determine Sn + Cu similarly. In this case heat with Bi–Hg for 30 minutes at 60°–80° C. To determine Sb, digest 0·5 grm. of alloy in 15 c.c. of concentrated H_2SO_4, dilute and filter off $PbSO_4$. Dilute with water, add 10–15 c.c. of concentrated HCl, boil for 5 minutes, dilute, and titrate hot with $KBrO_3$ until methyl orange indicator is decolorized. —S. G.

Quinaldinic Acid as an Analytical Reagent. II.—The Determination of Zinc in the Presence of Iron, Aluminium, Uranium, Beryllium, and Titanium. Priyadaranjan Rây and Anil Kumar Majundar (*Z. anal. Chem.*, 1935, **100**, 324–327).—The method previously described (Rây and Bose, *Met. Abs.*, 1934, **1**, 194) is carried out in the presence of an alkali tartrate to prevent precipitation of the elements mentioned in the title.—A. R. P.

Colorimetric Determination of Zinc with Dithizone. W. Deckert (*Z. anal. Chem.*, 1935, **100**, 387–390).—A. R. P.

X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

(Continued from pp. 245–246.)

***An Apparatus for Electron Diffraction at High Voltages.** G. P. Thomson (*Faraday Soc. Advance Copy*, **1935**, Mar., 2 pp.).—An apparatus for obtaining electron diffraction patterns of thin metal films is described which works well over the range of 45–85 kv.; it is based on the principle of two-stage acceleration, which has been much used for positive ions. The mechanical arrangement and electrical lay-out are illustrated diagrammatically, but the paper must be consulted for details.—A. R. P.

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

(Continued from pp. 246–249.

Dynamic Testing Applied to Metallurgical Development. A. V. de Forest (*J. Aeronaut. Sci.*, 1935, **2**, (2), 61).—Abstract of a paper read before the

American Institute of Aeronautical Sciences. Engineering materials used in aeronautical construction are subjected by actual service stresses to tests far more severe than those applied by ordinary testing appliances. The conditions of use differ from those of static testing principally in the importance assumed by surface conditions, *e.g.* by small superficial defects and stress concentrations. The material must be free from discontinuities, and the load must be kept below the fatigue limit of the material.—P. M. C. R.

***Impact Strength Tester.** Burrows Moore (*J. Sci. Instruments*, 1935, **12**, 108–111).—Describes the construction of a small portable self-contained instrument designed for impact tests on test-specimens in the form of ½-in. cubes. The instrument is of the falling-weight type, and was designed for tests on silica.—W. H.-R.

XII.—TEMPERATURE MEASUREMENT AND CONTROL

(Continued from pp. 249–250.)

A Simple Means for the Temperature Measurement of Aluminium Ingots. A. von Zeerleder (*Aluminium*, 1935, **17**, 199–201).—The use of thermocouples of the usual type for measuring the temperature of aluminium ingots during heat-treatment may lead to errors of up to 20° C., which may cause trouble later owing to incorrect heat-treatment; in addition there is also a very appreciable time lag even when the junction is inserted in a hole in the metal. These difficulties may be overcome by the use of a square block of heat insulating material fitted with a handle and with stout wires of nickel and nickel–chromium, forming the two elements of the couples, protruding just through the block on the opposite side to the handle and sharpened to points. By pressing these points into the metal so that they penetrate the oxide skin the temperature of the ingot can be read off from the galvanometer in 1–2 seconds with great accuracy.—A. R. P.

***Standard Tables for Chromel–Alumel Thermocouples.** Wm. F. Roeser, A. I. Dahl, and G. J. Gowens (*J. Research Nat. Bur. Stand.*, 1935, **14**, 239–246; *Research Paper* No. **767**).—Tables have been prepared giving the thermal e.m.f. of Chromel P *versus* Alumel, Chromel P *versus* platinum, and Alumel *versus* platinum at various temperatures in the range — 310°–2500° F. (— 190°–1372° C.). The values in the range 0°–2500° F. are based on the calibration of 15 representative No. 8 gauge Chromel–Alumel thermocouples selected after preliminary tests on 50 heats of each alloy made by the method regularly used. The tables give the temperature–e.m.f. relation of the thermocouples now being manufactured as closely as the wires can be reproduced at the present time. The guarantee limits have been fixed by the manufacturer at ± 5° F. in the range 0°–660° F. (— 18°–349° C.) and ± 0·75% in the range 660°–2300° F. (349°–1260° C.). The methods used in calibrating the thermocouples in the various temperature ranges are described briefly.—S. G.

Methods of Testing Thermocouples and Thermocouple Materials. Wm. F. Roeser and H. T. Wensel (*J. Research Nat. Bur. Stand.*, 1935, **14**, 247–282; *Research Paper* No. **768**).—Describes various methods used for testing thermocouples and thermocouple materials, and the precautions which must be observed in order to attain various degrees of accuracy. In particular, the methods developed and used at the (U.S.) Bureau of Standards are described in detail. The paper provides some guidance in the selection of the method which is best adapted to a given set of conditions.—S. G.

Non-Metallic Thermo-Elements. G. Keinath (*Arch. tech. Messen*, 1935, **4**, (46), T55).—The upper working limit of the platinum/platinum–rhodium thermocouple is about 1400° C., the exact value depending on the nature of the protecting tube. The substitution of carbon for one of the metals produced too small a thermoelectric effect, as did the carbon–graphite couple. The carbon–Silit (silicon carbide) element, however, has a thermoelectric power about 30 times that of the platinum/platinum–rhodium couple, and its effective temperature range is considerably greater; temperatures of 1800° C. may be measured by the use of this couple, which may be immersed in molten metals if necessary. Two drawbacks inherent in the element are its high electrical resistance, and the high thermal conductivity of the carbon, which necessitates the water-cooling of the cold-junction.—P. M. C. R.

A Useful Method of Graph Plotting. M. O'C. Horgan (*J. Sci. Instruments*, 1935, **12**, 123–124).—A note, describing the advantages of sloping axes for plotting calibration curves of instruments, which may be adjusted for different ranges. The method prevents confusion arising from the overlapping of different curves.—W. H.-R.

XIII.—FOUNDRY PRACTICE AND APPLIANCES

(Continued from pp. 250–252.)

Some Practical Non-Ferrous Foundry Problems. F. Dunleavy (*Met. Ind.* (*Lond.*), 1935, **46**, 351–354, 412–414, 458–459).—Abstract of a paper read before the Midlands Branch of the Institute of British Foundrymen. Discusses some of the problems that frequently confront small non-ferrous foundries and practical examples of the methods of solving them.—J. H. W.

Some Aspects of Non-Ferrous Founding. A. Logan (*Proc. Inst. Brit. Found.*, 1933–34, **27**, 483–511; discussion, 511–521).—See *Met. Abs.*, 1934, **1**, 257, 363.—S. G.

Porosity in Non-Ferrous Metal Castings. G. L. Bailey (*Proc. Inst. Brit. Found.*, 1933–34, **27**, 522–542).—See *Met. Abs.*, 1934, **1**, 257.—S. G.

Recent Advances in the Founding of Aluminium Alloys. I. G. Slater (*Met. Ind.* (*Lond.*), 1935, **46**, 379–382, 415–418, 433–436; and *Found. Trade J.*, 1935, **52**, 201–203, 221–223, 276; discussion, 255–256).—Read before the London Branch of the Institute of British Foundrymen. The circumstances guiding the choice of aluminium alloys to serve any particular purpose, the properties of the more commonly used alloys, and the melting practice, particularly as regards their liability to gas absorption, the formation of aluminium oxide, and contamination by impurities are described. The applications of electric crucible and open-hearth furnaces, and comparative costs with coke-furnace melting are given. The effect of the quality of the ingot metal on the density and the appearance of pinholes, various methods for the removal of gases from defective melts, casting technique as regards chill castings, gravity and pressure die-castings and sand castings, mould materials, design and testing of castings are discussed. The discussion centred on the use of aluminium moulding boxes, casting under pressure, making the metal sound, the Archbutt process, use of proprietory fluxes, relation between shrinkage and pinholes, and hydrogen inclusion.—J. H. W.

Studies in Cast Bronzes. F. W. Rowe (*Proc. Inst. Brit. Found.*, 1933–34, **27**, 318–331; discussion, 332–341).—See *Met. Abs.*, 1934, **1**, 363.—S. G.

Notes on the Founding of Phosphor–Bronze. R. C. Stockton (*Met. Ind.* (*Lond.*), 1935, **46**, 503–505).—The various factors governing the production of "cast-on" test-bars, the effect of phosphorus on bronze, the heat-treatment and hardness of phosphor–bronzes, and the treatment of centrifugally-cast bronze are discussed.—J. H. W.

Modern Marine Propellers: A Review of Manufacturing Methods. J. E. Newson (*Found. Trade J.*, 1935, **52**, 233–234; discussion, 234–238; and (abridged) *Machinery* (*Lond.*), 1935, **46**, 107–109).—Read before the Birmingham, Coventry, and West Midlands Branch of the Institute of British Foundrymen. The design, mould building and drying, furnaces used, casting, and finishing in the manufacture of large propellers (up to 55½ tons cast weight) in manganese–bronze are described, and the principal mechanical properties of the alloys used are given. Experiences with other alloys and defects liable to occur in large propeller castings are discussed.—J. H. W.

The Production of Marine Propellers. —— (*Machinery* (*Lond.*), 1935, **46,** 93–97).—An account of the methods used for building the moulds, melting, and casting in making large manganese–bronze propellers at the works of J. Stone and Co., Ltd., Deptford.—J. C. C.

Sodium–Zinc Alloy [as Deoxidizer for Brasses]. B. A. Weimer (*Du Pont Magazine,* 1935, **29,** (4), 18–19, 24).—A sodium–zinc alloy containing 2% sodium is used for deoxidizing brasses and preventing porosity. Its melting point is 140° C. above that of pure zinc. It has the advantage of introducing no undesirable constituents into the brass, since the sodium is oxidized and eliminated when it has done its work.—C. E. H.

Reconditioning Worn Car Journal Bearings. J. W. Lemon (*Railway Mech. Eng.,* 1934, **108,** 24–25).—After thorough cleaning of the bearing shells the old Babbitt metal is bored out, and the flat surfaces of the bearings ground off. The shells are then dipped into a flux consisting of hydrochloric acid and ammonium chloride, and " tinned " in a solder bath. The relining with new white metal is then carried out immediately. Various precautions to be observed in pouring the linings are detailed, and the recovery of old white-metal borings is described.—C. E. H.

The Manufacture and Application of Centrifugal Castings. T. R. Twigger (*Proc. Inst. Brit. Found.,* 1933–34, **27,** 595–610).—See *Met. Abs.,* 1934, **1,** 145. —S. G.

Gravity Die-Casting. E. C. Lewis (*J. Coventry Eng. Soc.,* 1934, **15,** 152–166).—An illustrated description of works' practice in the production of gravity die-castings of aluminium and magnesium alloys, die designs and manufacture, and foundry equipment.—R. G.

Recent Die-Casting Developments Open New Field for Product. Sam Tour and F. J. Tobias (*Steel,* 1934, **94,** (6), 25–27, 30).—See *Met. Abs.,* this volume, p. 178.—C. E. H.

Recent Developments in British Synthetic Moulding Sand Practice. J. J. Sheehan (*Proc. Inst. Brit. Found.,* 1933–34, **27,** 199–240; discussion, 240–256).—S. G.

Oven-Drying of Cores and Moulds. E. G. Fiegehen (*Proc. Inst. Brit. Found.,* 1933–34, **27,** 169–183; discussion, 184–198; and (abstract) *Mech. World,* 1934, **96,** 31–32).—See *Met. Abs.,* 1934, **1,** 621.—S. G.

