Vol. 3 Part I

The Monthly Journal of the
INSTITUTE OF METALS
and
METALLURGICAL ABSTRACTS

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JANUARY, 1936

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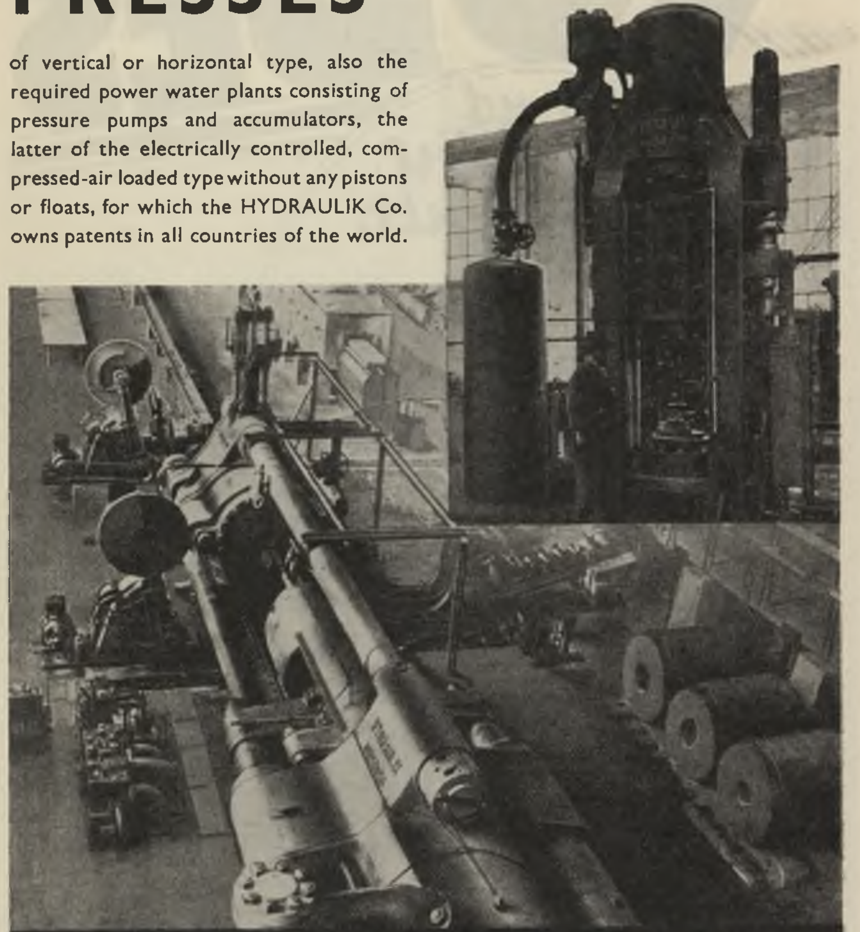

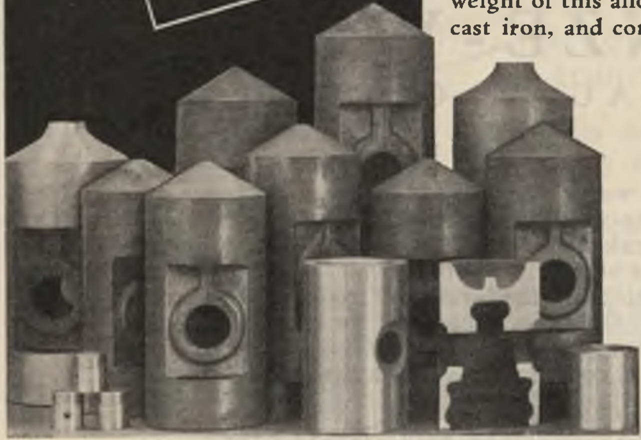


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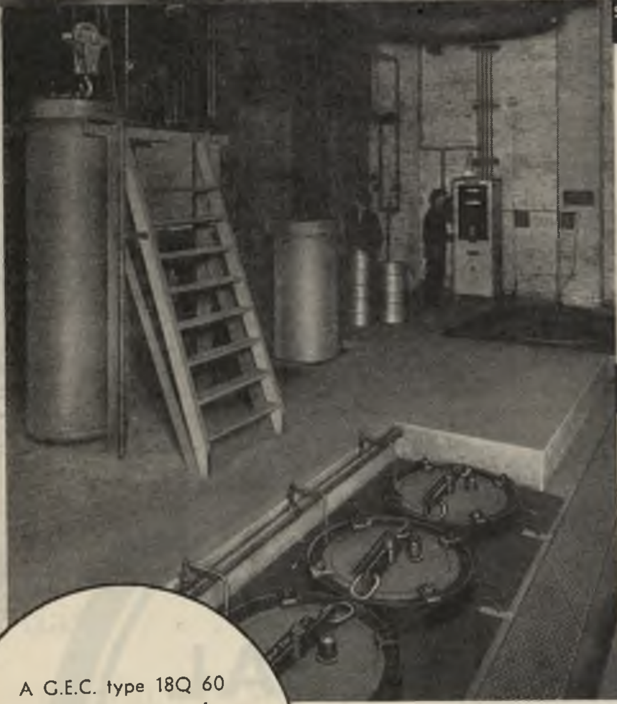

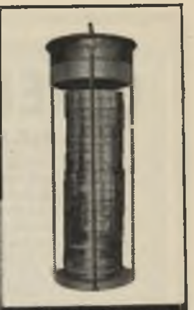

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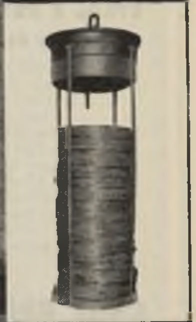

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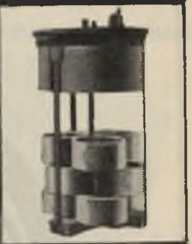

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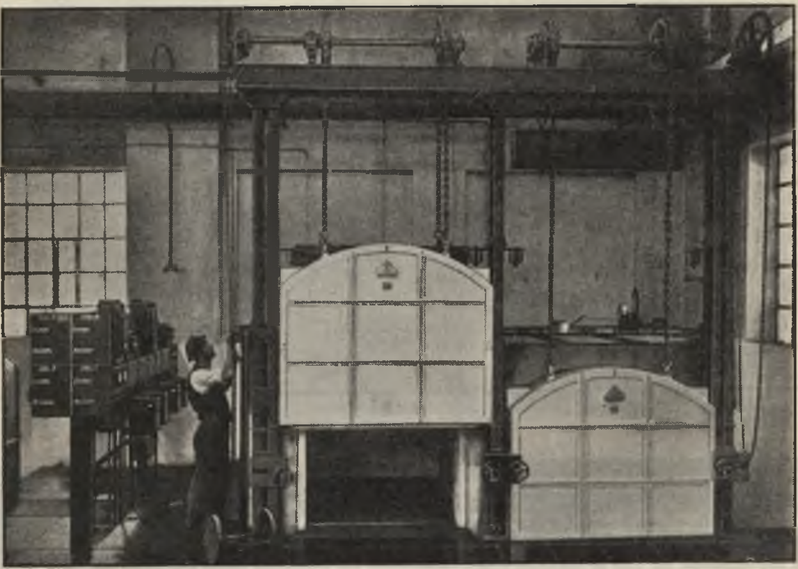

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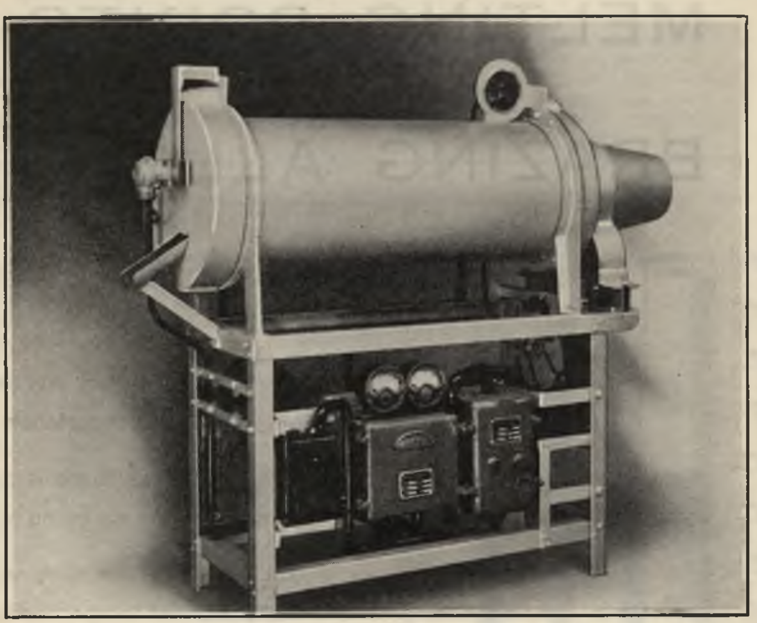

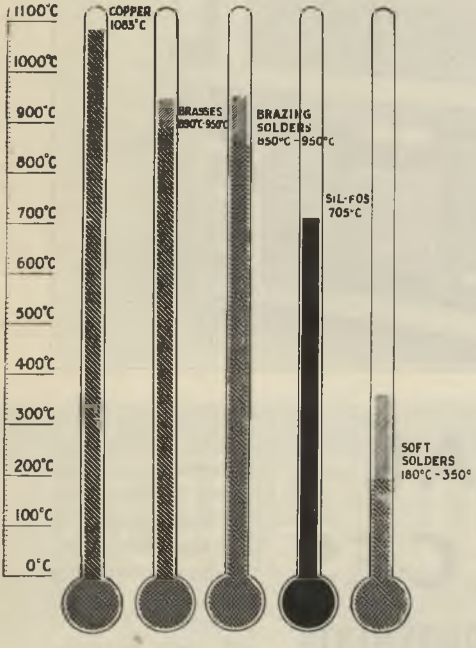
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A NEW YEAR MESSAGE

Much has happened of interest in our affairs since January, 1935, *such as the bringing of the income and expenditure of the Institute into more satisfactory relation than in the previous few years. The New Year is, however, the occasion for looking forward rather than back, in a rapid survey of developments projected for* 1936. *The more frequent publication of useful papers other than those describing original research should appeal to a wide circle of our membership, even though it may not altogether achieve the difficult aim of satisfying our critics in the Press. A series of General Discussions (differing substantially in character and scale from the admirable symposia which have made the Faraday Society so pre-eminent in this field), will shortly be inaugurated. The first will deal with a " border-line " subject of much practical importance to engineers but also directly interesting to metallurgists, chemists, and physicists.*

The proposed occasional reviews of progress in selected fields are not intended to fulfil the same purpose as the annual summaries of published work issued in other quarters. Such painstaking collections of abstracts are invaluable in a search of literature and in other ways but are apt to be a little indigestible. The Reviews will be written only by eminent workers who are acknowledged authorities in their subjects. It is intended that each review, an original contribution of merit, shall cover a period long enough for significant developments to have taken place in the subject.

For the first time the Institute will hold its autumn meeting in France. Already there are many indications of the attraction and success of the meeting to be held in September, 1936, *and our friends of the Bureau International des Applications de l'Aluminium, who have taken the lead in inviting the Institute to Paris, are well advanced with their plans.*

A word on the most important step of all. Early in the year proposals designed to secure a regular accession of new members to the Council will be put before the Institute for consideration. This object cannot be secured without some loss of accumulated experience and the Institute will lose, temporarily at least, the services of valuable Members of Council, if the proposals are approved. The Council has, however, come to the conclusion that the advantages of bringing in each year some of our active younger members and of widening the field of membership from which the Council is drawn are likely far to outweigh this drawback. One feature of the changes proposed is intended to associate the Local Sections more closely with the work of the Council.

Change for the sake of change has no attraction for those entrusted, for the time being, with the guidance of the Institute's activities. The developments proposed, some of which are mentioned above, are intended to keep the Institute abreast of the times and to render it steadily more useful to its members and more helpful in the science, manufacture, and application of the non-ferrous metals.

H. Moore

President.

January 1, 1936.

INSTITUTE NEWS AND ANNOUNCEMENTS

ANNUAL GENERAL MEETING, LONDON

MARCH 10–12, 1936.

The Twenty-Eighth Annual General Meeting will be held in the Hall of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1 (by kind permission of the Council of the Institution), on Wednesday and Thursday, March 11 and 12, beginning at 10 a.m. each day. The Annual General Meeting will be preceded, on Tuesday, March 10, by two other meetings. Of these the first will be an Extraordinary General Meeting (restricted to Fellows and Ordinary Members whose subscriptions have been paid) called to consider, and if deemed desirable, to pass a Special Resolution amending Articles 19 and 21 of the Articles of Association in accordance with a printed notice to be issued to Fellows and Ordinary Members and as referred to in the President's New Year Message on p. 1. Following the Extraordinary General Meeting there will be a Discussion on "**Metallic Wear**." This will be opened with the paper by Dr. H. W. Brownsdon, Member of Council, which appears in the December issue of the *Monthly Journal.* The Council has invited to participate in the Discussion members of the Institution of Automobile Engineers, Institution of Mechanical Engineers, Institution of Naval Architects, Iron and Steel Institute, and Royal Aeronautical Society.

The following is a provisional time-table of the meetings, full particulars of which will be issued before the end of January :

Tuesday, March 10.

5.30 p.m.	EXTRAORDINARY GENERAL MEETING in the Hall of the Institution of Mechanical Engineers.
7.30 p.m.– 10 p.m.	DISCUSSION on " METALLIC WEAR."

Wednesday, March 11.

10 a.m.– 12.30 p.m.	ANNUAL GENERAL MEETING. The Report of the Council and the Report of the Honorary Treasurer will be presented. The results of the election of the Council for the year 1936–1937 and of new members will be declared Induction of the new President. The President will read his Presidential Address. Papers will be discussed.
12.45 p.m.	Members who so desire will lunch together at St. Ermin's Restaurant (*table d'hôte* meal, 3*s*.).
2 p.m.– 4.30 p.m.	Papers will be discussed.
7 p.m. for 7.15 p.m.	Annual Dinner and Dance at the Trocadero Restaurant, Piccadilly Circus.

Thursday, March 12.

10 a.m.– 12.30 p.m.	Papers will be discussed.
12.45 p.m.	Members who so desire will lunch together at St. Ermin's Restaurant (*table d'hôte* meal, 3*s*.).
2 p.m.	Visits will be paid to Broadcasting House, two Fleet Street newspaper offices, the Fuel Research Station at East Greenwich, and Greenwich Observatory. (Private buses for Greenwich will leave St. Ermin's Restaurant at 2 p.m. *prompt*, return fare 2*s*.)

Institute News and Announcements

Certain of the papers that are to be discussed at the Meetings have already been published in the *Monthly Journal* (beginning with the October issue). In the next issue of this *Journal* other papers will be reproduced, together with a complete list of the papers to be presented for discussion.

Annual Dinner and Dance.

The Annual Dinner on March 11 will be followed by a Dance, as in recent years. The price of tickets (exclusive of wines) is 15*s*. There will be circulated to members in due course a form which may be used to apply for tickets for the Dinner and Dance and for the other functions that are being arranged in connection with the March Meeting. In the meantime application for tickets may be made by members who desire to reserve tables or seats for the Dinner.

Election of Council.

As only sufficient nominations to fill the vacancies announced at the last General Meeting have been made, no ballot will be necessary, and the following members, who have been nominated for election on the Council, will be declared duly elected at the Annual General Meeting :

President :

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

Vice-Presidents :

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

Members of Council :

S. F. Dorey, D.Sc., Wh.Ex.
Kenneth Gray.
Lieutenant-Colonel J. H. M. Greenly, C.B.E., M.A.
D. J. Macnaughtan.
C. J. Smithells, M.C., D.Sc.
F. Tomlinson.

Autumn Meeting, Paris, 1936.

As previously announced the next Autumn Meeting of the Institute will be held in Paris, from Monday, September 14, to Friday, September 18. In the evening of the first day of the meeting the Annual Autumn Lecture will be delivered by Professor P. A. J. Chevenard. On the following day papers will be presented for discussion in the morning, and in the afternoon there will be visits to Works, and a social function in the evening. On Wednesday, September 16, the sessions for the discussion of papers will be concluded in the morning. Further works' visits will take place in the afternoon and members will be entertained in the evening. On September 16 there will be visits to places of interest in the neighbourhood of Paris. The concluding day of the meeting will be devoted to a motor-coach excursion. As the Autumn Meeting of the Iron and Steel Institute opens at Düsseldorf on the following Monday, September 21, it is possible that many members of both Institutes may desire to spend the week-end in Paris before proceeding to Düsseldorf.

A detailed programme of the meeting will be issued in due course. In the meantime it would be a great convenience to the Paris friends of the Institute, who are concerned with the local arrangements, if they could be advised of the approximate number of members who expect to take part. There will, therefore, shortly be sent to each member a reply form which should be returned to the Secretary with an indication as to whether the member expects to participate in the Paris meeting.

New Publications.

It has been decided to bind Dr. W. Hume-Rothery's review on "**The Structure of Metals and Alloys**" and Dr. J. L. Haughton's "**Bibliography of the Literature Relating to Alloy Constitutional Diagrams**" in separate covers. These will be issued free to members of the Institute.

This method of publication will enable the second half-yearly issue of the bound *Journal* to be published earlier, and members will find the separately-bound publications more convenient to use.

Membership.

Forms of application for membership received by the Secretary by noon on February 13 will be considered by the Council on that day, and candidates whose names are then approved by the Council will be able to take part in the Annual General Meeting. Candidates elected from now until May will have the privilege of membership for the extended period ending June 30, 1937, instead of for the usual twelve months. Members are invited to acquaint friends who are qualified for membership of this concession. Forms of application for membership are found in each bound volume of the *Journal* and in the illustrated folder "The Institute of Metals: Its Aims and Objects," copies of which will be gladly supplied by the Secretary to any member or forwarded to a prospective member.

The following were elected to membership on December 12, 1935:

As Members.

Calderara, Colonel Attilio, London.
Edmundson, J. H., Napier, New Zealand.
Gibson, Commander (E) Cuthbert Walter Sumner, R.N., London.
Glen, Manwell Alexander Burns, M.C., Krupanj, Drinska Banovina, Jugoslavia.
Kennett, Stanley John, Ph.D., A.R.S.M., Liverpool.
Klare, Fritz Alfred, London.
McConway, John, Newcastle-upon-Tyne.
McCormick, John Thomas, M.Sc., Maribyrnong, Australia.
Mishima, Professor Tokushichi, D.Eng., Tokyo, Japan.
Panseri, Carlo, Dr.-Ing., Milano, Italy.
Price, George Henry Stuart, B.Sc., London.
Price, Ralph A., B.S., Chicago, U.S.A.
Ronaasen, Knut, B.Sc., M'Kana, N. Rhodesia.
Scattergood, Harry Gopsil, Birmingham.
Skript, George, Stoke Green, Bucks.
Stevenson, Earl P., M.A., Cambridge, Mass., U.S.A.
Stockmeyer, Friedrich Wilhelm, Dipl.-Ing., Stuttgart, Germany.
Todd, George E., Cincinnati, O., U.S.A.
Wimpenny, Leonard, Widnes, Lancs.
Wright, Albert, London.
Yoshioka, Vice-Admiral Yasusada, Kobe, Japan.

As Student Members.

Bull, Arthur Ramsay, Birmingham.
Gittins, M. G., Birmingham.
Hughes, John Richard, B.Sc., Birmingham.
Meats, Peter Annber Harold, B.A., Manchester.
Slator, Richard Henry, B.A., Bristol.
Tseng, Jun Chen, B.Sc., London.

PERSONAL NOTES

The Editor requests that his attention be directed to items of interest to members that might be included under the "Personal Notes" heading. All contributions for the February issue of the Monthly Journal *should reach him not later than January* 25.

Dr.-Ing. P. Brenner, Director of the Werkstoffabteilung der Deutschen Versuchsanstalt für Luftfahrt E.V., Berlin-Adlershof, will, on February 1, 1936, become Director of the new Research Laboratory of the Vereinigte Leichtmetallwerke G.m.b.H., Hannover-Bonn.

Professor P. A. J. Chevenard, Corresponding Member to the Council for France, has received from the Académie des Sciences the Marquet Prize.

Professor Dr. A. Glazunov was installed as Rector of the Ecole

Supérieure des Mines at Pribram, Czechoslovakia, on December 7. The new Rector subsequently delivered his inaugural address on the subject of "The Importance of Metallography to the Metallurgical and Mineral Industries."

Mr. G. W. Muir is on leave from Bombay and will remain in England until August, 1936. Correspondence may be forwarded to him at Kirkliston, Crescent Road, Liverpool 9.

Mr. John G. Shaw Scott has been selected by the London Passenger Transport Board as an Engineering Trainee to undergo two years special training, following his recently completed apprenticeship, at the Board's Chiswick Works.

Death.

Sir Richard Glazebrook, K.C.B., F.R.S., an Honorary Member of the Institute, died on December 15. Sir Richard, a former Director of the National Physical Laboratory, had been a member of the Institute since 1910.