Patternmaking. F. C. Edwards (*Proc. Inst. Brit. Found.,* 1933–34, **27,** 611–638; discussion, 638–647).—S. G.

XV.—FURNACES AND FUELS

(Continued from pp. 252–255.)

Measurements of the Specific Furnace Characteristics Associated with Oil Firing. E. Graf (*Feuerungstechnik,* 1935, **23,** 37–40).—Discusses type of oil burner used, characteristics of the combustion and furnace chambers including the efficiencies of combustion and utilization achieved, the degree of fineness of atomization, and effect of viscosity on the size of oil drop.—J. S. G. T.

The Electric Arc Null-Potential Furnace. S. E. Heuland (*Bull. Soc. franç. Élect.,* 1935, [v], **5,** 481–512).—A full account is given of the development and construction of the Heuland arc furnace. The water-cooled electrodes project downwards into the interior of the furnace, and their design and mounting, which are claimed completely to eliminate losses at the joints and to minimize electrode consumption, constitute the main feature of the new plant. Certain older types of furnace may be adapted to Heuland electrodes, endurance tests on which are described.—P. M. C. R.

XVI.—REFRACTORIES AND FURNACE MATERIALS

(Continued from pp. 255–256.)

Acid and Basic Bottoms of Copper-Refining Furnaces. Edmund R. Thews (*Met. Ind.* (*Lond.*), 1935, **46**, 464–465, 513–514).—The requirements of material for the hearths of copper-refining furnaces are set out, the use of magnesite bricks and silica hearths and their advantages and disadvantages are discussed. Neutral refractories have not given complete satisfaction for the purpose. The nature of fluxing materials, the sintering temperature, and the final preparation of the hearth are explained.—J. H. W.

***New Ceramic Materials as Aids for Research on Technically Important Fused Salt Electrolyses.** Heinz Borchers (*Metallwirtschaft*, 1935, **14**, 149–151).—Alumina crucibles burned at 1975° C. in an oxidizing atmosphere can be used up to 1350° C. in electrolysis of fused salts for the production of aluminium and magnesium.—v. G.

XVII.—HEAT-TREATMENT

(Continued from pp. 256–257.)

Quenching in Water, Brine, and Oil. I. N. Zavarine (*Metal Progress*, 1935, **27**, (4), 43–46).—Photographic studies of the behaviour of water, oil, and brine when used as quenching media show that both water and oil permit the formation of continuous envelopes of vapour around the quenched pieces. In both cases these envelopes are in a constant state of agitation while quenching proceeds, the water vapour film appearing to be thinner and to be in more rapid motion than that of oil vapour. A salt solution instantly forms a steam film, and simultaneously deposits on the surface of the object a thin film of salt. The violent and repeated rupture of this solid layer leads to the continuous destruction of the vapour envelope; this agitation by the salt crystals is believed to account for the high quenching efficiency of brine solutions.
—P. M. C. R.

XVIII.—WORKING

(Continued from pp. 257–259.)

***Stresses and Flow of Material in Tube Drawing.** Erich Siebel and Eberhard Weber (*Mitt. K.W.-Inst. Eisenforschung*, 1934, **16**, (20), 217–224).—See *Met. Abs.*, this volume, p. 257.—J. S. G. T.

***Distortion Characteristics Associated with Wire-Drawing.** Erich Siebel (*Mitt. K.W.-Inst. Eisenforschung*, 1934, **16**, 213–216).—The distortion of a copper rod of initial diameter 24 mm. after wire-drawing through a die of angle either 24° or 40° so that the diameter is decreased about 30% is investigated. The experimental results are based on a comparison of the form of a rectangular network ruled on the rod before drawing through the die with the form of the network after drawing. The results confirm the conclusion reached by Taylor and Quinney, *viz.* that the additional slip produced in the external zones of the drawn material decreases with the number of draws. This result is attributed to a difference in the nature of the hardening effected in the external zones and the core of the rod. It was assumed by Siebel and Hühne that the principal axes of deformation coincide with the principal stress axes. This is now found to be true only of the initial period of deformation.—J. S. G. T.

***Lubrication as Affected by Physical Properties of Lubricants.** Robert C. Williams (*Wire and Wire Products*, 1935, 10, (4), 145–146, 160).—W. records values of the coeff. of friction determined by drawing 0·0253 in. soft copper and 0·0250 in. 18 : 8 stainless steel wire at a speed of 30 cm./minute through a 0·0225-in. tungsten carbide die with a die angle, θ, of 18° (half-angle of throat 9°), using as lubricants various solid waxes and wax-like substances of moderately low melting point. The coeff. of friction was calculated from the equation: Die pull $= (myp)(A - a)(1 + \cot\frac{\theta}{2} \cdot cf)$ in which $myp =$ mean yield-point of wire (assumed equal to ultimate tensile strength of undrawn wire); $A - a =$ reduction in area of cross-section effected; and $cf =$ coeff. of friction. The coeff. of friction is less with solid waxes (0·07–0·15) than with mineral oils (0·21–0·29), but the value increases when the die is heated to the melting point of the wax until it equals that for mineral oils. Waxes of higher melting point become effective at temperatures approaching their melting points. W. concludes that, in order to realise the enhanced lubrication given by solid waxes in wire-drawing, the lubricant must adhere strongly to the surface of the wire or die or both, must be solid until it enters the region of high pressure between the wire and the bearing of the die, and must yield a fairly mobile liquid between the surfaces of wire and die while reduction is taking place. He believes that the coeff. of friction for a solid lubricant which meets these conditions depends on the viscosity and thickness of the film of lubricant rather than on the chemical nature of the lubricant, wire, and die, and attributes the lack of exact parallelism between the coeffs. found with copper and stainless steel to differences in adhesion of the lubricants to the two metals, to the influence of the temperature attained at the metal/die interface, and to the effect of points of asperity on wire and die.—W. E. A.

Diamond Die Manufacture. —— (*Wire Industry*, 1935, 2, 61–63).—An account of the manufacture of diamond dies at the Parkstone (Dorset) works of the British Diamond Wire Die Co., Ltd., with practical hints on the precautions to be observed by users of such dies (cf. following abstract).—W. E. A.

Composition Dies. —— (*Wire Industry*, 1935, 2, 93–94).—The economies offered by the use of composition dies instead of steel and chilled iron dies are outlined. Consideration of the shape of such dies, of their lubrication, and of the importance of correct preparation of the rods prior to drawing and of proper leading of the wire to and from the dies, with avoidance of shock loads on the latter, is followed by a description of methods of re-boring and re-polishing (cf. preceding abstract).—W. E. A.

Wire Cloth Manufacture. Activities of the United Wire Works, Ltd. —— (*Wire Industry*, 1935, 2, 43–45).—Editorial. A short, popular account of the manufacture of wire-cloth and gauze for paper-making and screening purposes, as carried on by the United Wire Works, Ltd. Fine brass and bronze wires for paper-machine cloths are diamond-drawn at speeds of 2000–3500 (*feet*, presumably: the length unit is omitted) per minute, and are bright-annealed in thermostatically-controlled electric furnaces.—W. E. A.

The Early History of Wire. F. C. Thompson (*Wire Industry*, 1935, 2, 159–162).—T. cites a Biblical reference to the production of wire by beating into plates, cutting into strips, and hammering on an anvil; quotes Guild regulations governing 8 wire-drawing establishments in Paris about A.D. 1270, and a Latin MS. of A.D. 1000 or earlier ascribed to Theophilus, in which occurs the earliest known reference to the wire-drawing die; and attributes the first application of mechanical power to wire-drawing to Rudolph of Nuremberg about 1350. Wire-drawing was introduced into England in 1565 as the result of an invitation to German wire-drawers by Queen Elizabeth, and its development was greatly influenced by the importance of card wire in the woollen industry. The old French method of production of draw-plates from wrought iron carburized by repeated heating with fragments of cast iron is quoted, and reference made to the accidental discovery of the beneficial effect of copper-coating in steel wire-drawing.—W. E. A.

On the Bending of Thick Aluminium Bars. —— Nicolini (*Aluminium*, 1935, **17**, 220–221).—A simple apparatus for bending thick aluminium bars at right angles by means of a lever and roller is described. After bending a bar 3·5 × 18 cm. in cross-section in the apparatus, the metal at the bend showed an increased tensile strength of 20%, an increased hardness of 30%, and a decrease of 57% in the elongation.—A. R. P.

XIX.—CLEANING AND FINISHING

(Continued from p. 259.)

Developments in Electrolytic Pickling. A. E. Chester and C. J. Krister (*Metal Cleaning and Finishing*, 1935, **7**, 30–33; *C. Abs.*, 1935, **29**, 2858).—A brief description of the Madsenell, the Hanson–Munning, the Bullard–Dunn, and the "Ferrolite" electro-pickling methods.—S. G.

The Removal of Vapours and Waste Gases in Pickling, Acid Brightening, and Metal Coating Works. R. Tiquet (*Galvano*, **1935**, (34), 26–30; (36), 28–32).—The characteristics of the various fumes and gases likely to be encountered are described, and a number of different systems for drawing them off and cleaning the polluted air are discussed. The choice of materials for the construction of the ducts, &c., is also touched upon.—C. E. H.

***Hydrogen-Ion Concentration of the Saliva of Picklers (Metal Cleaning).** I. V. Hecker (*Arch. Hyg.*, 1934, **5**, 255–262; *C. Abs.*, 1935, **29**, 2488).—In pickling plants where sulphuric acid or hydrochloric acid is used, the excellent condition of the gums and teeth of the workers were remarkable, in spite of the injurious effect of the gases on the health of the men. The investigation showed an increase of alkalinity of the saliva, the buffer property of which hindered a decalcifying action of the acid.—S. G.

Deposition of Metallic Copper on Antique Silver Coins During Electrolytic Cleaning and a Method for Its Removal. Earle R. Caley (*Tech. Studies Field Fine Arts*, 1935, **3**, 123–132; *C. Abs.*, 1935, **29**, 2455).—A simple method, suitable for nearly all cases, for the safe removal of metallic copper deposited on silver coins during electrolytic cleaning consists in immersing the coins for 5–10 minutes in a 5% silver nitrate solution in a shallow vessel that is given a gentle rocking motion, each coin being turned over with forceps at frequent intervals, they are then washed with running water, rubbed with moist sea-sand or a stiff brush, and can finally be given a high finish with a polishing powder or paste. With silver coins having incrustations containing a considerable proportion of copper compounds, only electrolysis in alkali cyanide solution combines effective cleaning with complete avoidance of copper plating; the method is slower, however, than with the silver nitrate method for removing copper plating.—S. G.

Cleaning of Tinned Surfaces. Edwin Klika (*Metal Cleaning and Finishing*, 1935, **7**, 76; *C. Abs.*, 1935, **29**, 2890).—The tarnish which develops on tinned articles on ageing can be removed and the finish restored to its original lustre by immersing the articles for 2–3 minutes in palm oil heated to 150° C. After draining, the excess oil is blown off the articles with an air blast. When larger articles are to be treated it is recommended to preheat these in boiling water before immersion to obviate excessive cooling of the oil. Another method consists in immersing the articles in 2% nitric acid, and is most efficient if the articles are preheated. The acid dip is immediately followed by a rinse in kerosene oil. The duration of the acid dip must be determined experimentally. Too short a dip does not restore the lustre and too long a dip increases the tarnish and produces a spangle effect. The dip and the rinse are operated at room temperature. The drying of the articles is best accomplished in heated sawdust.—S. G.