LOCAL SECTIONS NEWS

SYNOPSES OF PAPERS TO BE READ AT COMING MEETINGS *

London Section.

The Applications of Metals in Chemical Engineering. By H. W. Cremer, M.Sc. (*February* 6.)

A brief outline will be given of the extensive field covered by the chemical and allied industries and the following points will be considered: the duties which metals are required to perform in these industries; the need for close co-operation between the process metallurgist, the designer and the chemist in the production of chemical plant; the growing tendency for chemical processes to employ high temperatures and pressures, and the bearing of this on the development of new alloys to withstand severe conditions of service; metal problems of the future; some of the more recent developments in metals and alloys as they affect chemical engineering.

Manchester Metallurgical Society.

Refining of Metals by Sodium Carbonate. By N. L. Evans, B.Sc. (*February* 19.)

This paper will deal with the use of sodium carbonate as a refining and desulphurizing flux for ferrous and non-ferrous metals. The chemical and physical effects of the process, including grain-refinement, degasification, and removal of non-metallic inclusions, will be covered, and a description given of various items of plant and apparatus, such as teapot ladles, receivers, plunger mixers, &c., which assist in the application of the flux. Some attention will also be devoted to the action of alkalis on refractory materials. The lecture will be illustrated by lantern slides.

North-East Coast Section.

Some Recent Developments in the Hardening of Non-Ferrous Metals by Heat-Treatment. By W. T. Griffiths, M.Sc. (*February* 11.)

Although the use of heat-treatment to produce hardening or strengthening is extensively employed in the case of steels, and knowledge has been available for some time of the possibility of utilizing heat-treatment to improve the properties of non-ferrous alloys in a similar manner, except in the case of

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* For places and times of meetings the green folder programme, as issued to all Local Section members, should be consulted.

certain light alloys the application of this knowledge has been limited. Some reasons for this will be examined and the possibilities of a more general utilization of this type of heat-treatment discussed, with particular reference to data obtained during recent years.

Scottish Section.

Corrosion of Metals by Industrial Waters. By F. Hudson. (*February* 10.)

Part 1.—Examples of corroded cast-iron and steel articles used for handling industrial waters; cause and prevention of failures; use of alloy iron and steel; value of paint films and other protective coatings such as nitrogen-hardening, galvanizing, &c.

Part 2.—Examples of corroded high-tensile brass and other copper-base alloys; cause and prevention; examples of dezincification and corrosion-fatigue; corrosion of nickel silver.

Part 3.—Examples of corroded aluminium alloys; cause and prevention of corrosion; value of chemical coatings.

Part 4.—Examples of corroded tin–lead-base alloys as used for die-castings, &c.; cause and prevention of corrosion.

Considerable data have been collected during the past 3 years in this connection and investigations have been conducted with the help of Dr. Todd's Corrosimeter, and by means of paint tests by galvanic couple method, standard corrosion tests by salt-spray and immersion, &c., microscopic examination and analysis of corrosion products.

Sheffield Section.

Rose Engine-Turning and Enamelling. By R. S. Hill. (*February* 14.)

Rose engine-turning machines. (1) History and development from the early turning lathe. Lantern slides will show various stages in progress from the eighteenth century to the present day. (2) Engine-turning in the past and its application to modern silver and metal work. (Illustrated by lantern slides and actual specimens.)

Enamelling. (1) Manufacture of enamels; various styles of enamelling (Cloisonné, Bassetaille, Limoges, painted enamels, &c.). (2) Method of applying enamel to metal and the various metals suitable; present-day enamelling, silver, base metal and iron enamelling. Lantern slides will show types of enamelling through the ages, and actual examples of various styles of enamels will be on view.

Swansea Section.

Some Modern Developments in Stainless Steels. By J. H. G. Monypenny. (*February* 11.)

Stainless steels are essentially chromium steels, but many of them contain, in addition, a considerable amount of nickel. The broad classification thus suggested into (*a*) chromium steels and (*b*) chromium–nickel steels, may be usefully applied. On this basis, the modern developments which will be considered consist in the addition of other metals to one or other of the parent steels to improve their mechanical properties or to increase their stability against chemical attack.

The chromium–nickel steels have the wider usefulness, as they resist the attack of a greater range of chemicals than the other group. Their most important defect has been their tendency to undergo intergranular corrosion unless they had been finally heat-treated before use in a specific manner. The elimination of this defect, in greater or less degree, by various methods which have been proposed, constitutes the most important modern development and will be considered in detail.

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A DEEP-DRAWING TEST FOR ALUMINIUM.*

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P. C. VARLEY,‡ M.A.

SYNOPSIS.

A new test for estimating the deep-drawing quality of aluminium is described and figures are given illustrating its application to normal commercial purity metal in various tempers. The test consists essentially of two drawing operations of which the first, or cupping, operation does not alone distinguish clearly between different grades and tempers of the metal. The addition of a re-drawing operation, however, makes the test much more sensitive and distinguishes clearly between the drawing properties of the various grades.

The application of the test to aluminium of commercial purity has shown that the various medium tempers have surprisingly good drawing properties and might well be used more extensively for this purpose.

AT the recent joint discussion on "Cold-Pressing and Drawing,"[1] it was generally agreed that the normal tests, by which the mechanical properties of a metal are determined, really give very little indication of its relative suitability for cold-pressing or deep-drawing. That this should be so is really not surprising in view of the complex nature of the stresses set up in the drawing operation. Under the influence of the drawing tools the metal is subjected to plastic deformation, first of all in compression and then in tension, so that its suitability, or otherwise, is determined by its properties in the plastic range. Few, if any, of the ordinary mechanical tests give much indication of the behaviour of a metal in this range, though from time to time attempts have been made to devise simple means for testing the suitability of metal for drawing and pressing. These may be divided into two classes: (1) the so-called cupping tests of which the Erichsen test may be taken as typical, and (2) the tests based on the deep-drawing process itself.

The various cupping tests were described and discussed in a paper by Gough and Hankins[2] in their contribution to the above-mentioned joint discussion. These authors came to the conclusion that all the various cupping tests reflected the same property of the materials and that, in general, the results of their comparative tests did not suggest

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that, as a measure of ductility, any one form of cupping test possessed marked advantages over the others or over the elongation value obtained in the tensile test. Owing to the lack of suitable material they were only able to carry out a few tests to determine whether these cupping tests gave any indication of the performance of the metals in pressing, but in those tests which they did carry out an indication of performance was obtained in one case only. In the others little difference was shown by the cupping tests, although marked differences in drawing behaviour had been reported. However, by using the fluid-pressure (Jovignot) cupping tests to obtain stress–strain curves, these authors obtained indications that used in this manner the test would probably yield very valuable information with regard to the suitability of metal for drawing.

Tests based on the deep-drawing process have been described by G. R. Fischer [3] and others [4, 5]; these have been based on the drawing of various sizes of circles through the same tools, using as a criterion of the drawing properties the largest circles which will draw with, say, 50 per cent. failures. More recently Goederitz[6] has described a new attachment to the Erichsen apparatus which adapts the machine to the drawing and re-drawing of cylindrical shells. The apparatus is fitted with pressure gauges, and it is possible to obtain records of the pressures employed and the power absorbed in drawing. The use of this apparatus should enable much valuable information to be obtained as to the drawing characteristics of materials. Sachs [7] has also devised a wedge-drawing apparatus which has given promising results. Kelton and Edmunds [8] have also described a method for assessing the drawing properties of rolled zinc alloys based on the drawing of small cylindrical shells. These authors also state that re-drawing tests were carried out, but do not give any details.

The present authors' experience, in the case of aluminium, has shown that a test based on the first, or cupping, operation is not sufficiently sensitive to detect small differences in drawing properties, but that it is by no means necessary to employ elaborate pressure-measuring devices. The addition of a re-drawing operation increases the sensitivity of the test to a very large extent and, using only simple apparatus, which can readily be made in any fitting shop, it is possible to detect, and to some extent to evaluate, the small differences in drawing properties resulting from variations in composition, temper, and previous history of the metal.

In view, therefore, of the interest of the subject and of the increasing use of aluminium for draw-press operations it has been thought worth while to describe the application of this test and to give also some of the results which have been obtained with it.

DESCRIPTION OF TOOLS.

The press employed for these tests was an ordinary hand-operated single-acting screw press, of the type commonly known as a flypress. The tools employed for the first operation were of the inverted combination type, frequently used commercially for small work, which permit a double-action draw on a single-acting press. As can be seen from Figs. 1 and 2 (Plate I), these were simple in design and consisted of a die, which formed the top member, a punch, and a blank-holder. The pressure on the blank-holder was supplied by a 12 in. spring of 120 lb./in. strength, this having been found by trial to be the most suitable strength. The die was fitted with a spring-loaded ejector, and the blank holder had a number of concentric circles scribed on it as an aid to centering. The first punch made had a 45° taper so that the drawn shells would sit well in the re-drawing die. This shape was found to be very satisfactory for use with soft temper material but did not work at all well with medium tempers. For these it was found that a punch with a simple radiused end permitted a much heavier draw.

The tools were designed for use with metal 0·032 in. thick, the actual dimensions being :

	Inch.
Punch diameter	1·240
Die diameter	1·314
Die clearance	0·037
Radii on punch and die	0·25

According to Sachs[9, 10] the increase in thickness of the edge of the flange during drawing results in the superposition of a second process, akin to tube drawing, upon the deep-drawing process proper. This process is commonly known as ironing. If the die clearance is small, the load due to this may exceed that due to the deep-drawing. However, as can be seen from the curves given in his paper, with a clearance greater than 10 per cent. of the metal thickness the second process is of negligible importance. With the tools used in these experiments the clearance is sufficiently large, 15 per cent. above the metal thickness, for the extra load due to ironing to be neglected even if, as was sometimes the case, the metal used was rather thicker than had been intended, without being so large as to cause failures due to excessive die clearance. The value for the radii was chosen because, in commercial practice, it is found that the best value for this is between five and ten times the metal thickness.

The tools for the second operation were of the single-acting type, and are illustrated in Fig. 3 (Plate II). The die was made with 0·25 in. radius and was slightly recessed so that the shell from the first operation sat nicely in it. The punch was also given a radius of 0·25 in., although it is now realized that better results might have been obtained with a smaller radius at this point. Herrmann and Sachs [11] have shown that for the best results the radius on the punch should not exceed 0·3 of its diameter. Our own subsequent experiments have confirmed this, but as our tests have aimed at giving comparative rather than absolute figures we have not thought it worth while repeating them.

Actually, four sets of tools, for the second operation, were made, designed to give reductions of 33, 36, 40, and 44 per cent. The exact dimensions were :

Punch diameter, in. . . .	0·830	0·792	0·740	0·690
Reduction, per cent. . . .	33·1	36·2	40·3	44·3

The die clearance was in each case 0·037 in. as in the first operation.

APPLICATION OF THE TEST.

The application of the test to a particular sample of metal is very simple. The tools are first roughly centred but not clamped in position; a circle of about $2\frac{3}{8}$ in. diameter, and of the correct gauge, is then drawn, and while the die is still in its lowest position the punch is clamped firmly to the bed-plate. In this way it is possible to centre the punch to ± 0·0005 in. which is sufficiently accurate for the purpose. When this has been done and the spring pressure has been adjusted to such a value that it will just suppress puckering in a $2\frac{1}{2}$ in. circle (the largest size employed), a number of circles are drawn, say 30, in each of the sizes 2, $2\frac{1}{8}$, $2\frac{1}{4}$, $2\frac{3}{8}$, $2\frac{1}{2}$, and occasionally $2\frac{7}{16}$ in. Before drawing, each circle is lubricated by wiping it with a clean rag saturated with machine oil. No further lubrication is necessary even for re-drawing. The resulting shells are then tested by re-drawing. It has been found that the tools giving 33 per cent. reduction are sufficient for testing soft-temper material, but for the medium tempers it may be necessary to attempt a reduction as high as 44 per cent. before any failures are recorded. If the percentage of failures recorded is tabulated against the percentage reduction in the re-drawing operation and the size of the original circle, it is found that small differences in drawing properties are shown up quite clearly.

RESULTS OBTAINED.

As stated earlier in this paper, it does not seem to be possible to detect small differences in the drawing qualities of different samples of aluminium on the basis of the first operation alone. With all the samples of soft-temper material so far examined it has been found possible to draw a $2\frac{1}{2}$ in. diameter circle, equivalent to a reduction of 50·5 per cent. but larger sizes have always failed. Similarly with the various

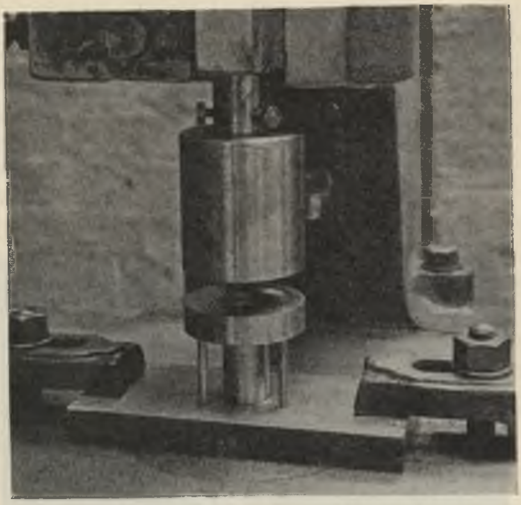

FIG. 1.—First Operation Tools in Position.

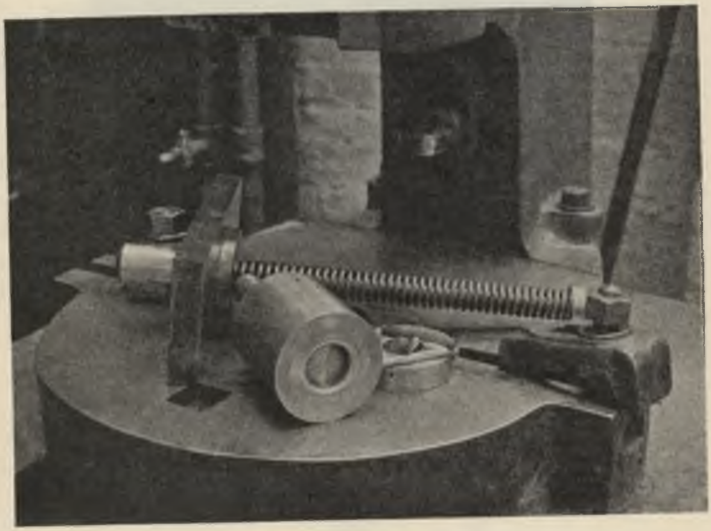

FIG. 2.—First Operation Tools Showing Details.

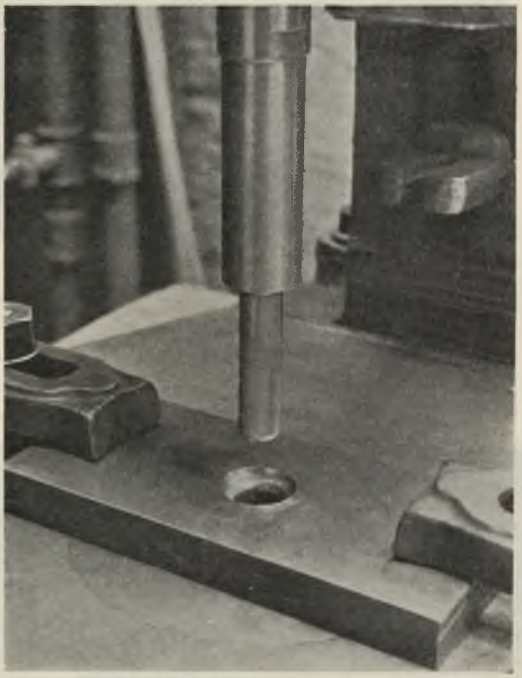

FIG. 3.—Re-Drawing Tools.

medium tempers, although the tensile strength of the samples examined has varied from 7 to nearly 10 tons/in.^{2} and the Erichsen value from 8·1 down to 6·6, it has always been possible to draw a circle $2\frac{7}{16}$ in. diameter, equivalent to a reduction of 49·2 per cent. By way of illustration it is proposed to describe the results obtained with one particular batch of metal in all the tempers commonly met with and also after different annealing treatments.

The analysis of the material was silicon 0·16, iron 0·41, copper trace, manganese trace, aluminium 99·43 per cent., and it was available in soft, medium-soft, medium, and medium-hard tempers, and also after an anneal at four times the finishing thickness. These were designated S0, S1, S2, S3, S4. In addition, further samples were prepared by annealing the S4 samples, these were designated S4A. All samples had been strip-rolled and were finished to 0·032 in. The mechanical properties are given in Table I.

TABLE I.—*Mechanical Properties*

Mark.	Thickness, Inch.	Elastic Limit (Commercial), Tons/in.^{2}.	Tensile Strength, Tons/in.^{2}.	Elongation on 2 in., Per Cent.	Bend Test.	Brinell No. 1 mm.; 5 kg.	Scleroscope No. (Magnifier Hammer).	Erichsen Value.	Grain-Size, Grains/mm.^{2}.
S0	0·032	1·96	5·68	38·9	2L17	21·8	5	10·1	1100
S1	0·033	6·30	7·36	10·7	2L17	32·7	10½	7·9	...
S2	0·033	7·28	8·07	7·3	2L17	34·4	12	7·4	...
S3	0·032	7·69	8·31	6·4	2L17	36·2	12½	7·0	...
S4	0·033	8·82	9·52	5·7	2L16	38·1	15	6·6	...
S4A	0·033	2·07	5·60	39·7	2L17	21·6	5	10·2	900

TESTS ON SOFT-TEMPER METAL.

With the two soft-temper samples, S0 and S4A, it was found possible, using the bevelled punch, to draw all sizes of circle up to and including 2½ in. in the first operation. In the second operation the larger shells failed when drawn with the tools giving 33 per cent. reduction. The actual figures obtained were :

Diameter of Original Circle, Inches.	Failures with 33 Per Cent. Reduction, Per Cent.	
	S0.	S4A.
2	nil	nil
2⅛	nil	nil
2¼	100	nil
2⅜	100	nil
$2\frac{7}{16}$	100	30
2½	100	85

From this it appears that although the mechanical properties of the two samples are very similar and although no difference could be detected in the first draw, the re-drawing operation has shown up a marked difference in drawing properties, those of S4A being distinctly more favourable than those of S0.

TESTS ON MEDIUM TEMPERS.

As with the soft-temper samples, all the medium samples drew equally well in the first operation. Using the radiused punch it was possible in all cases to draw a circle $2\frac{7}{16}$ in. diameter although a $2\frac{1}{2}$ in. circle failed in every case. The bevelled punch proved to be unsuitable for drawing medium-temper material and was, therefore, not employed for these tests.

The results of the second operation tests are shown in tabular form below.

TABLE II.

Diameter of Original Circle, Inches.	Per Cent. Failures.			
	33 Per Cent.	36 Per Cent.	40 Per Cent.	44 Per Cent. Reduction.
		S1. Medium-Soft.		
2	nil	nil	nil	100
$2\frac{1}{8}$	nil	nil	15	100
$2\frac{1}{4}$	nil	nil	100	100
$2\frac{3}{8}$	nil	50	100	100
$2\frac{7}{16}$	nil	40	100	100
		S2. Medium.		
2	nil	nil	nil	100
$2\frac{1}{8}$	nil	nil	nil	100
$2\frac{1}{4}$	nil	nil	nil	100
$2\frac{3}{8}$	nil	nil	40	100
$2\frac{7}{16}$	nil	nil	100	100
		S3. Medium-Hard.		
2	nil	nil	nil	100
$2\frac{1}{8}$	nil	nil	nil	100
$2\frac{1}{4}$	nil	nil	$7\frac{1}{2}$	100
$2\frac{3}{8}$	nil	$7\frac{1}{2}$	40	100
$2\frac{7}{16}$	nil	10	100	100
		S4 (2L4).		
2	nil	nil	nil	100
$2\frac{1}{8}$	nil	nil	nil	100
$2\frac{1}{4}$	nil	nil	nil	100
$2\frac{3}{8}$	nil	nil	nil*	100
$2\frac{7}{16}$	nil	nil	nil*	100

* These shells were very badly puckered.

Thus it will be seen that the medium tempers will stand a heavier reduction in the second operation than will soft temper, and that the ability to withstand a heavy reduction apparently increases with the hardness of the sample.

The results of these tests are of interest in several respects. In the first place they illustrate the authors' contention that it is impossible to obtain much information as to the drawing properties of a sample of aluminium from a study of a single-drawing operation, even though that operation be designed to stress the metal to the limit, but that a study of its behaviour on re-drawing can give one an excellent idea of its suitability for deep-drawing and will distinguish clearly between samples of slightly different drawing properties. In the second place they bring out the fact that with aluminium the various medium tempers possess excellent drawing properties and might well be used to advantage for many purposes where their additional strength and stiffness is likely to be of value. They also offer another advantage in that by their use it may in certain cases be possible to produce an article in fewer operations than would be the case if the starting point were soft-temper aluminium. In selecting the temper, each particular job must be considered on its merits as there are undoubtedly many cases where the greater ductility of soft-temper metal is of value; this is particularly the case where subsequent operations, such as beading or bulging, call for an actual expansion of the metal.