Controlling Cleaning Baths. H. C. Roberts (*Metal Cleaning and Finishing*, 1935, **7**, 34–36; *C. Abs.*, 1935, **29**, 2890).—Discusses the colorimetric determination of the p_H of alkaline cleaning baths for the purpose of controlling the maximum cleaning efficiency.—S. G.

Coloured Etching of Metal [*e.g.* Copper] Letters, Indicators, and Decorations of All Kinds. —— Rostosky (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 161–162).—Smooth velvety-black finishes can be obtained on copper, brass, steel, &c., by etching in a mixture of hydrochloric acid (d 1·15), antimony tellurite 40 grm., bismuth selenite 80 grm., and water 580 c.c. The strongly adherent film formed on the metal consists of a mixture of the selenides and tellurides of bismuth and antimony.—A. R. P.

Metal Colouring. A. Busser (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 162–163).—The composition of various solutions for colouring copper, zinc, brass, aluminium, nickel, iron, and gold are given.—A. R. P.

Polishing and Buffing Articles of Copper, Light Metals, and Tinplate. Rudolf Plücker (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 165).—Practical hints and suitable polishing and buffing media are given.—A. R. P.

Japanning Metal Parts [Brass, Steel]. William J. Miskella (*Met. Ind.* (*N.Y.*), 1935, **33**, 45–47).—A modern American plant is described and illustrated with details of the procedure used.—A. R. P.

Alarcar Treatment of Aluminium. Producing Case-Hardened, Coloured Aluminium with Insulating and Heat-Resisting Properties. —— (*Elect. Times*, 1935, **87**, (2255), 42).—This process produces a different microscopic structure of the oxide, compared with earlier methods, and is in a spongy form which is readily susceptible to dyeing and sealing. It is capable of taking a high polish, but may be given a matt finish. The aluminium parts are cleaned and immersed in a special electrolytic bath (composition not given). Coatings up to $\frac{1}{15000}$ in. can be deposited, and may subsequently be dipped into a dye bath. The case-hardened skin is exceptionally hard, resistant to all forms of corrosion, and maintains its polish indefinitely. It is also heat-resistant.—I. M.

XX.—JOINING

(Continued from pp. 260–261.)

***A Simple Method of Making Contacts with Thin Metal Foil [and of Joining Two Pieces of Thin Foil].** R. V. Jones (*J. Sci. Instruments*, 1935, **12**, 122–123).—Methods are described for making electrical connection to thin metal foil in cases where soldering is impracticable or adds appreciably to the heat capacity of the foil. To join thin gold foil to a piece of clean metal, the surface of the latter may be moistened with alcohol, and the foil allowed to fall on the moistened surface, when the surface tension of the alcohol pulls the foil into such intimate contact that it is impossible to strip the foil when the alcohol has evaporated. Two pieces of foil may be joined similarly using a dilute solution of pyroxylin in amyl acetate. The electrical resistances of such junctions remain constant to 0·25% over periods of days.—W. H.-R.

Economies in Tin Solders by the Use of New Alloys and New Methods. Erich Lueder (*Z.V.d.I.*, 1935, **79**, 100–103).—Discusses the development, use, and value of new German solders designed to economize in tin consumption.—K. S.

Aluminium Joints in High-Tension Cables. L. Lux (*Aluminium*, 1935, **17**, 202–208).—Methods of joining lengths of aluminium cables by soldering and welding and by the use of special clamps are described with reference to illustrations.—A. R. P.

Gas Welding of Aluminium Tank Structures. G. O. Hoglund (*Welding J.*, 1935, **32**, 50–52).—Modern developments in aluminium welding are briefly discussed with reference to transport tanks, brewery, dairy, and chemical equipment, furniture, and architecture.—H. W. G. H.

Special Problems in the Welding of Aluminium. —— (*Canad. Mach.*, 1935, **46**, (4), 35–37).—The importance of proper support, oxide removal, and joint preparation is emphasized, and special methods in connection with the oxy-acetylene welding of sheet metal are described. For cast materials a welding rod containing a small % of silicon is recommended, as eliminating the puddling rod. Bench methods of testing temperature are briefly described.—P. M. C. R.

Advances in Electric Welding of Light Metals. C. Haase and O. Plass (*Aluminium*, 1935, **17**, 209–216).—Modern types of welding machines are described and illustrated, and the microstructures of characteristic welds in various light alloys are shown in photomicrographs.—A. R. P.

The Fuller Carbo-Flux Arc Method of Light Sheet-Metal Working. —— (*Welding J.*, 1935, **32**, 12, 22–24).—A manual carbon-arc process is described in which the electrode holder produces a magnetic field round the arc, ensuring arc stability. Coated filler rods are used, the flux being designed to ionize the arc stream as well as to protect the metal. Welding speed and current curves are given for steel up to 16 G., but the process is also recommended for aluminium and copper.—H. W. G. H.

The Jointing of Lead Cable-Sheaths by Lead Burning, Known as Duct Splicing. W. A. Adams (*Post Office Elect. Eng. J.*, 1935, **28**, (1), 37–39).—A full description is given of the method perfected by the Birmingham P.O. Testing Branch for the replacement of lead sheathing by oxy-acetylene welding (" burning ") the new sections into position.—P. M. C. R.

The Hard Alloy " Armite." S. B. Kocharov (*Neft*, 1933, **4**, (11), 11; *C. Abs.*, 1935, **29**, 2133).—[In Russian.] The properties and application of the American alloy Armite (chemical composition not disclosed) are discussed. This alloy is manufactured in 4 types: (1) Armite arcweld, a powder; (2) Armite autoweld, in rods; (3) Armite inserts and compounds, chips; and (4) Armite hard facing rod. All these alloys are suitable for brazing drilling bits.—S. G.

Bronze Welding. C. H. S. Tupholme (*Met. Ind.* (*Lond.*), 1935, **46**, 431–432).—Bronze welding and brazing of cast iron, steel, wrought iron, and copper are described, and the use of a manganese–bronze welding rod in cases of surfaces exposed to severe wear is explained.—J. H. W.

Development and Progress of Bronze-Welding. R. Meslier (*Rev. Soud. Autogène*, 1935, **27**, (252), 7–12).—The rapid development of the process, particularly for steel and cast iron, is described. Some applications for copper and brass are illustrated. For copper, the method is recommended for thin sheets, in preference to welding: for brass, on the other hand, for material of thickness greater than 4 mm. A copper vessel is illustrated after hydraulic test, in which it had deformed to spherical shape without failure of any of the bronze-welded seams. The circumferential elongation was about 36%.—H. W. G. H.

Welding in the Automotive Industry. E. J. Raymond (*Modern Engineer*, 1935, **9**, 68–72).—The gas-welding of zinc-base die-castings, aluminium and magnesium alloys, for repair work is discussed.—H. W. G. H.

Methods of Welding. —— (*Soudure et Oxy-Coupage*, 1935, **12**, 243).—In the leftward method of welding, complicated movements of blowpipe and filler-rod are often executed by the operator. These are unnecessary and even harmful: movement of the blowpipe tip and the rod should be confined as far as possible to a steady progress along the line of the seam.—H. W. G. H.

The Practical Side of Resistance Welding. H. S. Jeffs (*Welding Ind.*, 1935, **3**, 23–29; discussion, 65–67).—Spot-, seam-, butt-, and flash-welding are discussed, with especial reference to correct setting-up of the machines, preparation of the material, handling of the work in the machine, minimizing of distortion and marking of the work. In replying to the discussion, J. maintained that resistance welds in ferrous metals were not fusion welds.—H. H.

Butt-Welding Theory. P. W. Fassler (*Welding Eng.*, 1935, **20**, (2), 26–28). —A method is described for calculating the heat and current requirements for butt-welding (not flash-welding).—H. W. G. H.

Spot-Welding. K. B. White (*Wire and Wire Products*, 1935, **10**, 143–144, 156).—W. summarizes in a table the present position with regard to the spot-welding of 250 pairs of metals and alloys, the majority of which are non-ferrous. The classification used is: good weld, completely miscible but brittle weld, poor weld, no weld. The usual method for making a spot-weld is described, and the vital importance of working with clean metal parts is emphasized. The choice of material for electrode tips is discussed; copper tips are recommended for high-resistance materials such as iron, nickel, Nichrome, and nickel–brass, and copper-rich copper–tungsten alloy tips if greater strength or longer life is required; for welds between low-resistance materials, like copper and aluminium, tungsten tips are best. Modifications of the method for spot-welding parts of widely different thickness, electrical resistance, or melting point are discussed, and a means of further localizing the area of intense heating by projection welding is outlined. Possible ill effects of intense local heating are minimized by the use of a high current for a short time and by welding under a suitable liquid.—W. E. A.

Use of Polarized Light as Applied to Welding Products. E. W. P. Smith (*J. Amer. Weld. Soc.*, 1935, **14**, (2), 21–24).—An elementary discussion on the effects of stress concentrations and a description of a simple polariscope for determining them qualitatively.—H. W. G. H.

The Resistance of Welds to Corrosion. A. Leroy and M. Bonnot (*Rev. Soud. Autogène*, 1935, **27**, (253), 2–6).—See *Met. Abs.*, this volume, p. 77.
—H. W. G. H.

XXI.—INDUSTRIAL USES AND APPLICATIONS

(Continued from pp. 261–265.)

†**Free Conductors of Aluminium and Aluminium Alloys.** Herbert Wiesthaler (*Z.V.d.I.*, 1935, **79**, 105–110).—The properties of Aldrey and steel-cored aluminium conductors are described.—K. S.

***Influence of Aluminium on the Reproduction, Respiration, and Fermentation of Yeast.** K. Trautwein (*Z. ges. Brau.*, 1934, **57**, 65–67, 69–71; *C. Abs.*, 1935, **29**, 2296).—Bottom-fermenting yeast was rapidly killed by treatment with $0{\cdot}01M$ $Al_2(SO_4)_3$. A $0{\cdot}001M$ concentration exerted a distinct inhibition on growth, while lower dilutions had no noticeable effect. Such high concentrations ($0{\cdot}01M$ corresponds to 6–7%), however, which are harmful to yeast never occur in brewing practice. Respiration was not affected by concentrations up to $0{\cdot}01M$, but fermentation proved to be very sensitive to aluminium salts. A $0{\cdot}0001M$ concentration in a solution made up from sugar and inorganic salts reduced the velocity of fermentation by 50%. In wort the harmful effect was not apparent, owing to precipitation of aluminium by the phosphates of malt.—S. G.

Aluminium with Regard to Textile Dyeing and Finishing Machinery. G. L. Atkinson (*Textile Colorist*, 1934, **56**, 129–130; *C. Abs.*, 1934, **28**, 2910).—Points out the advantages of more frequent use of aluminium for textile finishing machinery, in place of iron and steel.—S. G.

Aluminium Awnings. —— (*American Press Cutting*, **1935**, Mar. 18; *Light Metals Rev.*, 1935, **1**, 430).—Folding aluminium corrosion-resisting awnings have been introduced. They are simply operated, are durable, and fire-proof.
—I. M.

Aluminium for Furniture Construction. W. Gratwicke (*Cabinet Maker*, **1935**, Mar. 30).—I. M.

Cellulose-Coated Aluminium Record. —— (*Thomas's Register* (*N.Y.*), **1935**, April; *Light Metals Rev.*, 1935, **1**, 436).—Reproduction sound records of cellulose-coated aluminium can be cut in any transcription recording with sapphire points.—I. M.

Powdered Aluminium in Road Surfacings. —— (*Municipal J.*, **1935**, Mar. 8; *Light Metals Rev.*, 1935, **1**, 431).—It is reported from Germany that the addition of powdered aluminium to tar and bituminous surfacings gives high reflecting power and tends to keep the temperature of the surface considerably below the normal point, thereby checking softening in hot weather. —I. M.