As can be seen by reference to Table I, the drawing quality of the samples examined bore no relation to the Erichsen value or to the elongation in the tensile test. Although the medium tempers gave much lower values for these two properties than did the soft-temper material, they are not markedly inferior in drawing quality, as might have been expected, but actually withstood a much heavier draw in the second operation. Further, although samples S4A and S0 have almost identical mechanical properties, the differences being within the experimental error, they showed, on test, quite different drawing properties.

Although there exists a considerable amount of experimental evidence, both on a laboratory and a works' scale, which generally confirms the conclusions of these experiments, it has not yet been possible to obtain direct confirmation from works' trials. It would not be feasible to do this with existing tools as these are for the most part designed to work with ordinary soft-temper metal, but it is hoped that, as the favourable drawing properties of medium-temper aluminium become more widely known, hollow-ware manufacturers will take advantage of them when constructing new sets of tools for the manufacture of articles where its use is likely to be of advantage or to lead to a reduction of manufacturing costs. In this connection it should be borne in mind that although we have confidence that the test described gives a very good indication of the drawing properties of a material, particularly as it approximates so closely to manufacturing conditions for small articles, the actual percentage reductions obtainable will probably vary according to the type of press, the design of the tools, and the ratio of the thickness of the metal to the diameter of the blank.

CONCLUSIONS.

It would appear that the test described, although a simple one, is capable of distinguishing small differences in drawing properties, differences that would not be suspected from a study of the mechanical properties of the materials. At the same time it furnishes much useful information as to the actual behaviour of the metal in deep drawing.

ACKNOWLEDGMENTS.

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A STUDY OF THE FATIGUE CHARACTERISTICS OF THREE ALUMINIUM SPECIMENS EACH CONTAINING FROM FOUR TO SIX LARGE CRYSTALS.*

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SYNOPSIS.

Three specimens of aluminium, each consisting of from four to six large crystals, were submitted to alternating torsional fatigue tests. Each specimen was tested at a constant range of applied torque throughout: two specimens fractured, one remained unbroken. The observed changes in microstructure were related to the crystalline structure—as revealed by X-rays—and to the applied stressing system, particular attention being given to the influence of the intercrystalline boundaries on the deformation and fatigue-resistance.

It was found that the slip-band distribution of each specimen obeyed very closely the maximum resolved shear-stress law, calculated for each crystal as if it alone occupied the entire specimen: the influence of the boundaries on the slip-band distribution was extremely slight. Cracking occurred in regions subjected to high values of resolved shear stress. These regions were often situated in close proximity to a boundary, but the results indicate that the influence of boundaries, as such, on fatigue-cracking is very slight. In fact, it has been clearly established that fatigue-cracking is not initiated at the boundary, and also that the general course of a crack does not tend to follow a boundary.

The fatigue histories of the specimens reveal a fatigue limit, on an endurance basis of 10^8 stress cycles, of about ± 1·0 ton/in.^{2} resolved shear stress, which differs but little from that of single crystals of aluminium.

I. INTRODUCTION.

A SERIES [1] of previous papers contains the results of a study of the fatigue characteristics of single metallic crystals conforming to various representative space-lattice systems. One major conclusion which emerged from this work was that the deformation and failure characteristics, under fatigue stressing, of metals in their simplest form, were controlled essentially by what was termed [2] the "maximum resolved shear-stress law."

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In order to study the influence of crystal size and of the presence of intercrystalline boundaries, experiments were carried out, at a later stage, on specimens consisting of several large crystals. In the most important of such experiments,[3] tests were carried out on three specimens of aluminium each consisting of two crystals. In one specimen the intercrystalline boundary was mainly transverse to the axis of torsion; in another it was mainly longitudinal through that axis, whilst, in the third, the boundary had no special form, but the two constituent crystals were in mutual twin orientation. The observed distribution of slip-bands showed that the effect of the boundaries on the distribution of stress was extremely slight, each crystal behaving as if it alone composed the whole specimen, whilst the close approach of the general systems of slip to the boundary and the very small amount of anomalous slip in that region showed that even locally the boundary had a very limited field of influence. Some evidence was obtained, however, that the orientation of the boundary had a considerable effect on the *endurance* of the specimen at any given range of stress. The presence of the boundaries appeared scarcely to affect the formation and propagation of cracks. In each specimen, cracks were formed in a normal (with respect to the behaviour of single crystals) manner in regions of previous heavy slip, and in their development showed no tendency either to avoid the boundary or, on the other hand, to seek it out. In one or two cases, cracks commenced to propagate along the boundary, but proceeded thus for only a short distance before deviating entirely into one or other of the neighbouring crystals. To proceed further with the study of this very interesting aspect of fatigue, it was decided to make tests on specimens of the same total size but containing a larger number of crystals, and the experiments now to be described were designed and carried out.

Endurance tests again employing alternating torsional stresses have now been carried out on a further batch of three specimens, containing respectively four, five, and six crystals, the specimens being selected so that the general directions of the boundaries were approximately parallel to the axes of the specimens. Each specimen was tested throughout under a constant range of torsional stresses to afford some indication of the fatigue limit of specimens containing this number of individual crystals: it is unlikely that such a small variation in number, from four to six crystals, in a specimen would exhibit a "grain-size" effect. In general, the main objects of the experiments were: (1) to study the effect of the crystal boundaries on the slip-band distribution, and (2) to study the position of fatigue-cracking in relation to the resolved shear stress distribution and to crystal boundaries.

The general methods adopted in the work were essentially similar to those previously employed in tests on single crystals and large-crystal specimens: these methods have been fully described in previous papers[4] and detailed descriptions will not be given in the present paper.

II. Details of Specimens and Stressing Systems.

The bars from which the specimens were cut were partial failures of the strain and heat-treatment (Carpenter and Elam) method for producing single crystals. A number of trial specimens having the required dimensions were cut from two bars each consisting of a few large crystals; from these the three specimens which, in the etched state, showed the closest approach to the required type of intercrystalline boundaries, were selected. The crystal orientations of these crystals were not, of course, similar, even in the two specimens cut from the same bar, since the crystals in the latter did not continue throughout its length. The form and finished dimensions of the selected specimens were as shown in Fig. 1.

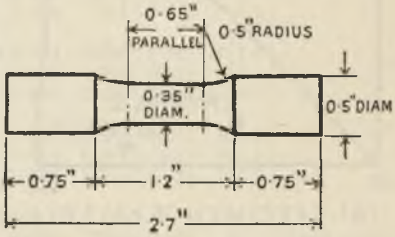


Fig. 1.—Form and Dimensions of Specimens (FKY1A, 1C, and 5A).

After machining, the specimens were heavily etched; using a

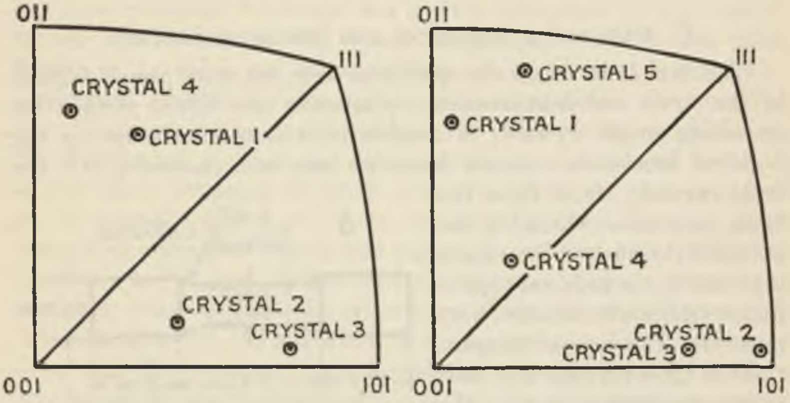
Table I.—*Spherical Co-Ordinates * of Cube Faces of Specimens.*

Specimen.	Plane.	Crystal 1.		Crystal 2.		Crystal 3.		Crystal 4.		Crystal 5.	
		θ.	ψ.	θ.	ψ.	θ.	ψ.	θ.	ψ.	θ.	ψ.
FKY1C	100	76·8	103·5	70·7	316·7	56·0	28·7	85·6	335·5	...	...
	010	59·3	5·5	84·1	48·7	87·7	120·2	56·5	68·4	...	...
	001	34·0	214·0	20·2	154·9	34·1	213·6	33·9	238·9	...	...
FKY1A	100	87·5	296·0	46·6	243·8	55·7	348·5	79·5	156·6	78·7	204·9
	010	57·6	27·7	87·9	335·6	87·9	79·9	75·5	249·4	50·8	304·2
	001	33·5	202·3	43·5	67·8	34·4	173·1	18·0	32·0	41·6	101·8
FKY5A	100	86·0	83·0	75·6	215·7	55·6	351·4	80·9	19·5	52·4†	242·7†
	010	82·1	173·6	54·9	316·1	82·1	86·9	58·6	115·1	75·6†	343·9†
	001	8·9	326·2	38·8	107·1	35·6	188·0	33·0	275·2	41·5†	90·5†

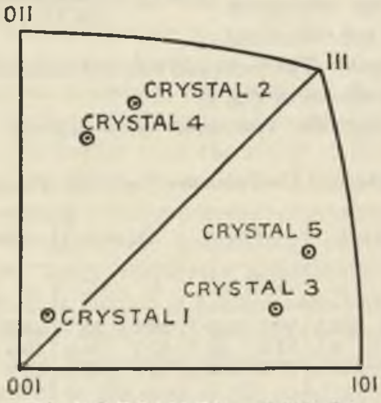
* With reference to the axis of the specimen, also to a plane containing the axis and reference mark of the specimen concerned.

† Deduced from one reflection and measured traces of slip-planes, as described in text.

microscope, the courses of the intercrystalline boundaries were then carefully surveyed and plotted. The developed surfaces of the test-portions of the specimens are shown in Figs. 3, 4, and 5; the traces of the boundaries are indicated in dotted lines in these diagrams.



(A) SPECIMEN FKY 1C (B) SPECIMEN FKY 1A



(C) SPECIMEN FKY 5A

Fig. 2.—Relative Orientations of Crystals and Specimen Axes.

The orientations of the crystals in each specimen were determined by X-ray analysis : Table I contains sufficient data for record purposes. Fig. 2 shows the relative orientations of each individual crystal : the method adopted in this diagram is to indicate the position of the axis of the relevant specimen relative to the crystallographic axes of the crystal concerned.

Table II.—*Values of Stress Constants,* A *and* α, *in Resolved Shear Stress Equations.*

Plane.	Direction.	Crystal 1.		Crystal 2.		Crystal 3.		Crystal 4.		Crystal 5.	
		A.	*a*°.	*A.*	*a*°.	*A.*	*a*°.	*A.*	*a*°.	*A.*	*a*°.
		(1) *Specimen FKY1C.*									
0	01	0·639	169·9	0·316	142·9	0·382	171·4	0·801	161·7	...	...
	02	0·840	100·9	0·590	31·0	0·786	113·1	0·433	99·7	...	...
	03	0·854	56·3	0·766	8·5	0·669	84·0	0·709	14·7	...	...
1	10	0·208	108·9	0·532	48·6	0·550	100·3	0·721	144·6	...	...
	12	0·514	39·8	0·446	132·4	0·434	62·9	0·562	131·8	...	...
	13	0·799	71·7	0·657	6·0	0·934	96·1	0·212	0·4	...	...
2	20	0·616	122·3	0·550	83·0	0·744	129·6	0·527	171·6	...	...
	21	0·485	103·2	0·614	73·7	0·592	148·4	0·455	34·1	...	...
	23	0·225	167·7	0·113	22·7	0·264	184·0	0·915	11·3	...	...
3	30	0·205	156·6	0·320	152·6	0·378	175·5	0·347	100·9	...	...
	31	0·944	141·7	0·784	95·8	0·955	157·4	0·635	127·2	...	...
	32	0·745	138·1	0·665	72·1	0·607	146·3	0·958	117·9	...	...
		(2) *Specimen FKY1A.*									
0	01	0·678	152·5	0·836	154·7	0·787	73·0	0·423	55·7	0·688	149·2
	02	0·781	123·5	0·564	116·9	0·664	43·9	0·507	173·2	0·902	26·1
	03	0·378	63·4	0·523	16·2	0·383	130·4	0·796	21·4	0·781	73·7
1	10	0·371	59·5	0·794	156·9	0·748	89·0	0·498	139·2	0·408	35·0
	12	0·612	90·1	0·435	125·1	0·274	43·2	0·506	81·9	0·575	73·8
	13	0·951	78·7	0·482	5·3	0·591	108·4	0·482	21·9	0·928	57·8
2	20	0·737	105·9	0·460	11·1	0·382	134·3	0·501	104·0	0·681	18·8
	21	0·249	152·6	0·538	10·9	0·603	106·3	0·557	138·1	0·411	26·3
	23	0·594	88·4	0·999	11·0	0·958	117·0	0·314	21·5	0·278	7·9
3	30	0·551	135·2	0·487	125·0	0·551	59·5	0·302	32·0	0·310	177·3
	31	0·926	152·5	0·512	116·4	0·435	23·5	0·743	103·7	0·975	169·9
	32	0·432	174·8	0·996	120·5	0·938	43·7	0·707	127·6	0·668	166·5
		(3) *Specimen FKY5A.*									
0	01	0·386	131·7	0·806	37·3	0·542	145·2	0·815	24·3	0·741	42·3
	02	0·308	118·2	0·516	153·6	0·838	82·8	0·537	135·8	0·917	162·9
	03	0·689	125·7	0·728	85·4	0·759	43·5	0·795	63·3	0·835	113·1
1	10	0·443	18·5	0·628	23·5	0·483	76·0	0·658	3·5	0·391	162·8
	12	0·601	49·1	0·440	45·2	0·467	29·8	0·517	7·4	0·584	112·3
	13	0·315	94·9	0·273	167·0	0·902	52·6	0·148	169·8	0·891	132·1
2	20	0·477	76·9	0·413	34·3	0·693	98·2	0·487	24·5	0·638	162·1
	21	0·529	24·3	0·561	91·2	0·504	101·1	0·486	82·9	0·419	150·7
	23	0·448	146·5	0·857	67·0	0·193	90·6	0·849	53·7	0·298	22·9
3	30	0·451	134·2	0·237	24·6	0·308	134·7	0·268	143·2	0·268	5·1
	31	0·556	66·2	0·727	178·7	0·969	124·0	0·699	167·8	0·959	18·2
	32	0·568	18·8	0·957	0·3	0·669	119·2	0·950	161·1	0·701	23·5

All three specimens were tested under alternating torsional stresses. The shear stresses resolved on the various octahedral planes in the directions of their intersections with the remaining planes of the same type were calculated for each crystal * as if it alone composed the whole specimen, using the results of the X-ray analysis also the equation $\frac{S_r}{S} = A \cos (\lambda - \alpha)$ which will be familiar from previous reports.

The complete set of values of the stress constants A and α, in the above equation, were deduced and are given in Table II. From these the relevant portions of the resolved shear-stress curves were calculated : these curves are reproduced as Figs. 3, 4, and 5. The slopes of the traces of the octahedral planes on the surfaces of the specimes were also calculated, and the slip observations made during the course of the tests were compared with the calculated values. It is unnecessary to reproduce these curves : the slip-bands in every case agreed very closely with the calculated slopes of the operative slip-planes.

III. COMPARISON OF SPECIMENS WITH RESPECT TO STRESS DISTRIBUTION.

Reference to Fig. 2 will show that the crystals in each specimen had purely arbitrary relative orientations, there being no simple relation between any two crystals in one specimen or between crystals in different specimens. With regard to the resolved shear stress distribution, the following points are of interest. Each specimen contained one crystal with a relatively low maximum stress factor † (0·69–0·79), the remaining crystals having values between 0·91 and 1·00. In all three cases, the crystal with a low stress factor had considerable width, *i.e.* subtended a fairly large λ value; in the case of specimen FKY5A it was the largest crystal in the specimen. Specimens FKY1A and FKY5A each contained one very narrow crystal. The maximum stress factor for each of these crystals was high, and in neither case were these crystals, adjacent to the previously mentioned crystals, subjected to a low value of shear stress. It will be seen, however,

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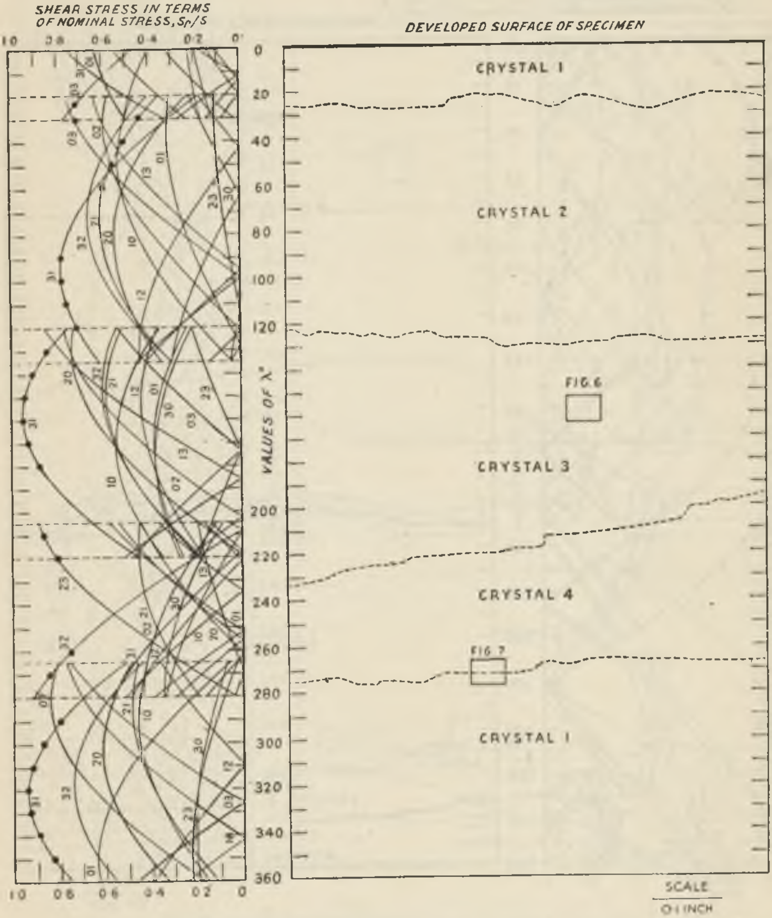
* In the case of crystal 5 in specimen FKY5A, only one X-ray reflection was obtained, and this was, of course, insufficient to define completely the crystal orientation. During the experiment two systems of slip-bands appeared on this crystal. Making the justifiable assumption that these represented the traces of octahedral planes, the recorded slopes, together with the known co-ordinates of the plane giving an X-ray reflection, were sufficient to enable the orientation of the whole crystal to be deduced. The resulting values have been recorded for reference purposes.

† The maximum stress factor represents the value of the constant A (see Table II) denoting the ratio of the maximum resolved shear stress, on the plane and in the direction concerned, to the nominal shear stress set up in the specimen.

that owing to the location of the stress curves round the circumferences of the specimens (see Figs. 3, 4, and 5) abrupt changes in actual value of resolved stress took place at many boundaries. Specimen FKY5A was exceptionally interesting as it contained a boundary having a very high value of maximum resolved shear stress on one side and an exceptionally low value on the other (Boundary between crystals 1 and 2, Fig. 5).

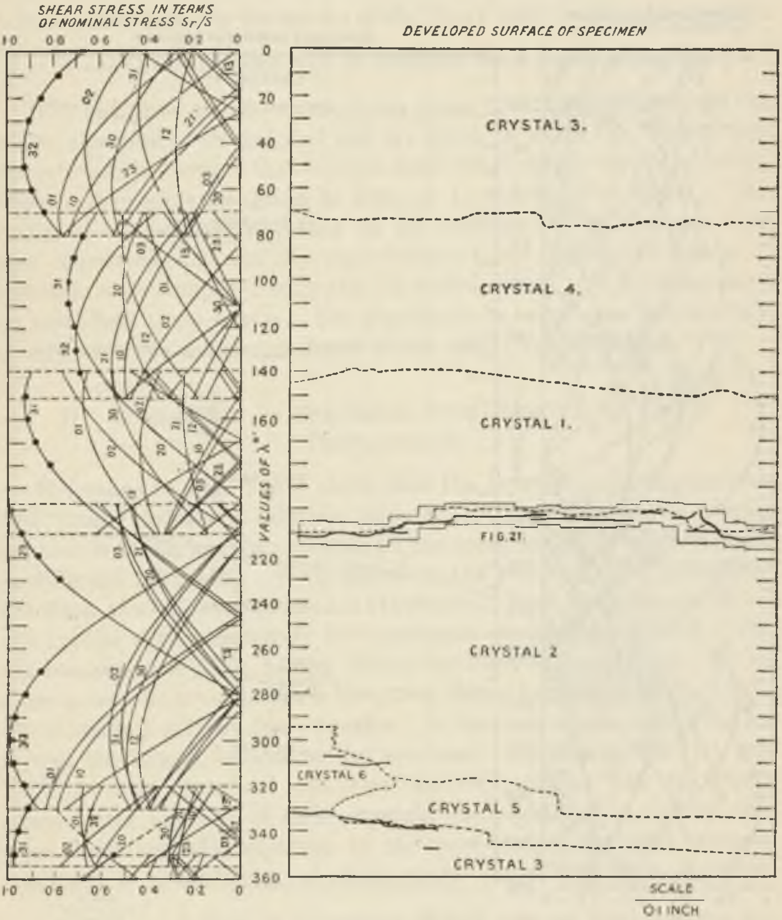


● indicates slip observed after 280,000 stress cycles.
---- (on developed surface) indicates approximate positions of crystal boundaries.

FIG. 3.—Specimen FKY1C.

IV. Summarized History of Tests.

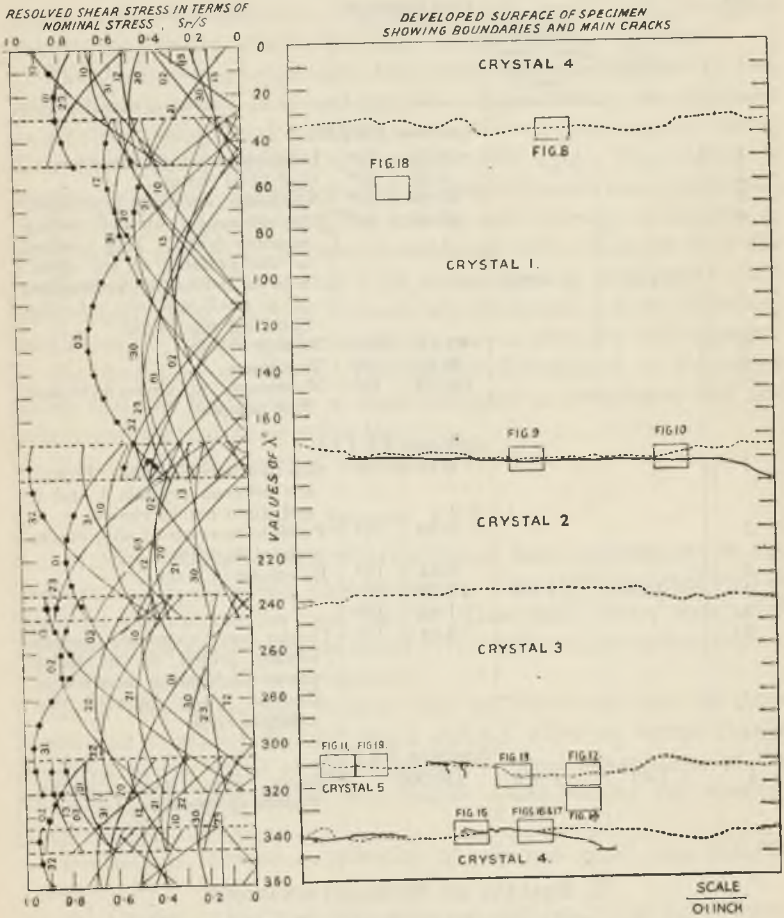
Each specimen was tested throughout at a constant range of applied alternating torque; the stress-cycle frequency in all cases was 1000 per minute. The tests on specimens 1C and 1A were interrupted at intervals, when the specimen was removed from the machine and submitted to a careful microscopical examination. A photographic record was made of those portions of the specimen which revealed



• indicates slip observed after test (3·04 × 10⁶ stress cycles).
▬ (on developed surface) indicates approximate positions of cracks.
- - - - (on developed surface) indicates approximate positions of crystal boundaries.

Fig. 4.—Specimen FKY1A.

features of interest. Specimen 5A which failed after at a low endurance was examined at the conclusion of the test only. The history of each specimen is briefly summarized in Table III.



- indicates slip observed after fracture.

▬ (on developed surface) indicates approximate positions of major cracks.

- - - - (on developed surface) indicates approximate positions of crystal boundaries.

Fig. 5.—Specimen FKY5A.

In terms of resolved shear stress the fatigue limit of the specimens is about ± 1·0 ton/in.^{2} : this value is little, if any, greater than that associated with single crystals of aluminium.

TABLE III.

Test No.	Applied Range of Stress, Tons/in.². Nominal Shear Stress $= \pm \frac{2T}{\pi r^3}$.	Applied Range of Stress, Tons/in.². Maximum Resolved Shear Stress $= \pm S_r$ (Max.).	Total Number of Stress Cycles.	General Observations.
			Specimen FKY1C.	
1	± 1·03	± 0·983	$0{\cdot}28 \times 10^6$	Light slip over all stress peaks.
2			$5{\cdot}92 \times 10^6$	Very little change.
3			$32{\cdot}26 \times 10^6$	No change, specimen repolished.
4			$37{\cdot}66 \times 10^6$	The oil supply on the testing machine failed. This resulted in the twisting of the specimen of 1·7° with production of a small quantity of slip. Specimen repolished.
5			$62{\cdot}14 \times 10^6$	No slip visible.
6			$80{\cdot}62 \times 10^6$	No change.
7			$100{\cdot}58 \times 10^6$	No change. Specimen unbroken. Test complete.
			Specimen FKY1A.	
1	± 1·10	± 1·100	$0{\cdot}10 \times 10^6$	Slip over stress peaks. Boundary between crystals 1 and 2, and slight cracks visible.
2			$0{\cdot}50 \times 10^6$	Possible increase of slip, cracks extend slightly.
3			$0{\cdot}84 \times 10^6$	Extension of cracks.
4			$1{\cdot}50 \times 10^6$	,, ,,
5			$1{\cdot}86 \times 10^6$	,, ,,
6			$3{\cdot}04 \times 10^6$	Cracks have extended further having joined up in many places to forms a nearly continuous crack between the enlarged ends.
			Specimen FKY5A.	
1	± 1·42	± 1·376	150,000	Heavy slip, many cracks. Failure of specimen.

V. RESULTS OF MICROEXAMINATIONS.

(1) *Specimen FKYIC* (± 0·983 ton/in.² maximum resolved shear stress).

(a) *Slip.*—The general appearance of the slip-bands observed on this specimen was similar to that previously observed on single crystals and described in earlier papers. The distribution of slip-bands agreed closely with that predicted by the resolved shear stress distribution (see Fig. 3): in Fig. 3 the black dots indicate the areas over which slip was observed. The applied range of stress was insufficient to produce slip over the complete surface, visible slip being absent in areas corresponding to low values of resolved shear stress. The only anomalous slip observed was in crystal 2 on plane 2, as shown in Fig. 3. Since a small amount of anomalous slip is often observed in the early stages of tests on specimens consisting of one crystal only, no great importance need be attached to such anomalous slip.

The production of slip-bands had practically ceased after the first 280,000 stress cycles had been applied: subsequently, the specimen became completely work-hardened under the applied range of stress. Everywhere, the intensity of slip was relatively light. Fig. 6 (Plate I) shows a typical area at a region where the resolved stress was a maximum.

(b) *Effect of Boundaries.*—The amount and intensity of slip was so small in the regions of boundaries (although still consistent with the resolved shear stress law) that little information on this aspect could be obtained. Fig. 7 (Plate I) shows slip in crystal 4 at its boundary with crystal 1. Neither increase nor decrease of intensity with approach to the boundary is visible. The general distribution of slip-bands shows that the specimen as a whole deformed in accordance with the maximum resolved shear stress law.

No cracks were observed throughout the test.

(2) *Specimen FKY1A.*

(a) *Slip.*—The slip-band distribution in this specimen, as in the former, was in extremely good agreement with that predicted by the resolved shear-stress law (see Fig. 4). Here again, there were areas exposed to low resolved stress values over which visible slip was absent.

No anomalous slip was observed.

It is very interesting to note that at boundaries such as those separating crystals 1 and 2,* also 1 and 4,* where an abrupt change occurred in the value of the maximum resolved shear stress at the boundary, the deformation was sharply controlled by the resolved shear stress criterion.

No definite increase in quantity of slip was noted after 500,000 stress cycles.

(b) *Cracks.*—After the first stage of the test ($0{\cdot}10 \times 10^6$ stress cycles) the boundary 1, 2 became visible in places as a slight surface disturbance. Several other markings were visible, in its close proximity, which may have been small cracks. After a total of $0{\cdot}84 \times 10^6$ cycles, these markings had grown more definite and left no doubt that in some regions close to or along the boundary, cracking had started.

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* In what follows, such boundaries will be designated by "1, 2," "1, 4," &c.

Very considerable attention has been given to the exact location of these cracks with regard to the intercrystalline boundary. A series of photographs was taken, after the first test, over the area containing the boundary, in such a way as to give a complete panoramic view. This procedure was repeated after each test except the second. At the end of the endurance test (total of $3{\cdot}04 \times 10^6$ stress cycles), the specimen was repolished and etched, and a further set of photographs, reproduced in Fig. 21 (Plate IX), was taken. Subsequent comparison of the panoramic views led to the conclusion that cracking had proceeded by the propagation of the original small cracks, and their final joining up. It was clearly established that these cracks did not form initially at the boundary, neither did they show any preference to follow the boundary in their course. At times, as shown in Fig. 20 (Plate VIII), their course does follow the boundary closely for a short length. It is possible that the initiation of cracking in these regions and the general direction of propagation of cracking is caused by the abrupt change in resolved shear stress which occurs at the boundary : the effect of the boundary, as such, is incidental.

As shown in Figs. 4 (p. 24) and 21 (Plate IX), cracking in this region occurred almost entirely in crystal 2 where the resolved shear stress curve 23 approached the maximum resolved shear stress on the specimen, increasing with closer proximity to the boundary. In two places, cracks extend for a short distance into crystal 1 where the resolved shear stress is relatively low.

After the second test, a few short cracks were visible in crystal 6 and its near neighbourhood. These cracks extended slightly during the remaining tests. Their position relative to the boundaries is uncertain since the final etch failed to show up the latter. It is certain, however, that these cracks occurred close to the boundaries, probably crossing them in places.

(3) *Specimen FKY5A.*

(a) *Slip.*—This specimen was subjected to a range of stress considerably exceeding the fatigue range, and heavy slip occurred over the complete specimen. Considering the marked distortion which occurred, it was somewhat surprising to find that the slip distribution was again in excellent agreement with the calculated resolved stress distribution (see Fig. 5). There was visible only a small amount of anomalous slip, occurring mainly on plane 2 of crystal 1 and on plane 2 of crystal 5; also, slip on plane 0 of crystal 2 was more persistent than predicted by the resolved stress curves. It will be seen from Fig. 5, however, that the general agreement was excellent.

(b) *Effect of Boundaries.*—(i) *Boundary* 4, 1. Part of this boundary

PLATE I.

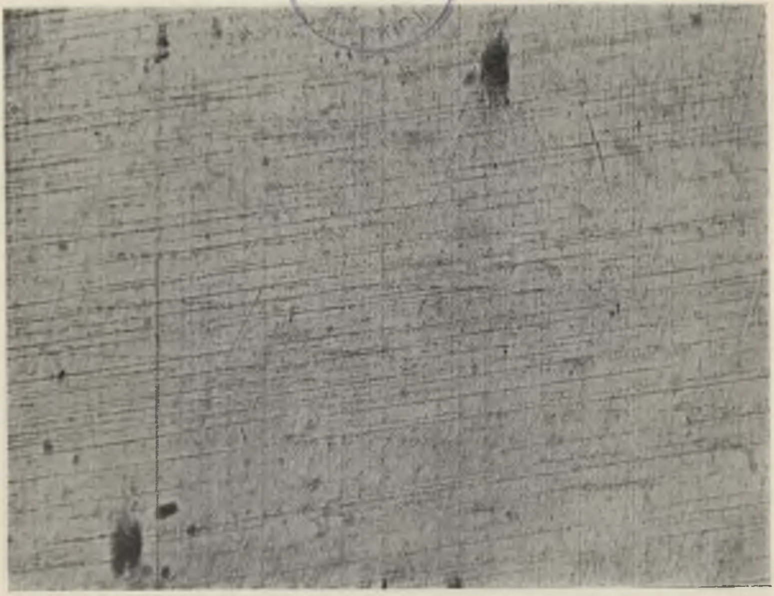

FIG. 6.—Specimen FKY1C. λ = 158°. Typical Slip (Crystal 3). × 100.

FIG. 7.—Specimen FKY1C. λ = 272°. Slip at Boundary 4, 1. × 100.

FIG. 8.—Specimen FKY5A. λ = 38°. Part of Boundary 4, 1. × 100.

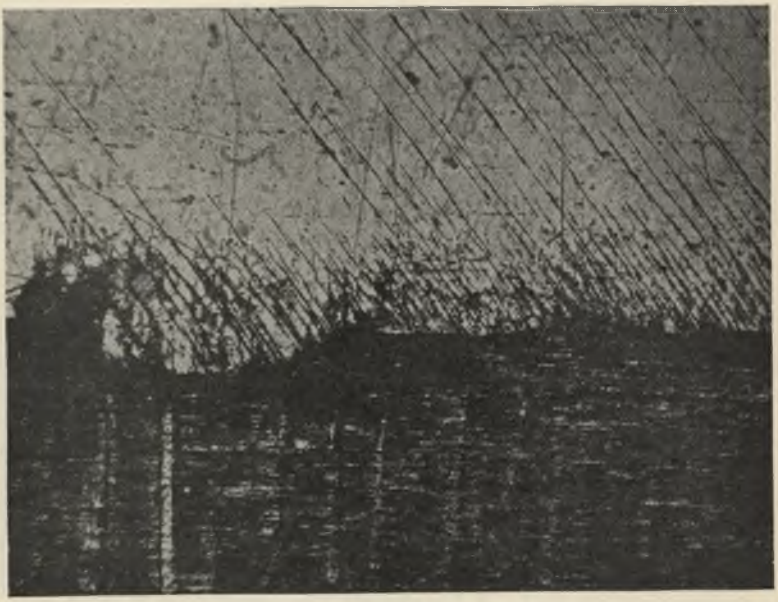

FIG. 9.—Specimen FKY5A. λ = 180·3°. Part of Boundary 1, 2. × 100.

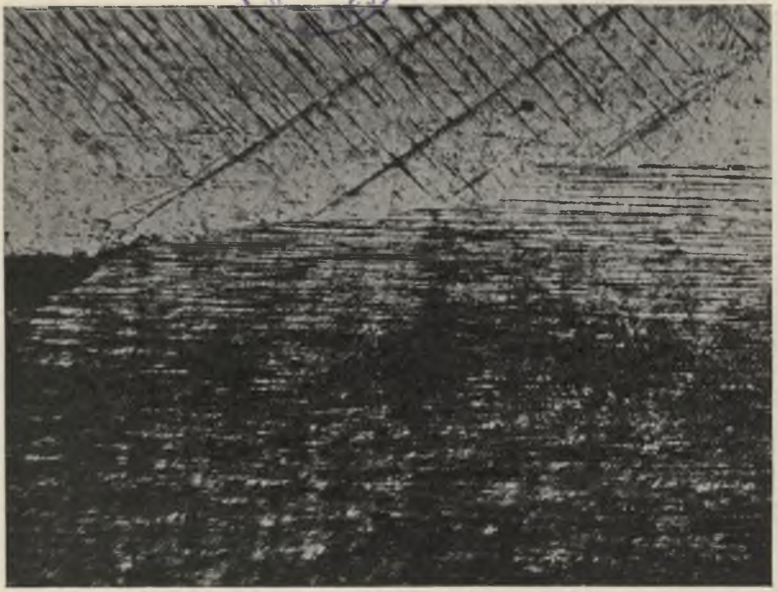

FIG. 10.—Specimen FKY5A. λ = 180·3°. Further Photograph of Boundary 1, 2. × 100.

FIG. 11.—Specimen FKY5A. λ = 310°. Part of Boundary 3, 5. × 100.

PLATE IV.

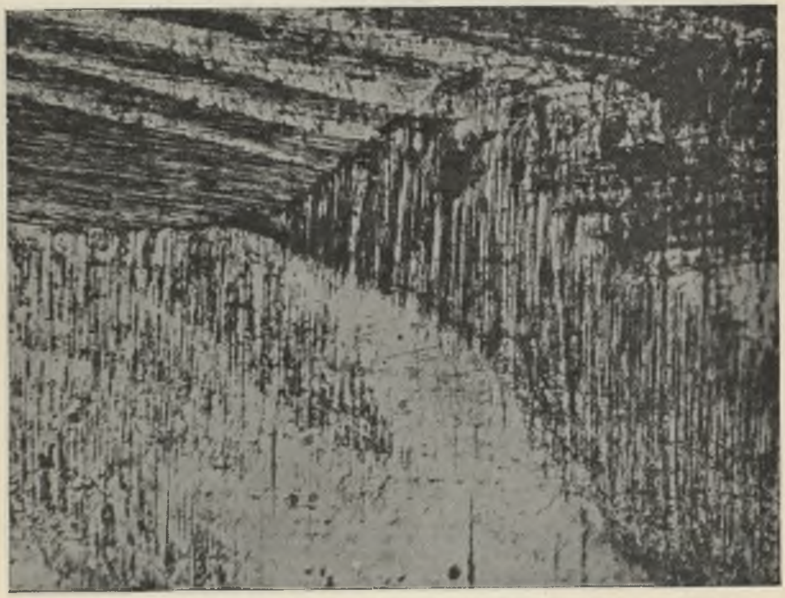

Fig. 12.—Specimen FKY5A. λ = 318°. Further Photograph of Boundary 3, 5. × 100.

Fig. 13.—Specimen FKY5A. λ = 318°. Further Photograph of Boundary 3, 5. × 100.

FIG. 14.—Specimen FKY5A. λ = 327°. Slip Near Centre of Crystal 5. × 100.

FIG. 15.—Specimen FKY5A. λ = 339°. Part of Boundary 5, 4. × 100.

FIG. 16.—Specimen FKY5A. $\lambda = 339°$. Part of Boundary 5, 4. × 100.

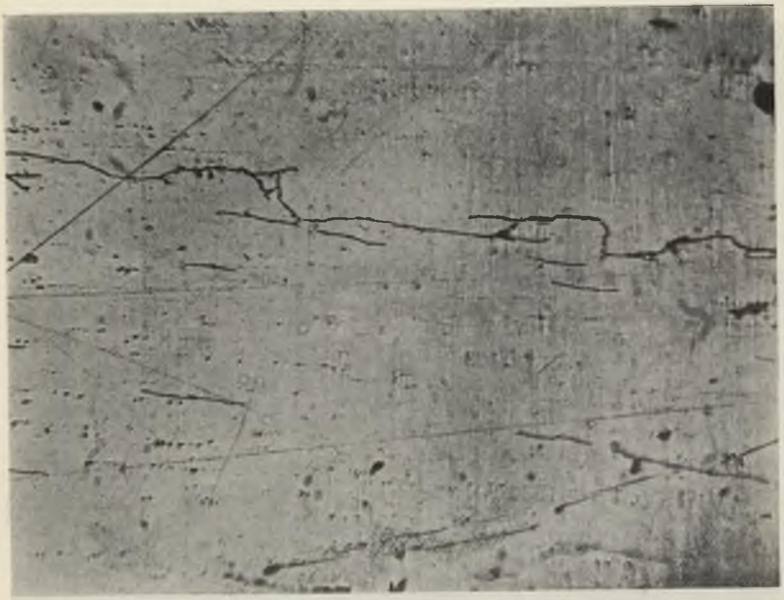

FIG. 17.—Specimen FKY5A. $\lambda = 341°$. Cracks Near Boundary 5, 4 (After Etching). × 100.

FIG. 18.—Specimen FKY5A. $\lambda = 62{\cdot}5$. Cracks in Crystal 1 at Low Resolved Shear Stress (After Etching). × 100.

FIG. 19.—Specimen FKY5A. $\lambda = 305°$. Cracks About Boundary 3, 5 (After Etching). × 100.

FIG. 20.—Specimen FKY1A. λ = 206°. Part of Boundary 1, 2 (Shown in Fig. 21, Plate IX) (After Etching). × 180.

PLATE IX.