New Aluminium Paint. —— (*Amer. Metal Market*, 1935, **42**, (22), 5).—A brief note. A new flexible aluminium paint which gives a scale-like metal sheathing for longer protection and has a smooth, brilliant finish, has recently been perfected. Dirt and dust do not attach themselves readily to the surface. Because of excellent water-resistant qualities (including salt-water) it withstands washing, and also chemical fumes, humid atmospheres, corrosion, rust, and decay. The one standard grade may be used in- and out-doors. One application covers stained and discoloured surfaces completely.—I. M.

Structural Aluminium. R. L. Templin (*Metal Progress*, 1935, **27**, (5), 34–39).—A brief review of special methods for forming and fabricating structural members in light alloys, and a discussion of the effect of the use of such members on design. The dimensions, weight, strength, and stiffness of a 5 in. standard I-beam in steel are compared with those of 5 corresponding beams of varying sizes in " 17 S.T." alloy. The use of light alloys to minimize deadweight is illustrated by a description of the Smithfield Street Bridge at Pittsburgh (see *Met. Abs.*, 1934, **1**, 215), and a description is given of the reconstruction of the Brooklyn Suspension Bridge, New York, the new decks and trusses for which will be of " 27 S.T." alloy.—P. M. C. R.

Duralumin in Aircraft Construction. F. P. Laudan (*Metal Progress*, 1935, **27**, (4), 39–42).—The preparation of Duralumin for use as longerons, skin stiffeners, bulkheads, and skin covering in modern aircraft is described, appropriate dimensions and mechanical properties being stated in each case. All Duralumin is anodically oxidized, whilst steel members are plated with cadmium or chromium.—P. M. C. R.

***Strength Tests of Thin-Walled Duralumin Cylinders in Combined Transverse Shear and Bending.** Eugene E. Lundquist (*Tech. Notes Nat. Advis. Cttee. Aeronautics*, No. **523**, 1935, 18 pp.).—In these tests if the magnitude of the shear is V, the moment M, and the radius of the cylinder r it is shown that M/rV is descriptive of a definite stress condition. When M/rV is large, failure of thin-walled Duralumin cylinders occurs in bending by a sudden collapse of the compression half of the cylinder, and the stress on the extreme fibre and the size of the wrinkles formed are both equal to their respective values for a similar cylinder in pure bending. When M/rV is small, failure occurs in shear by the formation of diagonal wrinkles on the side of the cylinder of a similar size and shape to those which occur in torsion tests. As M/rV approaches zero the shearing stress or the neutral axis at failure is approximately 1·25 times the allowable shearing stress in torsion. At intermediate values of M/rV there is a transition from failure by bending to failure by shear accompanied by a reduction in strength. A chart is given for calculating the strength of thin-walled cylinders in transverse shear and bending in which this reduction is allowed for.—A. R. P.

Light Metals and Their Use in Railway Work. F. Reidemeister (*Aluminium*, 1935, **17**, 217–220).—Comparative cost data of aluminium alloy and steel for railway wagons are given.—A. R. P.

A New Use for Cobalt. C. C. Downie (*Rayon and Melliand Textile Monthly*, 1935, **16**, 35; *C. Abs.*, 1935, **29**, 2361).—Mordanting of fabrics by electrolysis has been carried out successfully with cobalt anodes (prepared by hot-rolling cobalt on to nickel plates) and platinum cathodes.—S. G.

***The Action of Copper on Yeast [Copper in the Brewery].** M. H. van Laer (*Ann. zymol.*, 1934, [ii], **1**, 287–304).—See *Met. Abs.*, this volume, p. 124.—S. G.

Manufacturing Economies Open Wide Market for Pre-Chromed Copper Sheet. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**82**), 6).—The use of "Chrom-copper" a material which can be bent, drawn, or formed *after* the chromium-plating process is completed, for the construction of petrol pumps and kitchen sinks is illustrated.—J. S. G. T.

Further Deterioration of Famous Stadium Halted by Covering of Sheet Copper. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**80**), 5).—The protection of the concrete structure of the Lewisohn Stadium, New York, U.S.A., by sheet copper coloured with "Cabra" patina treatment is illustrated.—J. S. G. T.

Lead-Coated Copper Specified by Philadelphia Architects for Important Structures. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**80**), 13).—The use of lead-coated copper for the construction of gutter linings, eaves, pipes, &c., is illustrated.—J. S. G. T.

Shimmering Copper Mesh Accessories Lacelike in Delicacy. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**82**), 7).—The use of copper and bronze mesh material for the construction of bags, hats, belts, collars, &c., is referred to and illustrated.—J. S. G. T.

Gigantic Boulder Dam Project to Provide Vast Electric Power and Water Resources for Far West will Require over 30,000,000 Pounds of Copper for Transmission Lines. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**79**), 12–13).—The copper requirements in connection with the construction of Boulder Dam, U.S.A., are referred to.—J. S. G. T.

Brass Replaces Rusted Pipe in Federal Structure. —— (*Bull. Copper Brass Res. Assoc.*, 1935, (**82**), 5).—The replacement of the rust-laden water supply pipes in the Federal Building in Birmingham, Alabama, by brass piping is mentioned.—J. S. G. T.

New Materials [Bronzes] for Sliding Contact Bearings. —— (*Demag News*, 1934, **8C**, 33–36).—The sliding properties of 2 new bearing alloys, "Demag Edelbronze K" and "Special Bronze D.K.S. 35" (compositions not given) are shown graphically and discussed.—A. R. P.

The Bronzes as Engineering Materials. F. Johnstone Taylor (*Met. Ind.* (*Lond.*), 1935, **46**, 453–456).—The use of bronze sheet in engineering, its resistance to corrosion, the manufacture and properties of bronzes with a copper–tin base, of nickel–bronzes, "aluminium–bronze," and of alloys of the solid solution type are discussed. The recommended foundry practice, casting with nickel–bronze and silicon–copper, the importance of gating, and the method of ensuring a pressure-tight casting are described.—J. H. W.

Lining of Chemical Apparatus with Lead. A. M. Ginstling (*Khim. Mashinostroenie*, **1934**, (5), 30–31).—A review.—S. G.

Nickel and Its Non-Ferrous Applications. Robert C. Stanley (*Met. Ind.* (*N.Y.*), 1935, **33**, 52–54).—A brief outline is given of the uses of pure nickel and its non-ferrous alloys in industry.—A. R. P.

The Electro-Catadyn Process. A. Salmony (*Bull. Assoc. Suisse Élect.*, 1935, **26**, 206–207).—The sterilization of water through agitation with silvered objects was discovered by Naegli and subsequently confirmed by Krause. The action of infinitesimal quantities of silver in destroying not only existing bacteria, but similar organisms gaining access to the solution over a considerable subsequent period, is now applicable to large-scale processes, *e.g.* the sterilization of mineral waters and swimming baths. An apparatus for this purpose is described.—P. M. C. R.

†**Advances in the Field of Hard Metals.** Karl Becker (*Metallwirtschaft*, 1935, **14**, 233–235).—A review of recent patent literature.—v. G.

Lubrication of Anti-Friction Bearings: Conclusions.—I. F. Leister (*Machinist* (*Eur. Edn.*), 1935, **79**, 198–200E).—Experiments have been carried out to determine the effect of temperature and grease quantity on the lubrication of anti-friction bearings, using various greases. It was found that with a great many greases, the early operating temperature may be high, and that the greater the quantity of grease used, the higher the temperature reached and the earlier it becomes apparent.—J. H. W.

Influence of Metals on the Flavour of Condensed-Milk Products. Z. D. Roundy and H. C. Jackson (*Wisconsin Agric. Exper. Sta. Bull.* No. **428**, (Ann. Rep. 1932–1933), 1934, 35–36; *C. Abs.*, 1935, **29**, 3053).—Ten different samples of milk were condensed in pans of copper, nickel, and stainless steel, and examined for their copper content. The copper, nickel, and stainless steel pans yielded milk containing, respectively, 3·53, 1·26, and 0·56 mg. of copper per litre of evaporated milk. Lots of condensed milk or condensed ice-cream mixes which had been prepared in the copper pan and stored for 3 months at 6° developed a distinct tallowy flavour. Ice-cream made from this mix was off-flavoured.—S. G.

Cooling Tanks [in the Brewery]. F. Dieterlen (*Brasserie & Malterie*, 1935, **24**, 377–384; *C. Abs.*, 1935, **29**, 3105).—An address, discussing the metal, shape, installation, and manner of use of cooling tanks in the brewery.—S. G.

The Influence of Iron [and other Metals] on the Colouration of the Fibres in the Retting [of Flax and Hemp] by Bac. Felsinus.—III. D. Carbone (*Boll. soc. internat. microbiol., Sez. ital.*, 1933, **5**, 339–340; *C. Abs.*, 1934, **28**, 2909).—Several non-oxidizing steels and other metals were tested with good results (except for aluminium) in the retting of flax. All the metals examined gave good results for hemp.—S. G.

The Influence of Iron and Other Metals in the Microbiological Retting of Flax and Hemp.—IV. D. Carbone and A. Moggi (*Boll. soc. internat. microbiol., Sez. ital.*, 1935, **7**, 30–35; *C. Abs.*, 1935, **29**, 3168).—Cf. preceding abstract. Copper, zinc, lead, and iron exert an injurious action in the microbiological retting of flax and hemp; copper, iron, and lead even affect the colour of the fibres, which become dark green or grey. Aluminium is harmless. Tin, which does not act on the colour, hinders the anærobic retting of the hemp, but not the ærobic retting of hemp or either retting of flax.—S. G.

Spark Plugs and Their Improvement. Hans Navratiel (*Brennstoff- u. Wärmewirt.*, 1935, **17**, 21–25; *C. Abs.*, 1935, **29**, 3069).—The ionizing power of the plug can be increased by coating the insulator with a radioactive substance and coating the platinum or tungsten electrodes with alkali or alkaline earth metal oxides.—S. G.

Deposition of Metals on Glass in Vacuo, H. W. Lee (*Glass Ind.*, 1934, **15**, 271–272).—S. G.

XXII.—MISCELLANEOUS

(Continued from p. 265.)

Work of the British Non-Ferrous Metals Research Association. A. Brandt (*Plumbing Trade J.*, 1935, **14**, 326–329).—An account of the Association's work on the casting of metals, welding of copper, testing and corrosion of galvanized equipment, solders, freezing of water pipes, and development of the B.N.F. ternary alloys of lead for cable sheathing and water pipes.—C. E. H.

Metallurgical Research. B. H. Moore (*Met. Ind.* (*Lond.*), 1934, **27**, 89–91). —Portion of a paper read before the Kalgoorlie Branch of the Australian Institute of Mining and Metallurgy, outlining the use of the technical library, the personnel of the research staff, the form of research (pure or applied), and publication of reports.—J. H. W.

Aluminium Industry in Japan. Kwang-Chu Hsieh (*Golden Sea Research Inst. Chem. Ind.* (*China*) *Bull.* No. **12,** 1934, 1–22).—S. G.

***Chemical Investigations of the Ancient Metallic Implements in the Orient. V.—The Ancient Chinese Bronze Implements.—4.** Tsurumatsu Dōno (*Nippon Kwagaku Kwai Shi* (*J. Chem. Soc. Japan*), 1935, **56,** 52–56; *C. Abs.*, 1935, **29,** 2889).—The bronze implements from north China were analyzed. They seem to have been brought over from western Siberia.—S. G.