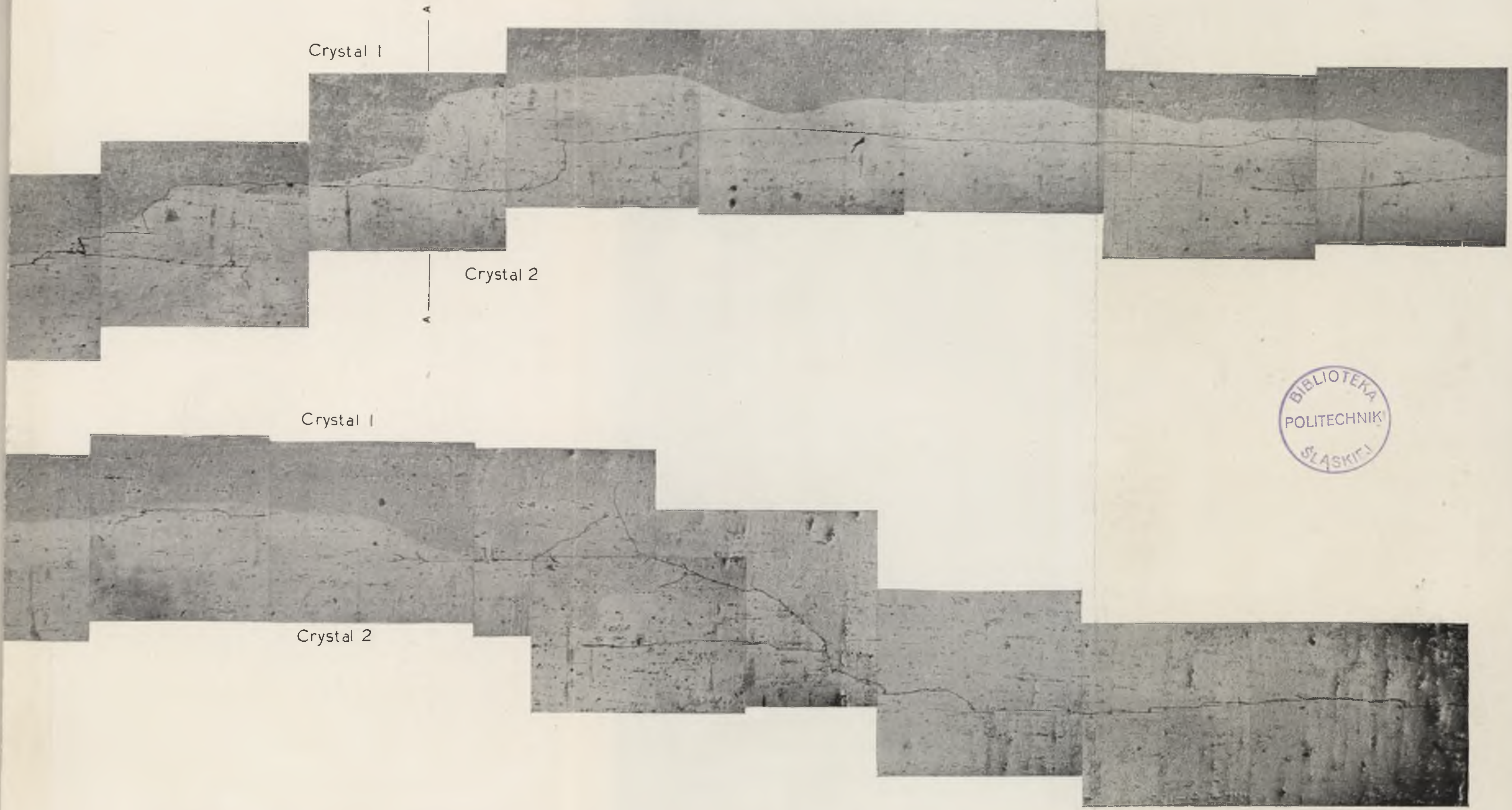

FIG. 21.—Specimen FKY1A. Panoramic View of Crack and Boundary after Etching. λ = 200°–211°. × 50.

[*To face Plate VIII.*

is shown in Fig. 8 (Plate II). Little change in intensity of slip was observed in either crystal, with close approach to the boundary, at which the slip system ceased quite abruptly.

(ii) *Boundary* 1, 2.—Figs. 9 and 10 (Plates II and III) are typical of this area. There is no evidence of any striking change in the slip on crystal 2 with proximity to the boundary. This slip was very heavy; the black line running close to the boundary is a crack. In crystal 1, the resolved shear stress was decreasing rapidly with approach to the boundary. The slip behaviour varied slightly with different positions longitudinally on the specimen. Thus Fig. 9 shows an area where slip on the 0 plane increased with approach to the boundary, whereas in Fig. 10 a decrease is noticed—possibly due to slip appearing in this area in the 32 direction with consequent partial inhibition of slip on the other plane. This boundary is exceptionally interesting because of the abrupt change in value of the resolved stress distribution.

(iii) *Boundary* 2, 3.—Boundary 2, 3 lay between two crystals on each of which two sets of slip were visible (refer to stress curves) the recorded slopes on crystal 2 being nearly equal to those on crystal 3. The slopes were about $\varphi = +76°$ and $\varphi = 0°$ on each crystal.* The boundary was only apparent because the intensity of slip differed in the two crystals. There was no evidence that the boundary had any effect on the slip distribution. Slip continued right up to the boundary.

Crystal 5 was the narrowest crystal in the specimen. Figs. 11, 12, and 13 (Plates III and IV) show different parts of boundary 3, 5. From these it is clear that there was considerable variation in slip distribution along the length of the crystal. Slip on both the observed sets of planes continued right up to the boundary without increase or decrease of intensity in regions where they were dominant. Fig. 14 (Plate V) shows slip typical of areas in the centre of the crystal, whilst Figs. 15 and 16 (Plates V and VI) show the boundary 5, 4. Slip on the 0 plane showed a tendency to stop short at this boundary (Fig. 16) although there was no drop in calculated resolved shear stress. Fig. 15 shows some anomalous slip on the 2 plane. This occurs close to the boundary only.

(c) *Cracks.—Before* the specimen was etched, cracks were observed in the neighbourhood of boundaries 1, 2 and 5, 4. The main crack was near boundary 1, 2, of which a panoramic series of photographs was taken. Figs. 9 and 10 (Plates II and III) are typical of small areas. The crack was located in crystal 2 except where it appeared to coincide with the boundary. The calculated resolved shear stress in crystal 2

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* φ = the angle, in the plane of the specimen surface at the point on the surface under consideration between the slip-band and a line perpendicular to the specimen axis.

was nearly a maximum for the specimen at this λ value (see Fig. 5), but the stress in the complementary crystal (2) was low.

The crack in the neighbourhood of boundary 5, 4 occurred mainly in crystal 4, where the resolved shear stress was also very high, but in certain areas (see Fig. 15, Plate V) appeared to coincide with the boundary. No cracks were observed, during this stage of the examination, in the area of crystal 3 corresponding to the stress peak 31 which was subjected to the maximum calculated operative resolved shear stress.

After the above-mentioned examination, and to study the relation of the cracks and boundaries in greater detail, the specimen was repolished and etched. It was found to be covered with a profuse system of cracks (see Figs. 17, 18, and 19, Plates VI and VII) the majority of which had not previously been visible. They were wavy but had a general direction parallel to the slopes of the traces of the operative slip-planes. In general, they occurred in the previously observed regions of heavy slip, *i.e.* in the areas of maximum stress. It is worthy of remark that cracks occurred in crystal 1 on which the resolved shear stresses were relatively low. No cracks could be seen, however, at the actual peak of the curve in crystal 1, the reason for which is obscure. An attempt at correlation of the length and frequency of the cracks with resolved shear stress produced no satisfactory result.

The long crack previously observed near boundary 1, 2 was again examined and photographed. It was established, as in the previous case of specimen FKY1A, that the crack was very close to the boundary but not along it.

Cracking in the neighbourhood of boundary 5, 4 was observed to be nearly continuous. The relations of these cracks with the boundary were uncertain since the latter were not clearly revealed by etching. Part of the longest crack in this region is shown in Fig. 17 (Plate VI).

Figs. 18 and 19 (Plate VII) are also of interest. Fig. 18 shows cracks in crystal 1 at a low resolved shear stress, although this represented the local maximum. Fig. 19 shows cracks about boundary 3, 5—the value of resolved stress in this portion of crystal 3 is greater than in any other area of the whole specimen.

VI. General Conclusions.

(1) The deformation, as judged by the slip-band distribution of each of the three specimens, was entirely consistent with that predicted by the stress distribution calculated on the assumption that each component crystal was uninfluenced by the presence of the remaining crystals and that the deformation was controlled by the maximum

resolved shear stress law: the total amount of anomalous slip was very small, not exceeding an amount often encountered in single crystals subjected to torsional couples while rigidly constrained laterally.

(2) The influence of the boundaries on the slip-bands formed in their neighbourhood was very slight and irregular. In many cases, the slip-bands persisted unaltered right up to the boundaries: in a few cases, the spacing of the bands increased near the boundary, in a few other cases, the spacing decreased as the boundary was approached.

(3) Two specimens were tested to destruction and, in each case, failure occurred principally by cracks which were situated in the near vicinity of the boundaries. In every case, however, these areas also happened to be those subjected to high values of resolved shear stress and, had the specimen been monocrystalline, cracking would have been expected in exactly the same areas. The observations indicate that the tendency of poly-crystalline specimens to crack may be increased when a boundary separates two regions subjected to widely differing values of resolved shear stress; the effect produced is probably due to the sudden change of resulting strain rather than to boundary influence as such.

(4) It has been fairly clearly established that: (*a*) fatigue-cracking does not commence at the boundary; (*b*) the general course of a crack, having encountered a boundary, displays no tendency to continue along the boundary; and (*c*) the cracks are mainly confined to that side of the boundary subjected to the highest value of resolved shear stress.

(5) The three specimens were each tested throughout at a constant range of stress and afford a good indication of the limiting fatigue range of this type (four to six crystals) of large-crystal specimen: the deduced value of the fatigue limit on an endurance basis of 10^8 stress cycles is $\pm 1{\cdot}0$ ton/in.^{2} maximum resolved shear stress. This value differs so slightly from the fatigue-resistance of single crystals of aluminium that, with the crystal size employed in the present tests, no " grain-size " effect on fatigue-resistance appears to be disclosed.

ACKNOWLEDGMENTS.

The work described forms part of a general research into the characteristics of fatigue phenomena financed by the Advisory Council of the Department of Scientific and Industrial Research and carried out under the general supervision of the Executive Committee of the National Physical Laboratory. The authors desire to acknowledge their indebtedness to these bodies for the opportunities and facilities afforded to carry out the work and for permission to publish the results,

and also to the Superintendents of the Physics and Metallurgical Departments of the Laboratory where the X-ray analyses and the polishing of the specimens, respectively, were carried out.

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THE MAGNESIUM–COPPER ALLOYS. PART V.—THE COPPER-RICH ALLOYS.*

By Professor W. R. D. JONES,† D.Sc., Member.

Synopsis.

The copper-rich alloys which contain magnesium do not offer much hope of being useful in view of the difficulty of obtaining sound castings and the fact that many copper-rich alloys with other metals can be obtained with much less trouble and have better mechanical properties.

Owing to the great affinity of magnesium for gases, considerable difficulty has been experienced in producing sound ingots of the magnesium–copper alloys. Unless the molten copper be free from gas and oxides before the magnesium is added, a large amount of dross is formed which is difficult to disentangle from the metal.

An improvement was obtained by pre-solidification of the copper, by the addition of phosphor–copper, and by passing a stream of dried nitrogen through the molten copper, before adding the magnesium. A large number of fluxes has been tried which make the molten material appear more fluid, but dross is still formed during the actual pouring operation and the column of liquid seems to be enclosed in a tube of dross which is enfolded into the solidifying metal.

Numerous experiments showed that the production of castings free from dross depends much more on the method of casting than on other factors such as the composition of the flux, the casting temperature, the mould, the mould dressing, or the mould temperature. The ingots were improved, however, by attention to these details, and there seemed to be little difference whether they were cast into dry sand, or green sand, or chills, as the ingots appeared to be quite sound, had good surfaces, and rang "true." In spite of these good indications, they showed the presence of dross inclusions when fractured. Some improvement was obtained by the use of a tundish during pouring, by playing a stream of coal-gas or of nitrogen on the stream of metal, and by the use of a bottom-pouring crucible.

An apparatus was then constructed on the Durville principle.

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Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LVIII, 1936. Reference should accordingly be as follows: *J. Inst. Metals*, 1936, **58** (Advance copy).

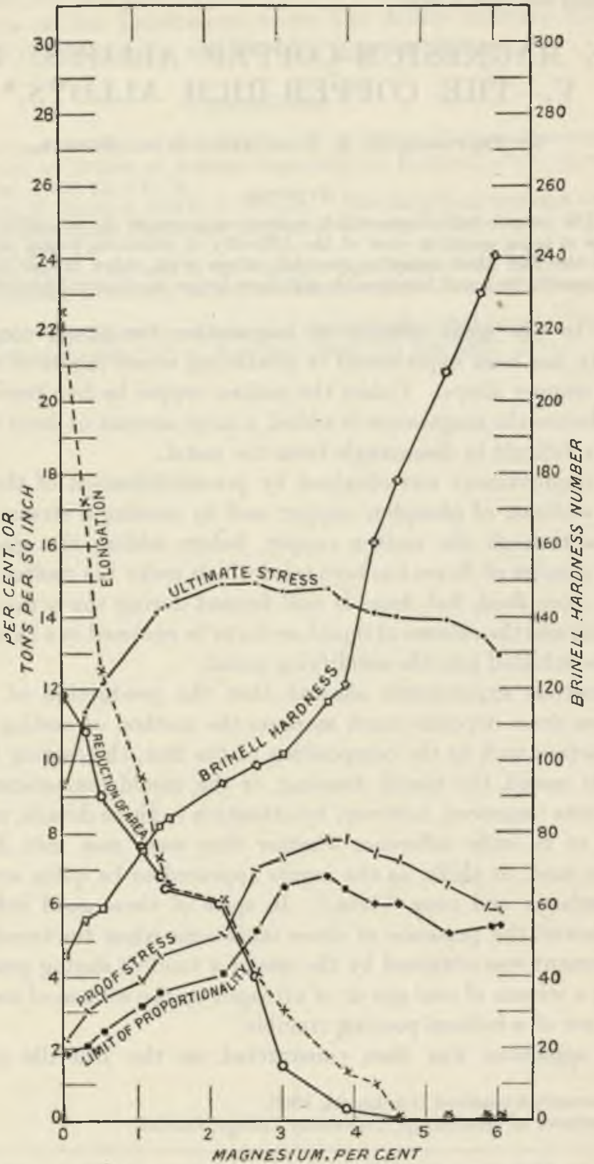

Fig. 1—Mechanical Properties of 1-In. Diameter Chill-Cast Bars, As Cast.

As the metal melted was comparatively small, the melting crucible itself was clamped to the mould and inverted. The following procedure was adopted to produce the chill-cast ingots, the properties of which are detailed in Figs. 1 and 2 : cathode copper melted under charcoal was thoroughly poled and allowed to solidify, quickly remelted, and the magnesium added. The metal was stirred and withdrawn after about 5 minutes, and the surface skimmed. The pot was then assembled in the casting apparatus, the channel and mould of which had been preheated to about 300°–350° C. and inverted. During the inversion, which took about 30 seconds, a stream of nitrogen from a cylinder was allowed to play on the surface of the metal.

The alloys which were most liable to contain dross are those containing from about ½ to 3 per cent. magnesium. It is possible that the eutectic which is formed with more than 2·6 per cent. magnesium keeps the alloy molten to a low temperature so that the dross can be disentangled and not trapped in the metal.

The properties of 1-in. diameter cast bars are given in Fig. 1.* These are only a selection from the results because many apparently sound ingots broke under very low loads due to the presence of small films of dross in the metal. They can be taken, however, as representative of the mechanical properties of sound bars.

Fig. 1 shows that the effect of adding magnesium to copper is to increase the tenacity, limit of proportionality, proof stress, and hardness, but also to decrease seriously the elongation and reduction of area. The optimum properties are obtained with the addition of about 2¼ per cent. magnesium, which is near the limit of solid solubility; with more than this amount the properties deteriorate and with an addition of 4·25 per cent. the alloys become very brittle and there is practically no elongation or reduction of area, while there is a great increase in hardness. The effect of annealing the chill-cast bars at 700° C. for 1 hr. is shown in Fig. 2, from which it can be seen that the annealing improved the properties (with the exception of tenacity, which decreased by about 1½ tons/in.^{2}).

A series of ingots 18 in. × 2½ in. in diameter was cast containing varying amounts of magnesium for rolling down to 1-in. diameter bars.

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* The tests were carried out on a Riehle multiple-lever testing machine carrying self-centering ⅞-in. screw grips. The test-pieces had screw-threaded ends and were 0·564 in. in diameter with a parallel length of 2·25 in. The limits of proportionality were obtained from load–extension diagrams obtained by the use of a Ewing extensometer. The proof stress has been taken as that giving a permanent extension of not more than 0·025 per cent. of the gauge-length of 2·00 in., *i.e.* 0·0005 in. and was obtained from the load–extension diagram. Brinell hardness tests were carried out on an Amsler machine using a 10 mm. ball and a load of 1000 kg. applied for 30 seconds.

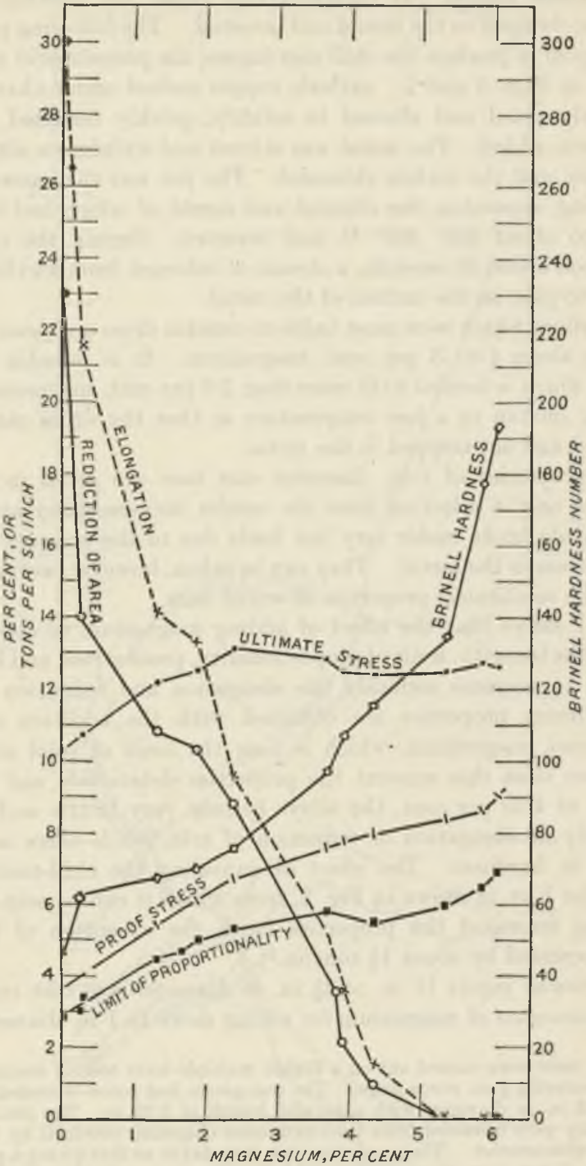

Fig. 2.—Mechanical Properties of 1-In. Diameter Chill-Cast Bars, After Annealing.

The skins of the ingots were fairly good, but the ingots were roughly machined before they were rolled. Through the courtesy of Mr. W. T. Griffiths, M.Sc., the ingots were rolled at the Research Laboratory of the Mond Nickel Company, Ltd., in Birmingham; Dr. L. B. Pfeil kindly superintended the rolling experiments. The results were most disappointing as only two bars from 10 ingots cast were obtained—these are marked 2F and 16F and contain, respectively, 1·42 and 0·17 per cent. magnesium. A 25-lb. melt was made at the Research and Development Department Laboratory of the Mond Nickel Company, Ltd., which on analysis gave copper 98·56 and magnesium 1·44 per cent. The copper was melted under a slag of barium chloride and the magnesium added in the form of sticks about $\frac{3}{4}$-in. in diameter, plunged by means of copper wire through the slag and beneath the surface of the molten metal. The metal was cast into an ingot 2-in. square and, after cropping, an attempt was made to roll it at 600° C. The ingot cracked at an early stage, thereby indicating that the use of square

TABLE I.—*Mechanical Properties of Forged Bars.*

No.	Magnesium, Per Cent.	Treatment.	Limit of Proportionality, Tons/in.^{2}.	Proof Stress.	Ultimate Stress.	Elongation on 2 in., Per Cent.	Reduction of Area, Per Cent.	Brinell Hardness No.
16F	0·71	As forged	9·0	13·2	22·9	33·6	63·3	95
		Heated 1 hr. at 700° C. and slowly cooled	2·7	3·9	18·0	53	76	57
		Heated 1 hr. at 700° C. and quenched	3·3	5·0	18·1	51	78	57
		Heated 1 hr. at 700° C. and quenched; then tempered 36 hrs. at 300° C.	2·9	3·7	17·9	64	83	57
2F	1·42	As forged	8·9	12·1	25·9	32	29·3	110
		Heated 1 hr. at 700° C. and slowly cooled	3·7	4·6	20·9	45	57	65
		Heated 1 hr. at 700° C. and quenched	3·8	4·6	21·0	57	65	64
		Heated 1 hr. at 700° C. and quenched; then tempered 36 hrs. at 300° C.	3·8	4·8	20·7	59	66	64

instead of round ingots gave no improvement. It would be unsafe finally to conclude that the magnesium–copper alloys which contain more than about 1½ per cent. magnesium are unforgeable, in view of the importance of such factors as cleanliness of metal, casting temperature, ingot shape, forging temperature, and reduction per pass. In the case of these ingots further experiments must be carried out in order to be certain that the bad results are not due to the presence of dross in the metal, as it is very difficult to avoid dross being formed during the actual teeming operation.