Lead Poisoning in a Scrap-Iron Warehouse [Cutting Lead-Coated Iron]. —— Kappe (*Arbeitsschutz*, **1934,** 165; *Chim. et Ind.*, 1935, **33,** 359; *C. Abs.*, 1935, **29,** 3067).—Lead poisoning was observed with workmen who cut, with a hydrogen or acetylene blast, iron that was coated with lead, intoxication being due to absorption of lead oxide vapours. Air collected in the neighbourhood of the flame contained 29·35 mg. lead/m.^{3}. Precautions are indicated which made it possible to avoid any signs of intoxication over a period of 4 months. —S. G.

Nickel—Past and Present. Robert C. Stanley (*Canad. Min. Met. Bull.* (*Transactions Section*), No. **277,** 1935, 176–208).—The history of the extraction and applications of nickel is traced from early times to the present day. A list of the forms of nickel commercially available is given together with their chief characteristics, and the proportions of the world's output of nickel absorbed in different applications are tabulated. The paper also contains data on price and output over a number of years.—C. E. H.

The Development of the Evaporation Process. Robley C. Williams (*Sibley J. Eng.*, 1934, **48,** (7), 99–100, 111).—A survey is given of the development of the process of depositing metallic films by evaporation. Aluminium is the most suitable material in every respect except that of hardness, the harder chromium possesses a comparatively low reflectivity. A satisfactory coating is made by depositing over a thin film of chromium a thicker layer of aluminium (" Chromaluminium " film). A *bibliography* is appended.—P. M. C. R.

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***Oxford, University of.** *Abstracts of Dissertations for the Degree of Doctor of Philosophy.* Volume VI. (Committee for Advanced Studies.) Cr. 8vo. Pp. v + 303. 1934. London: Oxford University Press (Humphrey Milford). (3*s.* 6*d.* net.)

***Partington, J. R.** *Origins and Development of Applied Chemistry.* Roy. 8vo. Pp. xii + 597. 1935. London, New York, and Toronto: Longmans, Green and Co. (45*s.* net.)

***Pilcher, Richard B.** *The Profession of Chemistry.* Third Edition. Demy 8vo. Pp. viii + 104. 1935. London: Institute of Chemistry, 30 Russell Sq., W.C.1. (2*s.* 6*d.* net.)

***Power Transmission.** *Trade Names Index and Directory, 1935–1936.* Demy 8vo. Pp. 140. 1935. London: Trade and Technical Press (Power Transmission), Ltd., 65–66 Chancery Lane, W.C.2. (1*s.*)

***Roeser, Wm., and H. T. Wensel.** *Methods of Testing Thermocouples and Thermocouple Materials.* (National Bureau of Standards, Research Paper No. 768.) Med. 8vo. Pp. 247–282, with 7 illustrations. 1935. Washington, D.C.: Government Printing Office. (5 cents.)

[See *Met. Abs.*, this volume, p. 306.]

***Roeser, Wm., A. I. Dahl, and G. J. Gowens.** *Standard Tables for Chromel–Alumel Thermocouples.* (National Bureau of Standards, Research Paper No. 767.) Med. 8vo. Pp. 239–246. 1935. Washington, D.C.: Government Printing Office. (5 cents.)

[See *Met. Abs.*, this volume, p. 306.]

***Roosevelt, R. M.** *Report on the Galvanizing Campaign of the American Zinc Institute, Inc. Its Accomplishments, Its Failures, and Its Future.* Talk Delivered on April 23, 1935, at the Convention of the Zinc Industry at St. Louis. [Mimeographed.] 4to. Pp. 12. [1935.] New York: American Zinc Institute, Inc., Suite 1562, Lincoln Bldg., 60 E. 42nd St.

***Stainless Steels.** *The Book of Stainless Steels. Corrosion-Resisting and Heat-Resisting Chromium Alloys.* Edited by E. E. Thum. Second Edition. Med. 8vo. Pp. xiii + 787, with 292 illustrations. 1935. Cleveland, O.: American Society for Metals.

***Stanley, Robert C.** *Nickel, Past and Present.* A Paper presented at the Second Empire Mining and Metallurgical Congress, Toronto, Ontario, Canada, 1927. Revised Edition. 6½ in. × 9 in. Pp. 73, with 3 folding charts. 1934. Toronto. Ont.: International Nickel Company of Canada, Ltd.; London: Mond Nickel Co., Ltd.

Verein deutscher Ingenieure. *Dauerfestigkeitsversuche mit Schweissverbindungen.* Bericht d. Kuratoriums für Dauerfestigkeitsversuche im Fachausschuss für Schweisstechnik beim Verein deutscher Ingenieure, durchgeführt 1930–1934. Pp. 46. 1935. Berlin: VDI-Verlag G.m.b.H. (M. 8.50.)

NEW PERIODICALS.

Boletin de la Faculté des Sciences franco-chinoise de Peiping. No. 1 (Nov. 1934). In French. University, Peiping, China.

Bulletin de la Sociedad química del Perú. Volume I, No. 1 (July 1934). Casilla 891, Lima, Peru. 5 Sols.

Chemistry (China). In Chinese. Volume I, No. 1 (Jan. 1934). Contains—in addition to articles, news, &c.—"Chinese Chemical Abstracts." Address: c/o Mr. An-Pang-Tai, Department of Chemistry, University of Nanking, China. Published Quarterly. Mex. $3.00.

Chinese Journal of Physics. Volume 1, No. 1 (Oct. 1933). Chinese Physical Society, c/o Mr. S. L. Ting, National Research Institute of Physics, Brenan and Yu-Yuen Roads, Shanghai, China. Published semi-annually. G.$2.00.

Contributions from the Institute of Chemistry, National Academy of Peiping. No. 1 (1934). In French (mostly) or English, with some abstracts in Chinese. National Academy, Peiping, China.

Contributions from the Institute of Physics, National Academy of Peiping. Vol. 1 (Dec. 1933). In French or English. National Academy, Peiping, China. Published irregularly.

La chimica e l'industria. A combination of *Giornale di chimica industriale ed applicata* and *L'Industria chimica.* Volume 17, No. 1 (first issue under new title, Jan. 1935). Published at: Via S. Paolo 10, Milano, Italy. Lire 100 per annum.

Research and Progress. Volume I, No. 1 (Jan. 1935). Published at Unter den Linden 38, Berlin, N.W.7. A quarterly review, in English, of German science. $1.50 per annum.

XXIV.—BOOK REVIEWS

(Continued from pp. 271–272.)

The Chemistry of Solids. By Cecil H. Desch. (The George Fisher Baker Non-Resident Lectureship in Chemistry at Cornell University.) Med. 8vo. Pp. xi + 213, with frontispiece and 55 illustrations. 1934. Ithaca, N.Y.: Cornell University Press ($2.50); London: Oxford University Press (Humphrey Milford) (11*s.* 6*d.* net).

The reading of this book requires time and deliberation, which are amply repaid by the pleasure and inspiration received, and the intending reader may be warned that he will be so interested as to feel impelled to traverse at least some chapters a second time. Cornell University deserves much gratitude for giving us this volume, which comes at a time when up-to-date surveys by the few who are capable of a wide enough perspective are vitally necessary to the enlightened progress of learning, teaching, and research in metallurgy. The volume is described as containing the substance of the lectures delivered by the author, which deal with selected topics and indicate the directions in which research is proceeding. This is true, but gives no adequate impression of the completeness of the work, or of the stimulus which it must give to the great majority of specialized scientific workers, especially in metallurgy, who find the inevitable difficulty in maintaining their knowledge on a broad enough basis.

The introductory lecture is something of a surprise, dealing as it does with philosophic and historical considerations, and many of the views put forward are deserving of a wider public than the book is likely to reach. A plea for the historical teaching of science and the scientific teaching of history is well worth stressing, and indeed without both it is impossible to visualize the ultimate social value of science. In asking whether the chemist must not seek to become a sociologist (in that he cannot divest himself of responsibility for the uses to which science is put), the author is probably preaching to the converted, since the scientist, by the habit of scientific thinking, is naturally led to a consideration of his work in relation to the community. Beyond this, however, the scientist is surely not responsible for the use of his results by others, any more than the pharmacist is responsible for the use of his weed killer for the closing of family feuds. The responsibility for the proper humanitarian use of scientific advance appears to lie finally with education, and the scientist may well be active in pressing for a modification of the present system of unscientifically teaching the young who will apply the science of to-morrow.

The author's refusal to admit the "principle of uncertainty" in science is impressive, and should be suggestive to those who, even in scientific papers, sometimes appear to regard anomalous results as accidents not necessarily demanding explanation or inquiry.

The various chapters deal with the constitution of solids, the growth of crystals, adsorption and crystal habit, the crystal boundary, etch figures, mosaic structure, surface films, passivity, abrasion and corrosion-fatigue, diffusion in solids, the Widmannstätten structure, the martensitic structure, the ageing and age-hardening of alloys, intermetallic compounds, the possible production of a vitreous phase by deformation, chemical changes in solids, the layered lattice, and fibre structure. All these subjects are fascinatingly surveyed and discussed, with experimental facts from all sources, many of which are possibly unfamiliar to applied science. The level of interest and judgment is so well maintained that it is scarcely possible to select any outstanding features for special remark.

Each of the chapters would serve admirably as a basis for a discussion, and little criticism could be made regarding the clarity with which the experimental facts are described and explained. In the chapter on crystal growth, however, the varying velocities of growth from arbitrarily ground faces of a crystal might have been made more easily comprehended by anticipating the chapter on mosaic structure. By this means the "non-crystalline" faces would be shown as jagged surfaces presenting a relatively large active area and, therefore, likely to be of rapid growth.

The matter is admirably set out and printed, and the proof reading has evidently been in most capable hands. The book should be widely read.—R. GENDERS.

Kristallplastizität. Von Dr. E. Schmid und Dr.-Ing. W. Boas. (Band XVII. Struktur und Eigenschaften der Materie, eine Monographiensammlung begründet von M. Born und J. Franck, herausgegeben von F. Hund und H. Mark.) Demy 8vo. Pp. x + 373, with 222 illustrations. 1935. Berlin: Julius Springer. (Geh., R.M. 32; geb., R.M. 33.80.)

The plastic state! How we have advanced in our knowledge of the tensile properties of matter since the days when Hooke, desirous of securing priority of discovery, published his well-known law of proportionality between stress and strain in the form of a jumble of letters which when properly sorted out made up the Latin sentence *ut tensio sic vis!* Why even as recently as the period of my schooldays, what happened in the range of stresses and strains outside the elastic limit was apparently one of the inscrutable mysteries ! The subject of crystal plasticity has advanced with giant strides within the last 20 years. The subject is one of great technical importance. The subject of " creep " in metals, to which the late Dr. Rosenhain devoted so much time, is but one of its many aspects. It is one that has thrown much light on the subject of crystal structure, but its theoretical and experimental aspects are very far from being completely worked out. Of the expert in crystal plasticity it can be truly said that he must necessarily get to know " more and more about less and less "—the subject has so many ramifications. Well, here is an excellent review of the subject which gives an account of developments up to 1934. The subjects discussed include crystallographic fundamentals, elasticity, production of crystals, crystal orientation, mechanism of deformation, plasticity and tenacity of metal and ionic crystals, theories of plasticity, and the properties of poly-crystalline technical materials. There is a bibliography of 703 references and an adequate subject-index. The book is well printed on good strong paper, the illustrations are clear and first-class. The price is rather high, taking the rate of exchange into account; even so, the book is one that I can heartily recommend to all metallurgists interested in the physical aspects of their science.

—J. S. G. Thomas.

International Conference on Physics, 1934. Papers and Discussions. In two volumes. Volume I: **Nuclear Physics.** Pp. viii + 257. (Bound, 12*s.* 6*d.*; unbound, 10*s.*) Volume II: **The Solid State of Matter.** Pp. viii + 182, illustrated. (Bound, 12*s.* 6*d.*; unbound, 10*s.*) **Reports on Symbols, Units, and Nomenclature.** Pp. 40. (Bound, 5*s.*; unbound, 2*s.* 9*d.*) 1935. London: The Physical Society.

The discussions at the International Conference on Physics held in London and Cambridge in 1934 were organized in two sections, the one dealing with the physics of the atom, the other dealing with the solid state of matter. The Conference was attended by about 600 members, and 31 papers were read by well-known experts and discussed by equally well-known experts. All the material was, therefore, available for the production of first-class books reviewing subjects which are now very much to the fore in the literature of physics and metallurgy. The Physical Society has earned the thanks of metallurgists by its publication of Vol. II of these Reports. The papers contained in this volume review matters of extreme import to metallurgical physics, *viz.* the structure of molecules and of the ideal lattice; the deviations of real crystals from the ideal lattice structure; plasticity and strain-hardening in crystals. Most of the papers have been abstracted elsewhere in this volume (see pp. 289–291). The papers contained in Vol. I (Nuclear Physics) are not of such immediate importance to metallurgists; they are, however, the daily bread of physicists. The subjects treated comprise: quantum theory, natural β-decay, artificial radioactivity, disintegration and synthesis of nuclei and particles, cosmic radiation. I especially commend the address of welcome delivered with characteristic humility by Sir F. Gowland Hopkins, and the prefatory remarks delivered by Lord Rutherford and Sir Wm. Bragg to the notice of all metallurgists. They will find the last mentioned an admirable summary of the work of the section devoted to the solid state. Sir William had evidently read and understood all the papers in this section—a very rare achievement surely in these slap-dash days. The main points of interest to metallurgists so far as the volume devoted to symbols, units, and nomenclature is concerned are that it is recommended and accepted that the gramme-calorie is the amount of heat required to raise the temperature of 1 gramme of water from 14·5° to 15·5° of the International Scale of Temperature under the pressure of one normal atmosphere, and that the unit of intensity of magnetizing fields, (H), be called the oerstedt and not the gauss as is now common practice. The name gauss is reserved for the unit of magnetic induction (B). To sum up my impressions I would say that here are three excellent volumes published at very reasonable prices that can be recommended wholeheartedly to all interested in the developments of physical and metallurgical sciences.

—J. S. G. Thomas

Gmelins Handbuch der anorganischen Chemie. Achte, völlig neu bearbeitete Auflage. Herausgegeben von der Deutschen Chemischen Gesellschaft. Bearbeitet von R. J. Meyer. System-Nummer 53: **Molybdän.** Pp. xviii + xi + 393, with 13 illustrations. 1935. Berlin: Verlag Chemie. (R.M. 64.)

The present volume of the eighth edition of Gmelin's handbook deals with the chemistry of molybdenum and its derivatives, and as with the elements which have been dealt with in the earlier volumes, the work opens with an account of the discovery of the element, and this is followed by a description of the occurrence of molybdenum minerals in various parts of the world. The methods of working up molybdenum ores and by-products and the commercial preparation of intermediate products, such as molybdic acid, molybdates, and the lower oxides of molybdenum are detailed. Some nine methods for the production of metallic molybdenum are given. The preparation of special forms of the metal, including pyrophoric, colloidal, single crystal, and mirror molybdenum, are described together with the working and uses of the metal. Then comes an account of the physical properties of the metal, which includes the properties of the atom, crystallographic, mechanical, thermal, optical, magnetic, and electrical properties. The electrochemical behaviour and the chemical behaviour of the metal with gases, common reagents, and metal are described. The detection and estimation of the element, including microchemical and electro-analytical methods, and the separation of molybdenum from the metals which are usually found with it are given in great detail. The alloys of molybdenum with antimony, bismuth, zinc, mercury, aluminium, titanium, zirconium, thorium, tin, lead, tantalum, and chromium are described at length. Then follows a full account of the compounds of molybdenum with oxygen, including the molybdates, molybdenum blue, and molybdenum bronze, compounds with nitrogen, fluorine, chlorine, bromine, iodine, sulphur, selenium, tellurium, boron, carbon, silicon, phosphorus, arsenic, and bismuth. The molybdates and complex hetero-molybdates of most metals are described. The material in this volume has been well chosen, it is accurately and concisely recorded, so that a very complete account of the present position of the chemistry of molybdenum, together with a very large number of references to the original literature is presented. The volume is a very useful one, which will be of great value to chemists. It is a book to be warmly recommended.

—James F. Spencer.

Méthodes modernes de Protection des Métaux contre la Corrosion. Par A. Guérillot. (Actualités scientifiques et industrielles.) Demy 8vo. Pp. 254, with 51 illustrations. 1935. Paris: J.-B. Baillière et fils. (25 francs.)

After a short introduction, reviewing modern theories of the mechanism of corrosion, the book is divided into three sections dealing with the three groups into which the author classifies methods of protection. The first and longest section describes electrolytic methods. The theories and laws of electrolysis are explained; methods and plant used in industry are described; brief details are given of copper, cadmium, nickel, and chromium deposition; the degree of protection afforded by such coatings, and methods of testing are discussed. The second section deals with non-electrolytic methods, amongst which are included hot-dipping processes, " clad " metals, cementation processes (nitriding, Sherardizing, Calorizing), sprayed coatings, chemical processes (Parkerizing, Bonderizing), anodic oxidation, and vitreous enamelling. The last section is devoted to paints and varnishes.

This is a useful survey of a wide subject. It is not written for the corrosion specialist, but the various processes are discussed in sufficient detail to enable a fairly accurate estimate of their scope to be drawn: their efficacy is also indicated, but no comparative figures are given.—H. W. G. Hignett.

La Cémentation des Produits Métallurgiques et sa Généralisation. Tome II.—**Généralisation de la Cémentation.** Par Léon Guillet. Roy. 8vo. Pp. x + 465, with 428 illustrations. 1935. Paris: Dunod. (Broché, 135 francs; relié, 145 francs.)

Although the greater part of the volume under review is devoted to the production of nitride coats and highly carbonized layers on steel, it contains numerous sections which concern the non-ferrous metallurgist. The mutual diffusion of several pairs of non-ferrous metals is illustrated by some good photomicrographs, and interesting information is provided regarding the cementation of iron with chromium, molybdenum, tungsten, uranium, vanadium, tantalum, titanium, zirconium, and cobalt. Of these, zirconium is said to give best protection against oxidation up to 1000° C., whilst molybdenum considerably reduces the attack upon iron by hydrochloric acid. Much of the chapter on Sherardizing is based on early work by Sang, Burgess, and others, researches, which—although now over 20 years old—have not altogether lost their value. The chapter devoted to calorizing contains an account of the process of Martin, based on heating in aluminium chloride vapour, and that of Mékér, in which the articles are heated in powdered iron–aluminium alloy. An appendix gives a summary of a paper by Nikonoff on the cementation of iron by molten aluminium, and reproduces a large part of a paper by Röhrig on the same subject; these features may be welcome to those who read Russian and German less easily than they read French.

The printing is satisfactory, and the numerous illustrations, culled from sources which are in each case acknowledged, are well reproduced; but, as in the case of so many excellent volumes which reach us from across the Channel, the purchaser is expected, before commencing his studies, to spend a strenuous *quart d'heure* with the paper-knife.—U. R. Evans.

Die-Castings: Their Design, Composition, Application, Specification, Testing, and Finishing. By Herbert Chase. Med. 8vo. Pp. viii + 264, with numerous illustrations. 1934. New York: John Wiley and Sons, Inc. ($3.50); London: Chapman and Hall, Ltd. (17*s.* 6*d.* net).

This is an interesting work and is intended for the information of manufacturers and others who are considering the employment of die-castings, rather than a guide to the producer of die-castings. The first two chapters, comprising 96 pages with many excellent illustrations, give arguments for the use of this type of manufacture and numerous examples of its successful application. In fact, it is so suggestive that this section of the book might well be adopted as the basis of a very comprehensive die-casters' illustrated catalogue.

A chapter on alloys for die-casting is good. It reviews the zinc, aluminium, copper, tin, lead, and magnesium alloys. Copious extracts from A.S.T.M. reports, particularly in respect to Zamak alloys, are included, relating to corrosion-resistance and the effect of ageing and heat-treatment of zinc-base alloys.

The aluminium alloys receive considerable attention, and the information on the copper and the magnesium alloys is useful and authoritative. Lead and tin alloys are noticed more briefly. Chapter IV devotes 65 pages to design of die-castings, the author wisely advises the designer to consult an experienced die-caster before preparing a final design, he also gives some valuable hints based upon the general principles of the art, which serve to make the detailed instructions intelligible and reasonable. The formation of screw threads, effects of shrinkage, trapped air, and porosity and the provision of draft allowances, coring, undercuts, and inserts are advised upon. Tolerances in general and specific designs are mentioned. Then follows a number of reproductions of drawings on reduced scale of actual typical die-casting jobs.

There is a short but useful chapter on specifications, inspection, and tests, again drawing freely from the A.S.T.M. publications. This deals with composition of alloys, sampling, physical properties, testing and visual inspection, including measurement of growth of castings under steam tests.

The final chapter is of considerable interest for it contains much valuable and practical information with respect to finishes for die-castings. It is pointed out that many castings are used without any applied finish, with advantage, but on the other hand there are numerous cases in which polishing, plating, and enamelling are desired for protection from corrosion and for decorative purposes, grinding, polishing, plating with copper, nickel, chromium, cadmium, black plating, anodic coating, and the application of organic finishes are briefly but usefully noted, and lacquering and enamelling are touched upon.

The book is a useful addition to the literature on the subject, but it does not give instruction on the art of die-casting or die-making, nor does it claim to do so.—A. H. Mundey.

Foundryman's Reference Book. By Jas. F. Bowe. Revised by A. A. Grubb. Third, and revised, Edition. Post 8vo. Pp. 219, illustrated. 1934. Albany, N.Y.: Albany Sand and Supply Co. ($2.00, post free.)

This handy little book is intended for ready reference by those engaged in grey iron, malleable iron, and the non-ferrous casting industries. The first 80 pages are devoted to a consideration of moulding sands with special reference to the products of the Albany Sand Company. The succeeding pages deal with the metallurgical data, first cupola operation and recommended iron mixtures for a wide range of applications, followed by non-ferrous alloys, notes on pyrometry, coremaking, fluxes, and brief notes on the commonest non-ferrous metals. Then come further notes on cast-iron mixtures, followed by the usual conversion tables and general information.

For a reference book to be of real value the data should be assembled and indexed in such a manner that no time is lost in locating the information sought, and this book contains so much that is useful that its value would be greatly enhanced by a more thoughtful planning and more complete indexing. For example, pp. 96–102 set out the iron mixtures recommended by the A.F.A., while pp. 179–190 give further lists covering the same products in many cases, but in which the compositions vary slightly. Again, on three separate pages, pp. 103, 126, and 211, there are given " Bright Dips for Brass," each are different, and only one is referred to in the index. On p. 156, under the heading of " Aluminium Bronze," appears one quaint remark, which seems out of place in a modern book of this type, " Place risers on heavy parts and cover same *so no air escapes from mould while pouring*."

The few typographical errors are not serious and the book is well printed, but to British readers the price of 2 dollars will appear high for a book of this class.—J. E. Newson.