Table I gives the results of the mechanical properties of the forged bars.

It can be concluded from these figures that heat-treatment increased the elongation and reduction of area and reduced the limit of proportionality and the breaking load. It is interesting to note that the age-hardening treatment did not result in any alteration to the properties which had not been effected already by the ordinary heat-treatment.

TABLE II.—*Brinell Hardness Numbers.*

No.	Magnesium, Per Cent.	As Received.	Quenched from 700° C. and Tempered at									Reheated at 700° C. for 2 Hrs. and Quenched.	
			As Quenched.	300° C. 4 Hrs.	300° C. 17 Hrs.	300° C. 36 Hrs.	300° C. 72 Hrs.	400° C. 4 Hrs.	500° C. 4 Hrs.	600° C. 4 Hrs.	500° C. 36 Hrs.	As Quenched.	Tempered 36 Hrs. at 300° C.
16F, as forged	0·71	94	56	57	55	57	57	58	57	55	57	55	56
2F, as forged	1·42	104	64	65	68	65	64	67	65	61	67	66	68
68·1, as cast	1·45	84	64	64	65	66	66	...	...	...	...	...	...
6N, as cast	2·49	98	78	78	76	76	75	82	89 ?	82	86	73	75

From the equilibrium diagram * of this series of alloys it is seen that the solubility of magnesium in copper decreases from 2·6 per cent. at 700° C. to about 2–2·2 per cent. at room temperatures. It might be expected, therefore, that some degree of age-hardening would take place, and experiments were carried out to examine this point. Specimens about 1-in. in diameter and $\frac{5}{16}$ in. thick were given various treatments, and the Brinell hardness number determined (1000/10/30), after grinding the surfaces to " 00 " Hubert French emery finish.

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* *J. Inst. Metals*, 1931, **46**, 402.

The preliminary heat-treatment consisted of heating the bars to 700° C. and maintaining the temperature for 1½ hrs. and quenching in water. During the ageing heat-treatments the temperature of the furnace was maintained by automatic control to ± 2° C., after which the test-pieces were quenched in water. The results are given in Tables II and III.

Table III.—*Brinell Hardness Numbers.*

No.	Magnesium, Per Cent.	Heated at 700° C. and Cooled Slowly.	Tempered 36 Hrs. at 300° C. after Slow Cooling.	Heated at 700° C. and Quenched.	Tempered 36 Hrs. at 300° C. after Quenching.
AD2	1·87	67	72	62	65
AD6	2·37	77	80	72	78
AD9	3·90	107	128	123	124
AD7	4·32	120	124	131	132
AD15	5·31	146	146	146	148
AD16	5·84	167	146	168	174
AD14	6·04	164	174	165	165

From the results of these experiments it can be concluded that, although there are a few irregularities in the hardness numbers, these alloys do not show age-hardening properties to any extent.

Examination of the specimens under the microscope revealed practically no differences except that the structures of the quenched specimens showed absorption of the dendritic pattern in Nos. 68 and 6N, giving in the former case an equiaxed polygonal structure of fairly regular grain-size and in the case of 6N a similar structure with isolated globules and threads of the compound $MgCu_2$; in the case of the forged specimens, Nos. 2F and 16F, the heat-treatment at 700° C. resulted in breaking up the dendritic pattern which had been distorted during forging and in producing a typical twinned α structure. Tempering produced no difference in the structure other than slightly increasing the grain-size with a rise in the tempering temperature.

Conclusions.

The effect of magnesium on copper is beneficial up to an addition of about 2 per cent., but the alloys do not offer much hope of being useful in view of the great difficulty of obtaining good castings and the fact that many copper-rich alloys with other metals, such as zinc, tin, and nickel, have better mechanical properties which can be obtained with much less trouble.

ACKNOWLEDGMENTS.

The author desires to acknowledge gratefully his indebtedness to the British Non-Ferrous Metals Research Association for supplying the cathode copper used in these experiments; and also to Mr. W. T. Griffiths, M.Sc., of the Research and Development Department of the Mond Nickel Company, Ltd., for his valuable help.

AN ELECTROLYTIC TEST FOR ZINC COATINGS ON WIRE.*

By S. C. BRITTON,† M.A., Member.

Synopsis.

A test for zinc coatings on wires has been designed to overcome the objections to tests based on chemical dissolution. Two tests are proposed: a stripping test designed to estimate the weight of coating which must be removed by uniform attack before the iron base is exposed, and a wrapping treatment followed by a stripping test designed to gauge the liability of a coating to crack. The stripping test is carried out by electrolysis in a specially designed cell, a fixed current density being employed so that each unit of testing time corresponds to a known weight of coating; at the end of the test, a short dip in copper sulphate solution serves to show whether the iron base has been exposed. The test is primarily intended to ascertain whether a coating meets a specification but can be used to determine the actual thickness of coatings. Potential measurements made during strippings provide information as to the structure of coatings. Thus, it has been shown that close-wiped coatings and galvannealed coatings consist almost entirely of zinc–iron alloy. Field tests are demonstrating that the test described gives satisfactory results for conditions of atmospheric exposure while the Preece test has marked shortcomings.

Zinc coatings are applied to wire by hot-dipping, electrodeposition, and by the modification of hot-dipping known as galvannealing. Coatings formed by hot-dipping consist of an outer layer of zinc similar in composition to the galvanizing bath and an inner layer, usually referred to as the "alloy-layer," which contains iron; electrodeposited coatings consist entirely of zinc, whilst galvannealed coatings may contain iron throughout their entire thickness. The rate of reaction of layers of coatings which contain iron with severely corrosive solutions, such as copper sulphate, is rather different from that of relatively pure zinc layers.[1, 2, 3]

In general, there is no reason to suppose that this difference bears any relation to any difference in resistance to corrosion in practical conditions; hence, the methods in common use for testing zinc coatings, which are based on the rate of chemical dissolution of the coating without any correction for any part of the coating which contains iron, are

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likely to yield results which represent neither thickness nor corrosion-resistance. In view of the shortcomings of such tests (*e.g.* the Preece test), a research on the subject of the testing of zinc coatings was carried out for the British Non-Ferrous Metals Research Association, and the electrolytic test described here was developed. Since the test was designed, but before it had been subjected to practical trial, A. Glazunov[4] has published details of a method of testing based on a rather similar principle.

EXPLANATORY OUTLINE OF THE TEST.

Two tests are proposed :

(1) A stripping test designed to estimate the useful weight of coating, *i.e.* the weight of coating which can be removed by uniform attack before any part of the iron base is exposed.

(2) A wrapping treatment, followed by a stripping test, designed to gauge the liability of the coating to crack on mechanical deformation. If cracks in the coating are produced by the wrapping, they become enlarged during stripping, and portions of the coating become detached so that the iron base is exposed earlier than would be the case if no cracking occurred.

In the stripping part of both tests, the coating is removed electrolytically at the same uniform rate from all parts of the test-piece. A fixed current density is employed so that the weight of coating removed from a given area is directly proportional to the time during which the current has been flowing. The " alloy-layer " of a hot-dipped coating is removed at substantially the same rate as the zinc layer, since the iron in the alloy layer also passes into solution at a rate very close to that of the zinc. The current is allowed to flow for a time, corresponding to the thickness which the coating under test is claimed to possess, and then the specimen is dipped for a brief period in copper sulphate solution to determine whether the iron base has been exposed at all. Copper is deposited as a black loose deposit on zinc or on zinc–iron alloy, but in a red form on exposed iron base. A preliminary rapid cleaning in dilute sulphuric acid is adopted to ensure that no film of oxide or of corrosion-product interferes with the necessary uniformity of attack.

THE APPARATUS.

The apparatus consists of :

(1) A cell designed specially to ensure a uniform current density over a test-piece of wire ; this is described below ;

(2) A moving-coil ammeter with ranges 0–1·0 and 0–5·0 amp. ;

(3) A supply of direct current at at least 20 v. ; current from a rectifier may be used, if only alternating current is normally available ;

(4) A variable resistance, appropriate to the voltage supply available. If direct current at 100 v. or more is available, it is a convenience if a fixed resistance of at least 25 ohms is connected in series with the cell. This resistance being large compared to that of the cell, changes in the cell do not materially affect the current flowing, and adjustment of the current density during the test becomes unnecessary. The circuit is illustrated in Fig. 1.

THE SOLUTIONS.

(1) 2 per cent. sulphuric acid.

(2) 10 per cent. copper sulphate.

(3) 20 parts of sodium chloride and 10 parts of zinc sulphate in 100 parts of water.

THE CELL.

The cell is illustrated in Fig. 2. A cylindrical glass jar, of not less than 3 in. internal diameter and not less than 5 in. deep, is fitted with an Ebonite cap pierced centrally by a sleeve terminal and with an Ebonite disc fixed to the bottom of the jar, having a circular depression in its centre of depth not greater than 0·05 in. The curved surface of the jar is completely covered by a roll of perforated zinc, which is sprung tightly against it. The cell is filled with a solution, having 20 parts sodium chloride and 10 parts zinc sulphate in 100 parts of water, to a depth of 4·0 in. above the top of the bottom Ebonite disc. The wire sample to be tested is held in position by the sleeve terminal, so that its bottom end rests in the central depression of the bottom disc. The sleeve terminal is connected to the positive pole of the electrical circuit, and the zinc lining of the jar to the negative pole.

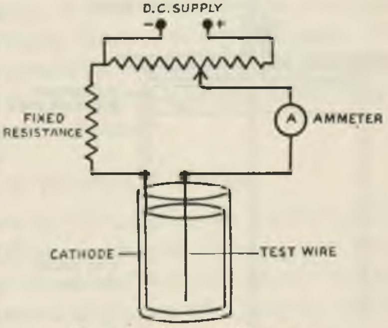

FIG. 1.—Circuit Diagram.

METHOD OF TESTING THE WEIGHT OF COATING.

A sample of length not less than 6 in. is cut and straightened by hand, so that all parts of its surface lie within 0·25 in. of a straight line joining the two ends. The sample is immersed in 2 per cent. sulphuric acid for 15 seconds and is then wiped with cotton-wool and introduced into the testing cell. The current is switched on and is adjusted to a value which provides a current density of 1·0 amp/in.^{2}, *i.e.* a current of 12·5 multiplied by the diameter of the wire in inches. This current removes

0·104 oz./ft.^{2} of zinc per minute. The current is maintained at the correct value for a time which the wire under test ought to withstand if it conforms with specification; if, for example, a wire is specified to have a useful coating of 0·52 oz./ft.^{2} the current should continue for 5·0 minutes. The wire is then removed from the cell, wiped with cotton wool, and immersed in 10 per cent. copper sulphate solution for 5 seconds. If no copper is deposited in a form having a bright red colour, the wire may be considered as meeting its specification.

The sulphuric acid for cleaning the samples and the copper sulphate for determining the end-point should be used in volumes of not less than 100 c.c. and should be renewed when 30 samples have been tested.

METHOD OF TESTING BRITTLENESS OF COATING.

The method recommended for testing the resistance of coating to cracking is similar in outline to the test laid down in British Standard Specification No. 443 for the copper sulphate dipping test; a test of the thickness of coating is made after a standard wrapping treatment. The wrapping is carried out as indicated in British Standard Specification No. 443. " The samples shall be wound on a mandrel so that a length of at least 12 in. is fully coiled. For galvanized line wire for telegraph and telephone purposes as covered by British Standard Specification No. 182, the mandrel shall have a diameter eight times that of the wire. For all other qualities of wire, the mandrel shall have a diameter four times that of the wire if the wire is tested before being used for armouring, stranding, or any similar process; and eight times that of the wire if the wire is tested after being subjected to any such process." The only amendment to this is that the speed of wrapping should approximate to one turn per second.

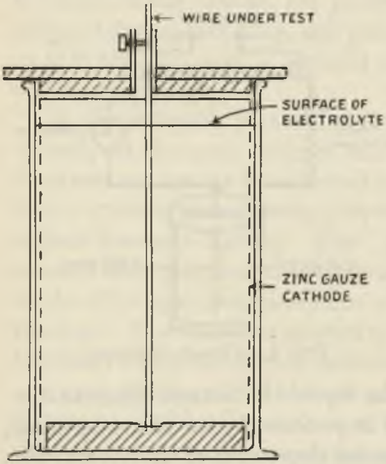

FIG. 2.—Section Through Cylindrical Cell Used for Wire.

The sample is unwound and straightened so that all parts of its surface lie within 0·25 in. of a line joining the two ends. The straightening may be carried out by pulling in a machine, but the stress applied should not exceed 85 per cent. of the breaking load of the wire. A length of

6 in. is cut from the portion which has been coiled, and is subjected to the stripping test for the period which the wire is specified to withstand after wrapping. If at the end of this period, the iron base of the wire is laid bare at any point, the sample has failed. The specified period should be 75 per cent. of the period for which the wire is specified in the undamaged state.

SOME EXTENSIONS OF THE TEST.

(1) *Determination of the Useful Thickness of a Coating.*

Whilst the test described is intended primarily to determine whether or not the thinnest parts of a coating are of a specified thickness, it may be employed to determine the actual thickness. The coating is stripped for a period; a test is then made with copper sulphate solution for bare iron; if none is detected, the sample is rinsed, replaced in the cell, and subjected to a further 15 seconds' stripping before testing again in copper sulphate. This process is repeated until failure occurs; a figure representing the thickness of the coating is then given by the total time during which the coating was being electrolytically stripped. The first period of immersion must necessarily be shorter than the period of stripping which causes failure, and if nothing is known of the coating tested, a preliminary rough test may be desirable.

(2) *Investigation of the Structure of Coatings.*

When a zinc coating is removed by electrolysis, the potential difference between the wire and the cathode varies with time in a way which may be used to give information about the structure of the coating. Fig. 3 shows the variation of potential difference with time for various coatings on wire. The form of the curve for hot-dipped coatings consists essentially of five parts the ends of which are indicated for Wire No. 1 of Fig. 3, by the letters *A B C D E F*. When electrolysis commences, the surface of the coating exposed to the electrolyte consists solely of zinc, and so long as it remains so, the potential does not alter. When, however, sufficient zinc has been removed to expose some of the layer of zinc–iron alloy, the potential begins to rise (the point *B* on the curve) and continues to change so long as the surface exposed to the electrolyte changes. Normally, the increase ceases when all of the zinc layer is removed, and the surface consists wholly of alloy, a condition represented by the point *C*. The potential then remains unchanged until some of the iron base becomes exposed (the point *D*), when it again rises as the area of bared iron increases to reach a steady value again when all the coating is removed. Since the coating is removed at a uniform rate from all parts of the wire, a time period of electrolysis corresponds to a definite weight of coating dissolved. Thus, time intervals of various sections of curve 1 of Fig. 3 represent :

AB : the thickness of the thinnest part of zinc layer ;
AC : the thickness of the thickest part of zinc layer ;
AD : the thickness of the thinnest part of the total coating ;
AE : the thickness of the thickest part of the coating.

From this it follows that the time intervals between *BC* and *DE* give an indication of the uniformity of the zinc layer, and of the total coating, respectively. It is only possible to deduce limits for the thickness of the alloy layer ; no part can be thicker than is represented by the time interval between *B* and *E* and no part can be thinner than is indicated by the time interval between *C* and *D*.

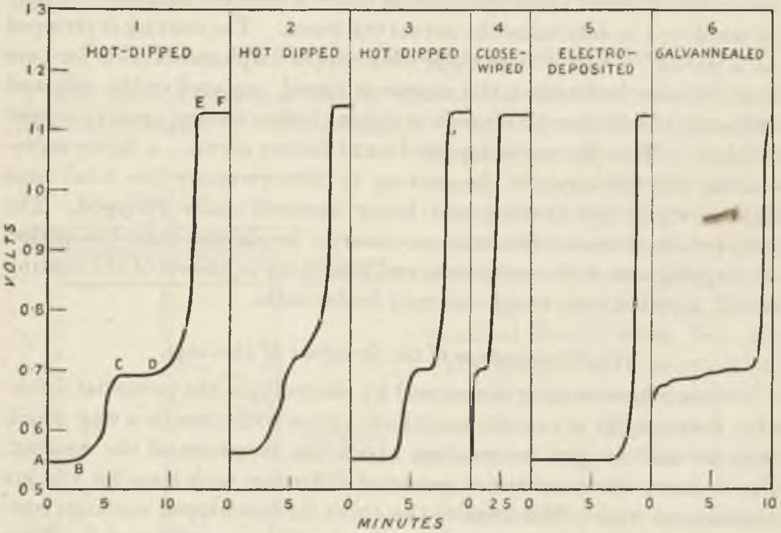

FIG. 3.

It will be noticed that curve 2 does not exhibit at all clearly a length corresponding to the section *CD* of curve 1. This effect does occasionally occur and may indicate either a coating with a very thin alloy layer or more generally a coating so uneven that the iron base is bared in some areas whilst some of the zinc layer remains on others. Usually, however, it is possible to gain information about the thicknesses of the layers of the coating. Thus, in Fig. 3, the absence of an alloy layer from the electrodeposited coating and the thinness of the zinc coating on the close-wiped and galvannealed coatings are revealed.

The numerical values of the potential measured vary with temperature, the current used, the condition of the electrolyte, and other factors, but sufficient control is easily maintained during the course of the stripping of one coating to ensure that the characteristic shape of curve is obtained. For coatings on wire the use of the cell and electrolyte as prescribed for the test of thickness, with a voltmeter connected between the wire and cylindrical cathode, gives adequate control of the conditions, without special precautions.

U. R. Evans [5] obtained potential–time curves, similar to those shown in Fig. 3, during the removal of zinc coatings by acid, but owing to the differing rates of solution of the various layers of the coatings, the time intervals obtained did not represent definite thicknesses of metal.

A. Glazunov,[4, 6] interpreting the same type of curves obtained during electrolytic removal of coatings, appears to regard the potential at any given instant as characteristic of only one phase of the coating, and, hence, to attribute the periods of changing potential to the dissolution of solid solutions. The areas of coating employed were somewhat smaller than those employed in the present research, in which the periods of changing potential always appeared to signify the exposure of more than one layer of the coating to the electrolyte.

DISCUSSION.

(1) *The Test for Thickness of Coating.*

The suggested electrolytic test provides a measure of the useful weight of a coating; it attempts no measure of the corrosion-resistance of the metal. There is evidence, however, that so far as atmospheric corrosion is concerned, the rate of corrosion of zinc coatings does not vary much with their nature, so that the result given by the test does, in fact, represent resistance to atmospheric corrosion.

The tests of the American Society for Testing Materials on zinc coatings applied by hot-dipping, electrodeposition, and sherardizing appear to be leading to the conclusion that for atmospheric corrosion the thickness of the coating is more important than its method of application.[7] Hippensteel, Borgmann, and Farnsworth [8] found no difference in the rate of loss of weight, in an industrial atmosphere, for hot-dipped, heat-treated hot-dipped, or sherardized coatings. W. S. Patterson [9] found that the resistance of hot-galvanized coatings and electrodeposited coatings was similar in conditions of simple atmospheric exposure where no erosion occurred. K. Daeves [10] has suggested that the nature of the iron base may affect the resistance of a zinc coating to corrosion, but it seems doubtful if any effect would be noticed before any of the iron base was bared. In the present research, some results obtained for the loss of weight of 12 S.W.G. galvanized wires at Sheffield indicated that the mode of application of the coating had little influence on the rate of corrosion. The results, which are shown in Table I, were obtained by comparing the weight of coating remaining on the wire after exposure with that originally on the wire.

TABLE I.—*Losses in Weight of No.* 12-*Gauge Galvanized Wires in* 76 *Weeks at Sheffield.*

Type of Coating.	Initial Weight of Coating, Oz./ft.^{2}.	Loss in Weight, Oz./ft.^{2}.	
Hot-galvanized (special process)	0·85	0·70	0·70
Hot-galvanized . . .	0·99	0·75	0·73
Hot-galvanized . . .	0·90	0·72	0·73
Electrodeposited . . .	0·94	0·72	0·70
Galvannealed . . .	1·13	0·76	0·76
Galvannealed . . .	1·13	0·71	

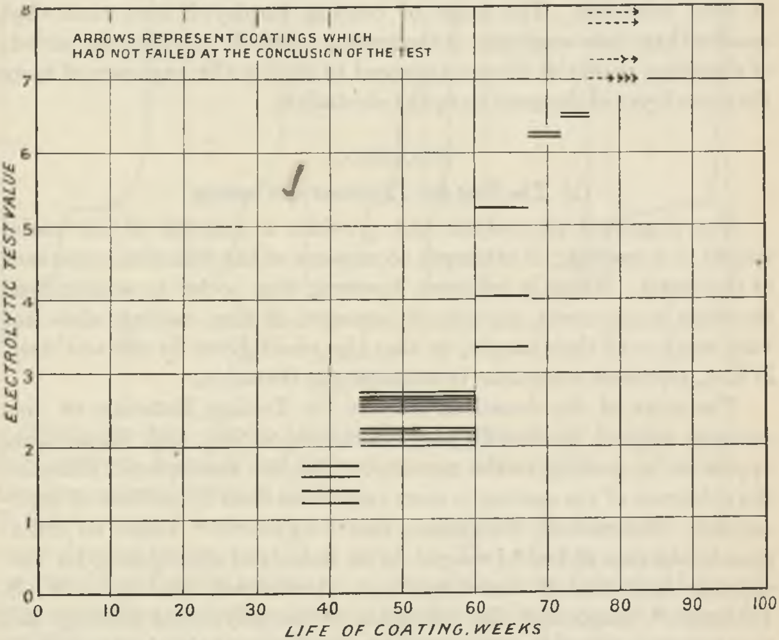

FIG. 4.—Electrolytic Test Value and Life at Sheffield of Coatings on Wire.