Die Metallfärbung. Von Georg Buchner. Vierte, neubearbeitete Auflage. (Oberflächenveredlung der Metalle, Band I.) Demy 8vo. Pp. 149. 1935. Berlin: M. Krayn. (R.M. 8.50.)

In this new edition this useful little book appears to have been thoroughly revised and somewhat enlarged. It contains a large number of practical recipes for producing coloured finishes of all types on iron, steel, and the common base metals and alloys and should prove of considerable interest and value to those engaged in the production of decorative metal articles. There is an excellent account of the principles underlying the various methods of producing coloured films, *e.g.* plating, heat tinting, etching, pickling, anodic oxidation, friction methods, diffusion processes, &c., and much information on the avoidance of defects. The book is well written and well produced and its price is reasonable.—A. R. Powell.

Praktisches Handbuch der gesamten Schweisstechnik. Von P. Schimpke und Hans A. Horn. Zweiter Band: **Elektrische Schweisstechnik.** Zweite neubearbeitete und vermehrte Auflage. Med. 8vo. Pp. viii + 274, with 375 illustrations in the text. 1935. Berlin: Julius Springer. (Geb., R.M. 15.)

An introductory section to the book deals with the fundamentals of the various processes and the properties of the materials for which they can be used. Copper, brass, bronze, aluminium and its alloys, lead, zinc, Monel metal, and the noble metals receive brief mention. Section II is a concise review of resistance welding, sufficiently up-to-date to include thyratron control of spot-welding machines, and comprehensive so far as German practice goes. A definite omission is the induction controller for seam-welding. Section III deals with arc welding. The characteristics of d.c. and a.c. arcs and of the principal types of welding machines are carefully explained. Electrodes, technique, weld properties, and applications for mild steel welding are discussed at some length. Alloy steels and non-ferrous metals are more briefly considered, the difficulties in the case of the latter—high heat conductivity, hot-shortness, ready oxidation and gas absorption—being pointed out. Then follows a concise survey of the gas-electric methods, shielded-arc, atomic hydrogen, and Arcogen. Electrolytic welding, electrical soldering, and arc cutting are briefly described and then there is an admirable section (VIII) on weld testing, including some remarks concerning modern research on weld stresses. The final section deals with the economics of welding, the various processes being compared.

This is a well-balanced book which can be recommended as a text-book for students or as a reference book for welders: it is well printed and illustrated, and even a very shaky knowledge of German enables one to discern that it is well written. It is a pity that there is no bibliography.—H. W. G. Hignett.

The Welding and Cutting Year-Book, 1934–1935. Edited by Cyril Helsby and Conrad Wilson Hamann. Demy 8vo. Pp. 250, with 130 illustrations. 1935. Reading: The Berkshire Printing Co., Ltd. (6*s.*)

Once more we sadly note the absence of information on the welding of non-ferrous metals. Can it be that the intensive publicity campaigns of this, that, or the other " development association " have failed to reach the editors of this Year-Book? The omission can scarcely be due to lack of space; the thirst-provoking Fig. 22 and several catalogue illustrations can well be spared. The most valuable part of the book is that devoted to design and the testing of welds, where the editors are " on their home ground."—H. W. G. Hignett.

Die Bedeutung der Zeitstudie für die Durchforschung und Wirtschaftlichkeit des Wassergasschweissvorganges dargestellt an dem Beispiele der mit Wassergas überlapptgeschweissten Rohre auf der Hammerschweissmaschine. Von Herbert Rossié. Med. 8vo. Pp. vi + 63, with 25 illustrations. 1934. Würzburg: Konrad Triltsch. (R.M. 3.)

In this booklet, the author describes the application of a technique, developed mainly on machining problems, to the hammer-welding of tubes on automatic machines, fitted with water-gas burners. In the first part of the book, the results of the time-study are set forth and interpreted. They throw considerable light on the technical aspects of the process, notably the size of water-gas burners most advantageous for different thicknesses of material. In the second part, the supervision and control of the process are considered. The work is of wider interest than its title indicates, for it clearly shows the great possibilities of this method of investigation of problems in all welding processes.—H. W. G. Hignett.

Elasticity, Structure, and Strength of Materials used in Engineering Construction. By C. A. P. Turner, C.E. Med. 8vo. Pp. xv + 416, with numerous illustrations. 1934. Minneapolis, Minn.: The Author, 342 Builders' Exchange. ($6.00, post free.)

Although everyone should be able to extract some amusement from this book, only the psychologist is likely to find it instructive. According to Dr. Turner, the whole of modern science from the theory of elasticity to the theory of relativity is founded on a series of gross errors, most of which Dr. Turner is at pains to expose. Unmathematical students will be pleased to learn that none of the natural laws of the universe involves anything more complicated than the rule of three; but the ease with which Dr. Turner deduces all the properties of metals and alloys from such simple data as the specific heats of the elements may give metallurgists an uneasy feeling that their profession must shortly disappear.

Dr. Turner's logic is not strong, but his arguments are occasionally specious. A little profit may perhaps be extracted from the book in the exercise of detecting the fallacies in some of the more outrageous arguments. Otherwise the book should find a place on our shelves between Stephen Leacock and P. G. Wodehouse.—H. L. Cox.

Origins and Development of Applied Chemistry. By J. R. Partington. Roy. 8vo. Pp. xii + 597. 1935. London: Longmans, Green & Co. (45*s.* net.)

This book gives a good, reasonably concise, and systematic account of the sources, production, and uses of materials in Egypt, Babylonia, Assyria, the Ægean, Asia Minor, Persia, Syria, and Palestine from the earliest times to the end of the Bronze Age. The first 212 pages are devoted to Egypt; here an extremely interesting account is given of the sources, extraction, methods of working, and uses in ancient Egypt of gold, electrum, silver, copper, bronze, tin, lead, brass, zinc, antimony, mercury, platinum metals, iron, steel, ceramics, glass, pigments, and various salts. Accounts are given of the processes of dyeing and embalming, followed by an excellent section on the papyri dealing with medicine and surgery. The Egyptian section concludes with the treatment of wood, beer, vinegar, wine, bread, leather, ivory, and ink.

Similar detailed treatment is accorded to Babylonia and Assyria in 108 pages, the Ægean civilization, Troy and Cyprus in 50 pages, Asia Minor in 13 pages, Persia in 38 pages, Phœnicia in 33 pages, and Palestine in 66 pages. Numerous analyses of metal, pottery, glazes, and glass are included in the text, and much of the information connected with the discovery, extraction, and uses of metals in the early civilizations given in existing works is corrected. The descriptions of the places where ores were worked in ancient times is particularly interesting, since some of these have been re-discovered and re-exploited on a considerable scale. The work, therefore, has in this respect a certain economic interest.

This is a masterly production, which testifies alike to the assiduous work and the profound scholarship of the author. Care is evidenced on every page. The author in his preface voices the fear that his time, opportunities, and general equipment would lead to a book which falls short of the ideal. Whilst appreciating the difficulties Professor Partington has overcome, the reviewer cannot admit anything but excellence in the finished work. Whether or no the book is ideal he cannot say, never having met the ideal. The book, as written, does what the ideal could never do, it stimulates the reader in all manner of ways. The 25,000 references given as footnotes make it comparatively simple for those interested in the subjects to pursue the study of any portion which may interest them particularly. That the author has tracked down the material to which he refers and that he has read his material in the original is very clear, and this fact enhances the value of the work. The use of the volume is rendered very easy by the voluminous and accurate indexes. The reviewer has never before met a book so completely indexed, some 63 pages are required for the printing of the five indexes, which are: authors and publications, persons and nations, places, subjects, and Greek.

Professor Partington, being a chemist, doubtless wrote for chemists. He has produced for them a fascinating story of the early development of their science; in addition his work contains much which will be of interest and importance to the geologist, archæologist, historian, and the general reader. All will find the book interesting, readable, and inspiring.

—James F. Spencer.

Handbook of Chemistry. Compiled and edited by Norbert Adolph Lange, assisted by Gordon M. Forker, with an Appendix of Mathematical Tables and Formulæ by Richard Stevens Burlington. Demy 8vo. Pp. xiv + 1265 + 248 + 29. 1934. Sandusky, O.: Handbook Publishers, Inc. ($6.00.)

This very excellent work of reference opens with a section on first-aid treatment of accidents and a list of antidotes for poisons, then follows a table of hazardous chemicals, in which the life and fire risks are stated together with the suitable type of storage for some 67 substances. Twenty-two pages are devoted to a description of the characteristics of the elements. Then follow a very long series of tables, which include, amongst numerous others, tables of isotopes, radii of atoms and ions, physical constants of the elements, radioactive elements and their constants, properties of minerals, synonyms of mineral names, radio-detector minerals, heavy liquids for mineral analysis, physical constants of inorganic compounds, composition of natural water, wood, coal, ignition temperature of gases, composition and physical properties of alloys, melting point and composition of fusible alloys, corrosion and heat-resistant alloys, etching solutions for ferrous and non-ferrous alloys, material for construction, resistance of wires, calibration of thermocouples, fusion points and composition of pyrometric cones, glossary of ceramic terms, shrinkage tables, classification of crystals, X-ray emission spectra of the K, L, and M series, wave-lengths of the principal lines in the emission spectra of the elements, electropotentials, electrometric determination of H ions, acid and base indicators, organic reagents for inorganic analysis, concentration of laboratory solutions, solubilities of inorganic compounds in water, solubility of gases, density of aqueous solutions, ionization constants of acids and bases, electro-conductivity of aqueous solutions, vapour pressure of various substances, orthobaric density of various substances, heats of solution, van der Waals' constants for gases, critical constants, specific heats of elements and compounds, heat conductivity of metals, alloys, solids, liquids and solutions, heats of combustion and formation, conductivity of commercial insulators, heat of fusion and heat of vaporization of elements and compounds, free energies, surface tension and viscosity of liquids, compressibility and cubical expansion of liquids, value of g at various stations. Then follow sections in which the commoner physicochemical equations are described, chemical terms are defined, laboratory recipes and a number of conversion tables of various kinds are given. The appendix contains mathematical formulæ, logarithms, anti-logarithms, and other mathematical tables.

This book stands by itself in the amount of data which it contains, every table in the work is far more comprehensive than the corresponding table in any existing handbook of the kind, and many of the tables included here are not to be found in other handbooks. Not only in the tables is this work so excellent, but also in the small items of interest and use which one finds throughout on all manner of subjects. The book is to be warmly recommended to all chemists and physicists.—JAMES F. SPENCER.

Crystals and the Polarizing Microscope. A Handbook for Chemists and Others. By N. H. Hartshorne and A. Stuart, with a Foreword by G. T. Morgan. Med. 8vo. Pp. viii + 272, with 217 illustrations. 1934. London: Edward Arnold and Co. (16*s.* net.)

This little book has been written with the dual object of making the application of the polarizing microscope to chemical problems more widely known and of providing the chemist with a handbook in which the method of examining crystals by the polarizing microscope is treated with special reference to his particular problems. The book opens with a description of the crystalline state, which is followed by an adequate account of the morphology of crystals. The optical properties of crystals come next under review; the theoretical treatment here is simple and sufficiently complete for the present purpose. The construction and use of the polarizing microscope, together with a description of four well-known modern microscopes, constitutes the material of the fifth chapter. The two following chapters deal with the microscopic examination of crystals: (i) with parallel light, and (ii) with convergent light. These are very useful chapters, and contain detailed and carefully considered accounts of a large number of optical measurements, together with a general discussion of interference figures. The seventh chapter gives examples of the use of the polarizing microscope in chemical practice. Here actual examples, taken from the chemical literature, have been used, and the ease with which the particular problems were solved is demonstrated. The concluding chapter is eminently practical, it is entitled "Method of Attack and Experiments." The authors describe in detail exactly how the optical examination of crystals is to be carried out in order to gain the maximum of information from it. They then propose 14 experiments, which the beginner is invited to perform, full working details are given in each case. A short summary is given at the end of each chapter. The book is written in a fascinating manner and it is very fully illustrated; its contents are clear and accurate. Without doubt the authors have achieved their object, for this book will do much in furthering Dr. Hartshorne's missionary enterprise. The book may be recommended most warmly to all chemists.