Direct confirmation of the validity of the electrolytic test and of the errors of the Preece test have been obtained from field tests. Samples of wire were exposed at Cambridge, Sheffield, and at Calshot, representing ordinary urban, industrial, and marine types of atmosphere. The test at Sheffield had to be discontinued in September, 1934, and Figs. 4 and 5 show the final results in graph form; the time taken for the iron base to show rust is plotted against the value obtained from the test. At Cambridge, it has been possible to determine the time quite closely, but at Sheffield, owing to the less frequent inspections of the wires, the time could only be fixed approximately. On the graphs, a line is drawn for each wire between the time at which it was last seen to be free from rust and the time at which rust was first seen.

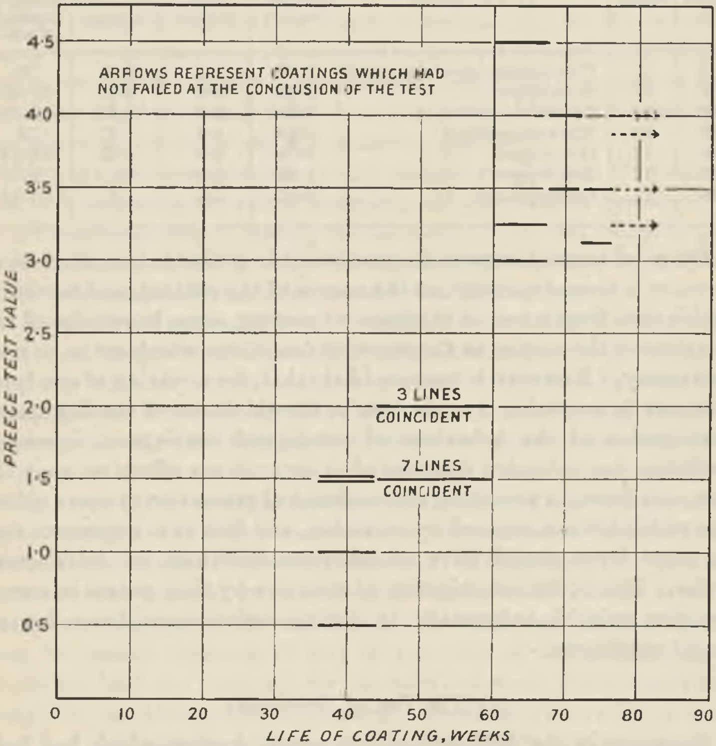

Fig. 5.—Preece Test Value and Life at Sheffield for Coatings on Wire.

The electrolytic test values seem to predict the order of merit shown by the field-test results for all types of coating. The Preece test indicates the relative values for hot-dipped coatings only moderately well, and places the galvannealed coatings and the electrodeposited coating quite out of order. The results so far available from the Cambridge test also show these features. Table II shows the values of some hot-dipped coatings, galvannealed coatings, and electrodeposited coatings as obtained by laboratory test and by field test at Sheffield; the superiority of the electrolytic test over the Preece test is clearly shown.

TABLE II.

Identification No.	Gauge.	Type of Coating.	Total Weight, Oz./ft.^{2}.	Preece Value, Minutes.	Electrolytic Value, Minutes.	Time for Rust to Appear at Sheffield, Weeks.
2	12	Hot-dipped (special process)	0·82	4·0	7·0	76
4	12	Hot-dipped	0·76	3·0	5·25	60–68
12	10	Electrodeposited	0·86	3·5	6·25	68–72
13	12	Electrodeposited	0·94	4·0	7·25	76
18	12	Hot-dipped	0·79	4·0	6·25	68–72
21	12	Hot-dipped	0·83	3·25	6·5	72–76
46	11	Galvannealed	0·57	4·5	4·1	60–68

For conditions of immersed corrosion, it is probable that the rate of corrosion is more dependent on the nature of the coating, and to obtain reliable data from a test of thickness of coating, some knowledge of the behaviour of the coating in the practical conditions which are to be used is necessary. However, it remains likely that, for a coating of one type, resistance to corrosion is a function of the thickness of coating metal. Investigation of the behaviour of hot-dipped coatings in immersed conditions has indicated that the alloy layer is not effective, as is the outer zinc layer, in providing electrochemical protection to areas of iron base which become exposed by corrosion, and that it is important that the outer layer should have an adequate thickness for satisfactory service. Hence, the investigation of structure by time–potential curves may give valuable information in testing corrosion-resistance for immersed conditions.

(2) *The Test of Brittleness.*

Exposure in the field test of a number of wires which had been wrapped on a mandrel, and then straightened again, showed that the wrapping only caused a serious shortening of life for those coatings which cracked so severely as to bare small areas of iron. In all other cases, even when the coating showed visible cracks before exposure, the wrapping made very little difference to the life of the coat. However, the conditions of the test were such that the wires did not suffer the movement or strain which, in service conditions might cause even the finest cracks to develop into serious damage.

Both the copper sulphate dipping test as laid down by British Standard Specification No. 443, and the proposed electrolytic test require the valuation of the coating after wrapping round a standard mandrel. Neither of them really tests the liability of a coating to crack; a heavy coating which cracked might show itself in either test, as specified, superior to a coating which was lighter though not cracked. A better test of liability to cracking would be to determine the reduction of the test-value of a coating which follows a standard wrapping test; a specification based on this principle would lay down a minimum for the test-value of the coating before wrapping and for the reduction which wrapping caused. The present method for specifying a minimum test-value before wrapping and another one after wrapping is more convenient and amounts to the same thing only if the actual coating of the wire does not far exceed the minimum specified.

A more serious objection to the present usual form of brittleness test is in respect to the actual wrapping and unwrapping operation. It is not sufficient only to specify the diameter of the coil which is to be made; the speed and manner of wrapping and unwrapping may also contribute to the effects of the operation on the coating.

Experiments carried out on the final straightening of wires which have been wrapped and then roughly straightened indicated the impracticability of specifying an extension or a load which could be relied on to straighten the wire. Such wires did not remain quite straight after the removal of stress until they had been subjected to a tension above about 90 per cent. of the breaking load; when such stresses were applied, the coating was apt to undergo additional damage varying with the actual stress used in a way which would not permit a standard specification of stress to be made. However, sufficient straightening for practical purposes was obtained by increasing the stress until the wire appeared straight to the eye whilst under load; the minimum stress to do this was, in general, between 70 and 80 per cent. of the ultimate stress. When the load was removed, wire samples lost most of the kinks due to wrapping, but always tended to return to the form of the coil from which they had originally been taken. It seems desirable that for a standard test the force applied should not exceed 85 per cent. of the breaking load of the wire.

LIMITS OF APPLICATION OF THE ELECTROLYTIC TEST.

The electrolytic test can only be applied to material which has such a shape that a uniform current density can be obtained over the whole surface of the test-piece; a special arrangement of cathode and test-piece is necessary for each shape of product. For simple shapes, an arrangement in which the least distance between anode and cathode is the same for all parts of the surface of each, such as is recommended for use with wire, is easily made, but it becomes difficult or impossible to achieve for many of the shapes which are coated with zinc. For such material, probably some form of copper sulphate dipping test remains the most serviceable form of test. The experience gained in its use during the present research suggests, however, that it is desirable to modify the standard Preece test procedure.

The Preece test has two serious faults; the difference in rate of attack of various types of coating by copper sulphate solution and the production of premature end-points. The first of these could be dealt with to some extent by multiplying the value obtained from the test by a factor appropriate to the type of coating test; this has already been tentatively suggested by Groesbeck and Walkup.[11] There is a difficulty in the provision of a correcting factor for hot-dipped coatings owing to the variation in the relative thicknesses of the constituent layers which may occur. The difficulty of premature end-points is lessened if test-pieces are cleaned by acid and rinsed in water before test; 15 seconds in 2 per cent. sulphuric acid was found to be effective both in ensuring that the first minute of immersion in copper sulphate did cause attack of all parts of the surface and in lessening trouble from premature end-points.

ACKNOWLEDGMENTS.

The work described in this paper was carried out in the Cambridge University Metallurgical Laboratories and the author's thanks are due to Professor R. S. Hutton, M.A., D.Sc., both for facilities provided and for the interest he showed, and to Dr. U. R. Evans for his helpful advice. The author wishes also to acknowledge the permission to publish this paper given by the Director and Council of the British Non-Ferrous Metals Research Association, and finally financial assistance afforded by a Fellowship of the Salters' Institute of Industrial Chemistry.

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MEETINGS OF OTHER SOCIETIES

FRIDAY, JANUARY 17.

INSTITUTE OF BRITISH FOUNDRYMEN, MIDDLESBROUGH BRANCH.—D. R. Kinnell: "Machine Moulding." (Cleveland Scientific and Technical Institute, Corporation Rd., Middlesbrough, at 7.45 p.m.)

MONDAY, JANUARY 20.

ROYAL AERONAUTICAL SOCIETY.—Professor W. L. Bragg, F.R.S.: "The Theory of Alloy Structures." (Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, at 6.30 p.m.)

SATURDAY, JANUARY 25.

INSTITUTE OF BRITISH FOUNDRYMEN, NEWCASTLE-UPON-TYNE AND DISTRICT BRANCH.—J. Roxburgh: "The Technique of Chilling." (Neville Hall, Westgate Rd., Newcastle-upon-Tyne, at 6.15 p.m.)

TUESDAY, JANUARY 28.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—G. A. Clavey: "Notes on the Application of Light Alloys to General Engineering." (39 Elmbank Crescent, Glasgow, at 7.30 p.m.)

SATURDAY, FEBRUARY 1.

INSTITUTE OF BRITISH FOUNDRYMEN, EAST MIDLANDS BRANCH.—A Preliminary Report on Moulding Costs by the Costing Sub-Committee of the Technical Committee. (Technical College, Derby, at 6 p.m.)

TUESDAY, FEBRUARY 4.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—P. S. Lewis: "Protective Finishes for Zinc." (James Watt Memorial Institute, Gt. Charles St., Birmingham, 3, at 7.30 p.m.)

WEDNESDAY, FEBRUARY 5.

INSTITUTE OF BRITISH FOUNDRYMEN, LONDON BRANCH.—N. P. Newman: "How to Reduce Core-Making Costs." (Charing Cross Hotel, London, W.C.2, at 8 p.m.)

FRIDAY, FEBRUARY 7.

INSTITUTE OF BRITISH FOUNDRYMEN, BIRMINGHAM, COVENTRY, AND WEST MIDLANDS BRANCH.—W. H. Smith: "Modern Core Shop Production." (James Watt Memorial Institute, Gt. Charles St., Birmingham, 3, at 7.30 p.m.)

SATURDAY, FEBRUARY 8.

INSTITUTE OF BRITISH FOUNDRYMEN, SCOTTISH BRANCH.—R. Liddle: "A Plea for Loam Moulding." (Royal Technical College, George St., Glasgow, at 4 p.m.)

INSTITUTE OF BRITISH FOUNDRYMEN, WEST RIDING OF YORKSHIRE BRANCH.—A Preliminary Report on Moulding Costs by the Costing Sub-Committee of the Technical Committee. (Technical College, Bradford, at 6.30 p.m.)

TUESDAY, FEBRUARY 11.

INSTITUTE OF BRITISH FOUNDRYMEN, LANCASHIRE BRANCH, BURNLEY SECTION.—H. Stead: "Patternmaking—The Craftsman and His Craft." (Municipal College, Ormerod Rd., Burnley, at 7.15 p.m.)

WEDNESDAY, FEBRUARY 12.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—J. W. Perring: "The Colouring of Metals." R. Holloway: "The Lacquering of Metals." (Northampton Polytechnic Institute, St. John St., Clerkenwell, London, E.C.1, at 8.15 p.m.)

INSTITUTE OF BRITISH FOUNDRYMEN, LANCASHIRE BRANCH, PRESTON SECTION.—A. L. Key: "Materials and Processes used in the Production of Internal Combustion Engine Castings." (Technical College, Corporation St., Preston, at 7.30 p.m.)

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METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 3 JANUARY 1936 Part 1

I.—PROPERTIES OF METALS

***Diamagnetism of Copper.** S. Ramachandra Rao (*Proc. Indian Acad. Sci.*, 1935, 2, (3A), 249–259).—Colloidal copper, prepared by electrical dispersion in benzene or propyl alcohol, is found to have a diamagnetic susceptibility (χ) which increases as the size of the particles decreases, the critical diameter of the particles below which large changes of χ occur being 0·8 μ. The value of χ for copper in bulk is 0·080. The results with colloidal powders enable χ for the surface layer and the thickness of this layer to be determined. These are, respectively, 0·200 and 300 A. On the basis of the theory due to Honda and Shimizu, the density of the surface layer is found to be 8·404; the density of the metal in mass is 8·943.—J. S. G. T.

***Experiments on the Electrolytic Separation of the Isotopes of Lithium.** A. Eucken and K. Bratzler (*Z. physikal. Chem.*, 1935, [A], **174**, 269–272).—Attempts to separate lithium into its isotopes by electrolysis of lithium sulphate solution using a flowing mercury cathode failed to effect any appreciable separation after four repetitions.—B. Bl.

***On the Magnetostriction of Single Crystals of Nickel at Various Temperatures.** Kôtarô Honda, Hakar Masumoto, and Yuki Shirakawa (*Sci. Rep. Tôhoku Imp. Univ.*, 1935, [i], 24, 391–410).—[In English.] The magnetization of single crystals of nickel at various temperatures ranging from − 252° to 370° C. was measured by the ballistic method. The magnetization at ordinary temperatures in the direction of the [111] axis increases at first rapidly and then slowly with the increase of the field, and afterwards reaches a saturation value. As the temperature is increased, the magnetization in weak fields gradually becomes easier and the saturation value of magnetization becomes less. The magnetization curves in the direction of the [110] and [100] axes are similar in form; they are almost the same as for the [111] axis, but at low temperatures the saturation value is not reached even in a field of 1000 oersteds. The saturation value of magnetization of a nickel crystal at absolute zero has been estimated to be 523 gauss.—S. G.

***Ionization of Hydrogen Gas in Contact with Platinum, Copper, and Nickel.** C. Y. Meng, Paul A. Anderson, and Y. M. Hsieh (*J. Chinese Chem. Soc.*, 1935, 3, 103–114).—[In English.] The ionization of hydrogen in contact with platinum, copper, and nickel is studied quantitatively at different temperatures. An illustrated description is given of the ionization chamber and the purifier employed. Mercury vapour was eliminated by means of a potassium trap. Ionization of hydrogen occurred in the case of all three metals, the current observed being very small at room temperature and increasing markedly at about 65° C. Copper and nickel produced a slightly higher degree of ionization than platinum: the authors deduce that the activation of hydrogen in contact with platinum, which does not occur if copper or nickel are used, cannot be the result of ionization.—P. M. C. R.

The Effect of Crystalline Fields on the Magnetic Susceptibilities of Sm^{+++} and Eu^{+++} and the Heat Capacity of Sm^{+++}. Amelia Frank (*Phys. Rev.*, 1935, [ii], 48, 765–771).—By assuming that the ion is subject to a crystalline field of a special type, it is shown that theoretical values of the paramagnetic susceptibility of samarium (Sm^{+++}) are in satisfactory agreement with the experimental

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* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

data of Freed over the range from 74° K. to room temperature. In contrast to Sm^{+++}, europium (Eu^{+++}) behaves like the free ion even in the presence of a crystalline field. The general shape of the heat capacity–temperature curve of Sm^{+++} is shown to agree with that obtained experimentally by Ahlberg and Freed, but the theoretical values of heat capacity are consistently lower than the experimental values.—J. S. G. T.

***On the Increase in Deformability and Decrease in Cleavability [of Tin, Bismuth, and Zinc] with Increase in Temperature.** G. Tammann and W. Müller (*Z. Metallkunde*, 1935, **27**, 187–189).—If single crystals of the above metals are indented with the Brinell ball, characteristic twin lamellæ appear in definite crystallographic directions around the impression. Somewhat similar effects are produced by scratching the surface of the crystal with a diamond, small parallel fissures being produced on either side of the scratch forming a herringbone effect. With increasing temperature of test these effects become gradually less pronounced and eventually disappear, *i.e.* the once brittle metal becomes plastic. This disappearance takes place at definite temperatures which correspond with those at which the metal can be worked, *i.e.* for zinc 130° C., for bismuth 150° C., and for antimony 300° C. Single crystals of bismuth can be bent without fracture at temperatures above 100° C., whereas those of antimony can be bent only above 350° C. Since antimony at 300° C. is approximately as brittle as bismuth at 20° C. it follows that the two metals are equally brittle at temperatures which are the same fraction of their melting points in ° abs.—A. R. P.

***Effects of High Shearing Stress Combined with High Hydrostatic Pressure.** P. W. Bridgman (*Phys. Rev.*, 1935, [ii], **48**, 825–847).—Mean hydrostatic pressures up to 50,000 kg./cm.^{2} combined with shearing stresses up to the plastic flow point are produced in thin discs confined between hardened steel parts so mounted that they may be subjected to normal pressure and torque simultaneously. Qualitative and quantitative studies are made of the effects of such stresses. Among the qualitative effects, it is found that many substances, *e.g.* celluloid, normally stable become unstable and may detonate, and some substances normally inert to each other, combine explosively. The shearing stress at plastic flow at 50,000 kg./cm.^{2} may increase to as much as 10 or more times its normal value at atm. pressure; this is contrary to accepted views within a narrower pressure range. If the substance undergoes a polymorphic transition under these conditions of stress, a break may occur in the shearing stress–pressure curve. A number of new polymorphic transitions has thus been found amongst the elements, of which 57 have been examined. The metals exhibiting polymorphism are lithium, strontium, calcium, barium, cadmium, zinc, vanadium, manganese, antimony, tellurium, lanthanum, cerium, erbium, thallium, bismuth, thorium, tin, yttrium, and praseodymium. —J. S. G. T.

***Polymorphism, Principally of the Elements, up to 50,000 kg./cm.^{2}.** P. W. Bridgman (*Phys. Rev.*, 1935, [ii], 48, 893–906).—A new technique, whereby pressures of 50,000 kg./cm.^{2} and higher can be applied to solids, and parameters of any transitions measured, is described. Many of the elements have been examined, in the new pressure range, for evidence of polymorphism. New modifications are found in the cases of bismuth, mercury, thallium, tellurium, gallium, and iodine.—J. S. G. T.

***The Theory of Surface Tension of Liquid Metals.** D. V. Gogate and Dulch Sinha Kothari (*Phil. Mag.*, 1935, [vii], **20**, 1136–1144).—A formula for the surface tension of liquid metals is derived by means of a theory which applies Fermi–Dirac statistics to the motion of electrons in a plane monomolecular film. Satisfactory agreement between calculated and experimental values of surface tension is shown by results relating to 15 metals.—J. S. G. T.

***The Pressure Effect of Electrical Resistance of Metals.** N. K. Saha (*Indian J. Physics*, 1935, **9**, (6), 623–635).—The pressure coeff. of electrical resistance of metals and the change of resistance at different pressures are calculated using the rigid ionic model of Nordheim. Good agreement is found between experimental and theoretical values in the cases of gold, silver, and copper, and, in general, for metals of low compressibility. The results are compared with those of Kroll using Fermi's statistical theory of ionic potential. Nordheim's model, using a screened Coulombian potential, gives the more consistent results. The alkalis, possessing very high compressibility, yield no satisfactory results on either form of theory.—J. S. G. T.

†Superconductivity. H. G. Smith and J. O. Wilhelm (*Rev. Modern Physics*, 1935, **7**, 237–271).—Superconductivity is comprehensively reviewed. The subjects discussed include: the phenomenon of superconductivity; superconducting metals; interruption of superconductivity by a magnetic field; distribution of magnetic field around a superconductor; current in a closed superconducting circuit; thermoelectric effects; specific heats; thermal conductivity; superconductivity in thin films; anomalous superconducting alloys; theories of superconductivity; thermodynamics; electrodynamics; the London theory; the spontaneous current theory; quantum–mechanical theories.—J. S. G. T.

†The State of Research on Superconductivity. W. Meissner (*Elektrotech. Z.*, 1935, **56**, 1061–1065).—Researches made during recent years have led to the following conclusions: superconductivity occurs not only in pure metals but also in all types of alloys including intermetallic compounds. The transition point to superconductivity varies between 0·3° and 9·2° abs. and is influenced by temperature and by external magnetic fields; in both cases hysteresis effects have been observed and in massive specimens of pure metals the magnetic induction suddenly becomes zero at the transition point. The specific heat and the heat conductivity change only slightly, but there is a relation between the effect of magnetic fields and the change in specific heat. Theories of superconductivity are briefly discussed.—B. Bl.