—JAMES F. SPENCER.

Organic Reagents for Metals. By the Staff of the Research Laboratory of Hopkin and Williams, Ltd. Second Edition. Demy 8vo. Pp. 107. 1934. London: Hopkin and Williams, Ltd., 16–17 Cross Street, Hatton Garden, E.C.1. (1*s.* 3*d.*)

The first edition of this useful little book was reviewed in *J. Inst. Metals*, 1933, **53**, 687; this edition follows closely the lines of the first, but, since the subject-matter has been revised and amplified and monographs dealing with the use of eight new reagents have been added, it contains 46 more pages than its predecessor. The description of the analytical procedures are, in general, excellent, but the reviewer feels bound to protest against the tendency to multiply the number of rather expensive reagents recommended for some of the metals, *e.g.* there are six reagents for copper and four for cadmium, and some of these are admittedly much inferior to others. Again a whole page is devoted to the determination of iron by cupferron when much cheaper processes are available; the use of this reagent for the determination and separation of some of the rarer metals is of much greater importance and interest. A fuller description might also have been given of the use of dimethylglyoxime for the separation and determination of palladium; incidentally in the brief account given it is stated that the metal must be in the quadrivalent form, whereas, of course, it is the divalent form which is precipitated. It is stated on p. 33 that the palladium glyoxime compound has no definite formula, but Gilchrist (*J. Res. Nat. Bur. Standards*, 1934, **12**, 291) has recently shown that the dried compound is analogous to that of nickel and contains 31·67 per cent. of the metal. The reviewer suggests that in a future edition the monographs on dihydroxytartaric acid for sodium, allyl iodide hexamine and β-naphthaquinoline for cadmium, thioglycollic acid for iron and sodium 6-chloro-5-nitrotoluene-3-sulphate might be omitted and that monographs on phenylhydrazine and tannin be included. The latter is a very inexpensive organic reagent which has been shown by Schoeller and his collaborators to be the only reagent which affords a satisfactory separation of titanium from zirconium, and of tantalum from columbium, two of the most difficult problems in the analytical chemistry of the metals prior to this work.—A. R. Powell.

Ausführung potentiometrischer Analysen nebst vollständigen Analysenvorschriften für technische Produkte. Von Werner Hiltner. Med. 8vo. Pp. viii + 141, with 16 illustrations. 1935. Berlin: Julius Springer. (R.M. 6.60.)

This book represents a very successful attempt of the author to collect together under one cover and in a logical sequence the results of his own researches and those of other workers in the field of potentiometric analysis and to indicate to the industrial analyst the value of this new weapon and technique in solving some of his everyday problems. The theoretical side of the subject is described only briefly, but sufficiently lucidly to allow of the novice obtaining an adequate understanding of the principles on which his work is based and a thorough grasp of the functions of the various parts of the apparatus employed. The middle 60 pages of the book contain descriptions of methods for the potentiometric determination of the rare and common metals, both singly and in various mixtures, and of a considerable number of anions, while the final 25 pages are devoted to the application of the method in technical analysis, *e.g.* the analysis of alloys, smelter products, and plating baths. The production of the book is fully up to the usual high standard of the publishers.—A. R. Powell.

Metallurgical Spectrum Analysis. With Visual Atlas (in separate portfolio). By Welton Joseph Crook. 4to. Pp. vii + 82, with 16 illustrations and 24 plates in portfolio. 1935. Stanford University, Cal.: Stanford University Press ($12.50); London: Oxford University Press (Humphrey Milford) (56*s.* net).

This work is mainly concerned with the spectrographic detection of 31 common metals of metallurgical interest and the principal feature is the Arc Spectrum Atlas (Visual Atlas), consisting of 20 plates showing the positions of the lines in the spectra of these metals in relation to the iron spectrum. Plates 1–10 cover the range 2796–3428 A.; Plates 11–20 the range 5056–5670 A., and there are 4 charts of iron spectra with the wave-lengths marked on them.

The author, who is Professor of Metallurgy at Stanford University, finding that the Atlas previously published by J. Bardet in 1926 was not entirely satisfactory, undertook the compilation of an improved Atlas of arc spectra.

In the explanatory book, "Metallurgical Spectrum Analysis," the equipment and the use of the carbon arc or Pfund iron arc in analysis are described. A grating spectrograph was used, and reasons for using this type of instrument in preference to the more generally used prism spectrograph are put forward. The scale of the reproductions is such that the direct comparison of enlargements of spectra with the charts facilitates the recognition of the spectrum lines.

A bibliography and an adequate index are given. A few errors have been noted (some mistakes in the references quoted and incorrect designation of the cyanogen bands in the carbon spectrum), but these are not serious.

In conjunction with the charts, a list of "Prominent and Persistent Arc Spectrum Lines" followed by a "Table of Arc Spectrum Lines" containing some 9500 lines in the two regions studied have been compiled. (Tables of lines in the range 2800–3400 A. were published by the same author in 1933, and these have now been revised and extended.)

Professor Crook has brought enthusiasm to a laborious task, resulting in a valuable contribution to the literature on the subject. The printing and arrangement of matter are good.
—D. M. Smith.

Clinical and Pathological Applications of Spectrum Analysis with Notes on Spectrography in Chemistry and Mineralogy, and Tables for Qualitative Analysis. Being the Authorized Translation of Part II of "Die Chemische Emissionsspektralanalyse." By Walther Gerlach and Werner Gerlach. Translated by Joyce Hilger Twyman. Med. 8vo. Pp. 143, with 52 illustrations. 1934. London: Adam Hilger, Ltd., 98 King's Rd., N.W.1. (15*s.*)

Although the greater part of this book deals with the use of the spectroscope in medical diagnoses it contains useful sections on the use of this instrument in the examination of tellurium, copper, and antimony, in the determination of tellurium in bismuth, and in the testing of platinum, iridium, rhodium, aluminium, silver, zinc and lead for the presence of impurities, the characteristic lines and methods for exciting them being given in all cases. A useful bibliography occupies the last 6 pages. The book is well printed on excellent paper and the spectrographs shown are extremely clear and instructive.—A. R. Powell.

A German–English Dictionary for Chemists. By Austin M. Patterson. Second Edition. Cr. 8vo. Pp. xx + 411. 1935. New York: John Wiley and Sons, Inc. ($3.00); London: Chapman and Hall, Ltd. (15*s.* net).

There is little need to describe this valuable pocket-book in detail, for all who have to translate or read German chemical literature must already look upon " Patterson " as an old and well-tried friend in all their difficulties. This new edition will, therefore, be welcome especially as, since the first edition appeared in 1917, great advances have been made not only in the experimental side of chemistry but also on the theoretical, entailing the coining of many new words. This growth is evidenced by the expansion of the book from 316 to 411 pages despite the attempt which has been made to keep the size within reasonable limits by adopting the paragraph style for entries beginning with the same word element, and by omitting some uncommon and non-technical words which appeared in the first edition as well as all words which have the same or a similar spelling in both languages. Altogether about 42,000 entries are included and many additional meanings are given to old words. We can thoroughly recommend those who have a copy of the old edition, probably now almost worn out, to throw it away and buy the new, and those who have never had a copy to buy one now; it is an excellent investment.—A. R. POWELL.

Bergtechnisches Taschenwörterbuch. I Teil: **Englisch-Deutsch.** Von W. Schulz, H. Louis, und —— Goethe. Sup. Roy. 16mo. Pp. 90. 1934. Essen: Verlag Glückauf G.m.b.H. (R.M. 4.20.)

This newcomer among the many technical dictionaries which have been published during recent years breaks a good deal of new ground not covered by any other similar work in that it is intended almost exclusively for the use of miners. Practically every mining term appears to be included, even archaic terms and those used in local mining parlance; the reviewer must confess that many of the English words given are quite strange to him and could be understood only by the aid of the German equivalent. The English miner in German-speaking countries will undoubtedly find this dictionary of great value.—A. R. POWELL.

The English–Russian Technical Dictionary. Edited by Adolph E. Chernukhin. Fcap. 8vo. Pp. xxix + 1215. 1934. Moscow and Leningrad: State Theoretical-Technical Publishing House. (Rbl. 10.)

A comprehensive compilation of 100,000 words and expressions used in all branches of science and technology. Each basic root-word forms a nucleus round which are grouped its derivatives and compounds, and every effort is made not only to give the Russian technical equivalent, but to render the meaning clear to unscientific or untrained readers. This method sometimes detracts from the conciseness of the text.

The method for using the dictionary as well as various peculiarities of English grammar are explained in the preface, which also gives advice to would-be translators. A comparative list of the more commonly used English and American terms is attached. The text gives the impression of being compiled without a thorough knowledge of the English language: a number of the terms and expressions are incorrect, and the spelling is not infrequently faulty. Unless, therefore, the user exercises discretion, he will be liable to be misled: this is particularly so in the glossary of so-called usual abbreviations at the end of the volume. The volume is poorly set-out, the inferior quality of the paper and ink producing a blurred effect, which renders quick reference difficult.

With all its faults, however, the dictionary should be of considerable use as a general technical reference in the two languages, which was urgently required.—M. ZVEGINTZOV.

A Technical German–Russian Dictionary. By A. A. and L. A. Erasmus. Third Edition. Pp. 1050. 1932. Edited by the State Encyclopædic and Dictionary Printing Offices " Soviet Encyclopædia." Moscow and Leningrad: State Theoretical-Technical Publishing House. (Rbl. 5.)

Contains 34,000 words from all the principal branches of technology, together with an explanation of the method of using the volume. This dictionary within its more limited range is markedly superior to the Anglo-Russian dictionary of Chernukhin (preceding review), both as regards conciseness, accuracy, print, and general set-out. This is in part due to the better knowledge of German as a technical language and greater experience in compiling and printing such reference books.—M. ZVEGINTZOV.

The Directory of Shipowners, Shipbuilders, and Marine Engineers, 1935. Thirty-Third edition. Compiled under the direction of the Editor of *Shipbuilding and Shipping Record*. Demy 8vo. Pp. 812 + 71. 1935. London: The Directory Publishing Co., Ltd., 33 Tothill Street, Westminster, S.W.1. (20*s.* net.)

This Directory covers the principal features connected with the shipping, shipbuilding, and marine engineering industries. On the shipping side it gives information as to the ownership of any specific vessel, who built the ship, who constructed the engines, and the year of its going into commission. In addition, there are the gross, net, and deadweight tonnages; the cubic capacities of the holds, in the case of a large number of cargo ships; the passenger accommodation, the draught, speed, and so on. The shipbuilding section gives details of the shipyards and marine engineering establishments, including output capacity and ship-repairing facilities. The value of the entries is enhanced by the inclusion of the names of directors or partners, managers, marine superintendents, superintending engineers, naval architects, and other officials according to business carried on by the respective firms.

At the end is a list of consulting marine engineers and naval architects and of societies, associations, and federations connected with the industries. Government departments which deal with marine work and the classification societies of the world form a separate section. There are more than 25,000 individual references, all indexed.

The whole matter has been carefully revised and includes the important changes which have occurred in shipping managements during the past year.


M B
MA GL
MK BL

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