II.—PROPERTIES OF ALLOYS

***The System Iron–Cobalt–Cobalt Silicide–Iron Silicide.** Rudolf Vogel and Kurt Rosenthal (*Arch. Eisenhüttenwesen*, 1935–1936, **9**, 293–298).—The system was examined by thermal and micrographic methods and the equilibria are shown in a series of ternary and quasi-binary diagrams. CoSi and FeSi form a continuous series of solid solutions, and on addition of the other metal form the ternary compound FeCoSi below 980° C. In the section iron–cobalt–Co_2Si–FeCoSi–FeSi there are four planes of 4-phase equilibrium, two of which relate to transformation reactions, two to eutectic reactions, and one to a eutectoidal transformation. Analogous planes of equilibria occur in the section FeSi–FeCoSi–Co_2Si–CoSi, and since FeSi and CoSi and Co_2Si and FeCoSi form continuous series of solid solutions the 3-phase equilibria in the quasi-binary system Co_2Si–CoSi merge into those of the quasi-binary system FeSi–FeCoSi. —A. R. P.

***The Reflection Coefficient of the Series of Copper–Nickel Binary Solid Solutions.** P. Bergmann and W. Guertler (*Z. tech. Physik*, 1935, **16**, 235–236).—Reflection coeffs. of 9 copper–nickel alloys containing from 0 to 100% of nickel are tabulated for the range of wave-lengths 4670–6100 A. The selective reflectivity of copper tends to disappear as the % of nickel in the alloy is increased. Alloys containing about 25 atomic-% of nickel or more, have about the same reflectivity as pure nickel.—J. S. G. T.

***The System Copper–Nickel–Iron.** W. Köster and W. Dannöhl (*Z. Metallkunde*, 1935, **27**, 220–226).—The ternary diagram and several pseudo-binary sections through it have been constructed from the results of thermal analysis, magnetometric measurements, and determinations of the electrical resistance. The boundary of the field in which the α–γ transformation occurs is a straight line joining the copper corner of the ternary diagram with 28% nickel on the iron–nickel side. The miscibility gap in the iron–copper system is gradually closed by addition of nickel, disappearing entirely with 27% nickel at 1220° C. and with 82% nickel at room temperature; hence alloys within this range are amenable to precipitation-hardening treatment, which in certain alloys containing about 50% nickel leads also to changes in the Curie point.—A. R. P.

†**On the Mechanism of Precipitation [in Supersaturated Solid Solution Silver–Copper Alloys].** U. Dehlinger (*Z. Metallkunde*, 1935, **27**, 209–212).—Microscopic observations on the separation of silver from supersaturated solid solution in copper shows that the particles of silver first precipitated in no way influence the rate or form of subsequent precipitations, and therefore precipitation cannot be attributed to nuclei formation but must be ascribed to lattice distortion probably at the boundaries of mosaic blocks. At these points very thin films of silver are probably first formed, and these subsequently coagulate into grains which can be detected first by X-rays and then, as they grow in size, by microscopic examination. In deformed and recrystallized metal microscopic observations reveal the presence, at the boundaries of regions in which precipitation has already begun, of an active factor which accelerates further precipitation and which is the cause of the high rate of precipitation, and the production of microscopically detectable heterogeneity.—A. R. P.

Caro Bronze. —— (*Machines*, **1935**, (Nov.), 6).—A brief description is given of a phosphor–bronze bearing alloy containing copper 91·2, tin 8·5, and phosphorus 0·3%; the alloy is used in the cold-drawn condition.—P. M. C. R.

***The Materials for Condenser Tubes.** Yoshiro Fujii (*Tetsu-to-Hagane* (*J. Iron Steel Inst. Japan*), 1935, **21**, 568–575; *C. Abs.*, 1935, **29**, 7912).—[In Japanese.] Seven kinds of copper-base alloys and two stainless steels were subjected to tests of sp. gr., corrosion in a 3% aqueous sodium chloride solution, corrosion in sea-water, thermal conductivity, microstructure, and various mechanical properties. The actual test of the small condensers which were specially constructed using tubes made of the above-mentioned materials was carried out over a period of 4 years. In all these tests the following alloys showed good results: Hiro-ken (The Hiro Naval Arsenal) A alloy; aluminium 3, zinc 16%, remainder copper; and zinc 27, tin 1, iron 0·03%, remainder copper.—S. G.

***Magnesium–Aluminium–Nickel Alloys.** G. Guzzoni (*Chimica e industria* (*Italy*), 1935, **17**, 293–300; and *Industria meccanica*, 1935, **13**, 690–696; *C. Abs.*, 1935, **29**, 7917).—The effect of additions of nickel to alloys of magnesium and aluminium was determined. The best results were obtained with 3·5–4·0% aluminium and 0·5–0·6% nickel. All the alloys require a flux to improve castability; a mixture of anhydrous magnesium chloride and sodium chloride in equal parts was found best. Increasing the nickel content above 0·5% improves the tensile strength slightly, but reduces the castability and ductility. Alloys containing more than 2% nickel are almost impossible to make owing to the limited solubility with aluminium present, even though magnesium and nickel alone mix in all proportions. The optimum alloy mentioned above has the following properties: tensile strength 17–19 kg./mm.^{2}, elongation 8–12%, Brinell hardness 50–55. The best conditions for pouring are to heat to 850° C., hold for 10–15 minutes, and to pour when the temperature has decreased to 760°–780° C. Extrusion is carried out as for other light alloys, a temperature of 300°–350° C. being best. A tungsten–steel die should be used, tempered at 450° C.; moulds are best made of iron or mild steel free from graphite and nickel. These alloys could not be heat-treated, hardened, tempered, or annealed successfully. For extrusions the alloy giving the best results contained aluminium 7 and nickel 1·0%; it had a tensile strength of 30–31 kg./mm.^{2} and an elongation of 14%. Nickel makes the alloy more corrosive, thus counteracting the improvement due to aluminium. The alloys are difficult to weld.—S. G.

***The Equilibria Between Iron and Nickel and Their Silica-Saturated Silicates.** Peter Bardenheuer and Erwin Brauns (*Mitt. K.W. Inst. Eisenforschung*, 1935, **17**, 128–132).—The equilibria between nickel–iron alloys and nickel–iron silicate slags at 1600° C. were determined; the distribution of iron and nickel between metal and slag layers agrees very closely with the ideal mass-action law. The oxide content of the metal layer in nickel-rich melts is determined almost entirely by the nickel oxide content of the slag layer and decreases with decreasing temperature; addition of excess of iron to the metal layer changes the partition coeff. of nickel oxide only by about 5%.—A. R. P.

Magnetic Properties of Some Nickel Alloys. Ray Chaudri and P. N. Sen Gupta (*Science and Culture*, 1935, **1**, 114–115; *C. Abs.*, 1935, **29**, 7918).—50 : 50 and 60 : 40 alloys of nickel and aluminium resemble nickel oxide in magnetic susceptibilities; hysteresis is absent. It is not possible to locate the Curie point. A 70 : 30 alloy of nickel and chromium shows a change of curvature on the temperature–magnetic susceptibility diagram at about 400° C.—S. G.

***The Solubility of Deuterium and Hydrogen in Solid Palladium.** A. Sieverts and G. Zapf (*Z. physikal. Chem.*, 1935, [A], **174**, 359–364).—The values obtained between 300° and 1100° C. are in approximate agreement with those obtained by others. The relation between the solubilities of deuterium and hydrogen is 0·67 at 300° C., 0·91 at 1000° C., and approximates to unity at higher temperatures. The solubility of both isotopes in palladium is proportional to the square root of the gas pressure at constant temperature. —B. Bl.

***The Electrical Resistance of Hydrogen-Charged Wires of Palladium–Silver and Palladium–Gold Alloys.** A. Sieverts and H. Hagen (*Z. physikal. Chem.*, 1935, [A], **174**, 247–261).—The pressure–concentration isotherms of alloys with 5 and 10% silver are similar to those of pure palladium; they show hysteresis at 150° and at 200° C., a second section in which the concentration of hydrogen is independent of the pressure. All other isotherms have a parabolic shape. The pressure–electrical resistance isotherms are similar to those of palladium up to 30 atomic-% silver, but the change in resistance for equal increments of pressure and hydrogen content become smaller with increasing silver content. In alloys with 30 and 40 atomic-% silver the electrical resistance becomes smaller by absorption of hydrogen within a definite range of temperature and pressure; in alloys with 50 and 60 atomic-% silver absorption of hydrogen again causes large increases in the resistance. Palladium–gold alloys behave similarly to palladium–silver alloys with the same atomic-% palladium, but the decrease in resistance by hydrogen absorption in the 35 atomic-% gold alloy is much greater than in the 39 atomic-% silver alloy. —B. Bl.

***On the Equilibrium Diagram of the Silver-Rich Silver–Aluminium Alloys, with a Note on the Nature of the Transformations.** Ichiji Obinata and Masami Hagiya (*Kinzoku no Kenkyu*, 1935, **12**, 419–429).—[In Japanese.] The equilibrium diagram of the silver–aluminium alloys containing 0–11% aluminium was revised from the results of X-ray analysis at ordinary and high temperatures, electrical resistance measurements, and microscopic examination. Alloys containing 5·7–8 and 2% aluminium undergo the eutectoid and the metatectic transformation at 615° and 420° C., respectively. While the metatectic transformation can easily be suppressed by quenching in water, complete suppression of the eutectoid transformation is scarcely possible. Thus, the alloys quenched from the β field always consist of the γ-phase, supersaturated with silver, showing the diffraction lines belonging to the hexagonal close-packed lattice. On heating, the quenched hypo-eutectoid alloys, an anomalous increase of resistance was observed at about 200° C., which is considered to be due to the formation of a compound Ag_3Al. The crystal structure of the β-phase was determined by X-ray analysis at high temperatures. As anticipated, this phase has a body-centred cubic lattice, the parameter of which is $3{\cdot}29^5$ A. at 700° C. (Al = 7·98%).—S. G.

***The Electrical Resistance of Hydrogen-Charged Tantalum Wire.** A. Sieverts and H. Brüning (*Z. physikal. Chem.*, 1935, [A], **174**, 365–369).—The absorption of hydrogen and the change in resistance produced thereby in a tantalum wire have been determined at 400°–600° C. and at pressures from 1 atm. upwards. At 500°–600° C. the dissolved hydrogen is exactly proportional to the square root of the pressures, but appreciable deviations occur at 400° C. The increase in resistance is in all cases proportional to the amount of hydrogen absorbed. The phenomena observed in the tantalum–hydrogen system are thus similar to those in the palladium–hydrogen system; in both cases the relationships observed are in conformity with the above laws as long as no new phase is formed.—B. Bl.

***Decaying Intermetallic Compounds.** G. Tammann and A. Rühenbeck (*Z. anorg. Chem.*, 1935, **223**, 288–296; and (summary) *Light Metals Research*, 1935, **4**, 20–24).—The intermetallic compounds of some metals with aluminium, silicon, calcium, magnesium, and cerium decompose on exposure to moist air owing to the reaction of the above-named metals with the moisture to form hydroxides, the other component of the compound being liberated as finely divided metal; examples discussed are the compounds $FeAl_3$, AlSb, PbCa, AgCa, $SnMg_2$, and BiCe. On the other hand no such reaction occurs with such compounds as Al_3Mg_4 and AuMg. The difference in behaviour is attributed to the formation of a non-porous, protective film in the latter, and the non-formation of such a film in the former case.—A. R. P.

***Examination of the Law of Mass Action of Concentrated Molten Solutions by Potential Measurements.** F. Neubert and F. Sauerwald (*Z. physikal. Chem.*, 1935, [A], **174**, 161–198).—The equilibrium constants and activity relationships in the reaction of metals with their molten salts were determined by measurements of the electrochemical potentials in order to confirm the constants determined analytically, the corresponding activities and the molecular weights derived from the results. In practically all cases the Lorenz–van Laar mass action law does not apply, the smallest deviations of the mean values of the constants from the ideal mass action law being about 25%. The following reactions were examined: lead with molten tin and silver chlorides and with silver bromide and iodide; lead chloride with thallium, zinc, and cadmium; cadmium and stannous chloride; and thallium and cadmium chloride.—B. Bl.

***On a New Method of Determining Transformation Points [Solidus of Copper–Silver Alloys].** H. Nipper and E. Lips (*Z. Metallkunde*, 1935, **27**, 242–243).—Changes in the structure of alloys at high temperatures are usually accompanied by sudden changes in the mechanical properties. An apparatus has been constructed, therefore, to determine the torsion of wires at gradually increasing temperatures with automatic registration of the results; the method was applied to the determination of the solidus of copper–silver alloys.—A. R. P.

Stereo-Chemistry of Solids. Wilhelm Biltz (*Ber. deut. chem. Ges.*, 1935, [A], **68**, 91–108).—The space occupied by the actual particles of a solid may be approximately represented by the sum of single increments each bearing a definite relationship to the nature and condition of the corresponding particle. The principle is applied to the case of certain glasses, the density of which can be accurately predicted from their composition, and of 2 series of intermetallic compounds, in which " noble " and " base " metals, respectively, preponderate. The additive character of the increments rather than of the atomic volumes explains the striking discrepancies between observed and calculated molecular volumes in the latter case. This is further illustrated by references to the alkali metal amalgams. The particles of intermetallic compounds are compared to material in a state of mechanical compression, and the accompanying contraction in electronic volume is further related to variations in the ionic charges. The conception of the space-lattice is examined, from the standpoint of space increments.—P. M. C. R.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

***Statistical Investigations of the Structure of Metals.—I.** E. Scheil (*Z. Metallkunde*, 1935, **27**, 199–208; discussion, 208–209).—Mathematical procedures for calculating the area and volume occupied by the various constituents of metals and alloys are described with reference chiefly to ferrous metals.—A. R. P.

†**Relation Between Diffusion and Structure of Solid Alloys.** W. Seith and A. Keil (*Z. Metallkunde*, 1935, **27**, 213–215).—Recent work of the authors and others is reviewed in an attempt to obtain a relation between the movement of atoms in solid solutions and other properties of the alloys. The amount of movement depends on the chemical affinity between, and the size of, the component atoms, and its dependence on the relative concentrations of the component atoms is in many cases determined by the melting points. Diffusion is appreciably increased by recrystallization and by transformations; in most cases too the passage of a direct current through the alloy causes the components to diffuse in opposite directions (electrolytic migration).—A. R. P.

***Detection of Metallographic Processes by Radioactive Methods.** O. Werner (*Z. Metallkunde*, 1935, **27**, 215–219).—The diffusion of radioactive emanations through a metal lattice is regulated by the lattice vibrations of the metal and hence the course of the temperature–radioactivity curve of a metal containing a radioactive substance, *e.g.* thorium-*X*, is determined by the frequency and amplitude of the atomic movements in the metal. The temperature coeff. of radioactivity of different metals is inversely proportional to the characteristic temperature of Debye's theory of solid bodies. Determination of this coeff. affords a means for calculating the energy absorbed in rolling a metal into sheet (this is illustrated by experiments on gold), for calculating the amount of dissolved hydrogen in the metal (illustrated by experiments on electrolytic copper), for determining the transformation point of metals (illustrated by curves for thallium and iron), for determining the Curie point (of iron and nickel), and for studying the course of the sintering process with compressed metal powders (illustrated by experiments on molybdenum and carbonyl nickel).—A. R. P.

*†**The Lattice Constants of Beryllium.** E. A. Owen and Llewelyn Pickup (*Phil. Mag.*, 1935, [vii], **20**, 1155–1158).—Redetermined values of the lattice constants at 18° C., of annealed beryllium of very high purity (Fe, 0·01%; C, 0·05%; N, 0·005%; and traces of silicon and aluminium) are: $a = 2{\cdot}2810_5$ A.; c (axial ratio) $= 1{\cdot}5682$. These values are in close agreement with the author's previous values and differ somewhat from those of other experimenters.—J. S. G. T.

†**The X-Ray Powder Photography of Alloys.** A. J. Bradley (*Metallurgia*, 1935, **13**, 69–70).—A condensed report of a lecture to the Midland Metallurgical Societies. The use of X-ray powder photography, as compared with

photomicrography, in establishing the equilibrium diagrams of the alloy systems is considered. The method of spacing determination is briefly described and the application of lattice space measurements in determining accurate coeffs. of expansion referred to. The influence of heat-treatment on X-ray photography in giving rise either to complete phase changes or to atomic distribution is discussed with particular reference to the nickel–aluminium, copper–aluminium, and iron–aluminium systems.—J. W. D.

***Precise Determination of Angles and Lattice Constants by the Debye–Scherrer Method.** M. Straumanis and A. Ievins (*Naturwiss.*, 1935, **23**, 833).—The usual method is modified in that the end of the film is placed at an angle of 90° instead of at 0° or 180° to the primary X-ray; by measuring the interference rings with small and large ∂ the points of entrance and exit of the X-ray beam can be determined and hence the exact diameter of the camera. The lattice parameter of sodium chloride was found to be $a = 5{\cdot}6264 \pm 0{\cdot}0003$ A.—B. Bl.

IV.—CORROSION

***Inhibiting Additions to Solutions Which Attack Aluminium.** H. Röhrig (*Aluminium*, 1935, **17**, 559–562).—Read before the VII Congrès International des Mines, de la Métallurgie, et de la Géologie, Paris, 1935. Various substances which inhibit the action of mineral acids on ferrous alloys also inhibit or greatly reduce the rate of attack of acids on aluminium and its alloys, thus addition of 1% of nicotine sulphate to 20% hydrochloric acid reduces the loss in weight of pure aluminium therein from 239 to 3·8 grm./m.^{2} in 15 minutes, while 0·1% of dibenzyl sulphide in 10% hydrochloric acid reduces the loss in weight from 77·1 to 2·8 grm./m.^{2} in 90 minutes. Still more effective is the inhibitor known as "Sparbeize 20," addition of which to *N*-hydrochloric acid reduces its attack on pure aluminium from 532 to 0·15 grm./m.^{2} in 6 hrs.
—A. R. P.

***Comparison of the Resistance to Corrosion of 11 Light Alloys under Natural and Laboratory Conditions.** E. K. O. Schmidt and E. Böschel (*Luftfahrtforschung*, 1935, **12**, 116–120).—Tests were carried out in the laboratory by the D.V.L. method and under natural conditions in the North Sea on the behaviour of various grades of Duralumin, K.S.–Seewasser alloy, Hydronalium, Anticorodal S, and Silumin. The results showed that the laboratory tests provide a comparative guide to the resistance to corrosion under practical conditions in about $\frac{1}{18}$ of the time. The alloys tested fall into 3 groups: (I) those which show appreciable reduction in strength in sea-water in about a fortnight—Duralumin 681 ZB, Duralumin 681 A, and Duralumin 681 H; (II) those which suffer a loss in strength only after 6 months' exposure—Silumin, Anticorodal S; and (III) those which remain practically unaffected for 2 years—Duralumin 681 K, Duralplat, K.S.–Seewasser, and Hydronalium.
—A. R. P.

***On the Corrosion-Resistance of Hydronalium Especially Against Sea-Water.** G. Siebel (*Aluminium*, 1935, **17**, 562–567).—Hydronalium alloys with magnesium 7–12 and manganese 0·3–0·5% have a high resistance to sea-water which is practically the same in the cast (heterogeneous) state as in the homogenized condition. After cold-work, however, the homogenized alloys become unstable at temperatures of 60° C. and higher and the new phase precipitated at the grain boundaries in a highly dispersed form induces serious intercrystalline corrosion in salt-water. By tempering at temperatures just below the solubility line to obtain a heterogeneous structure which is stable this sensitivity to intercrystalline corrosion on warming is entirely removed; a similar effect is produced by small additions of zinc, calcium, silicon, titanium, or chromium which more or less stabilize the homogeneous state or at least render it insensitive to tempering.—A. R. P.

***The Corrosive Action of Sulphur on Metallic Copper During Vulcanization.** Shozo Satake (*J. Soc. Rubber Ind. Japan*, 1935, 8, 461–471; *C. Abs.*, 1935, **29**, 8403).—[In Japanese.] The corrosive action of compounded sulphur was studied by keeping copper and a rubber plate in contact during vulcanization. The corrosion can be expressed by the equation $x = Kt^n$, where x is the extent of corrosion in t hrs., and K and n are constants depending on the conditions of test. That n is inversely proportional to the velocity const. of vulcanization, which in turn is related only to the temperature of vulcanization and the kind and amount of accelerator, was confirmed by tests of the speed of vulcanization of the same rubber sample used in the corrosion test. K is directly proportional to the sulphur used in compounding (% by volume). The relation between K and the velocity const. of vulcanization was also studied. The corrosive action of combined sulphur (acetone–insoluble sulphur) in vulcanized rubber on copper is weak, and corrosion of copper during vulcanization is due mainly to the presence of free sulphur. The ratio of formation of sulphides was : $Cu_2S : CuS = 5 : 3$, and this ratio remained nearly const. and was not influenced by changing the percentage of sulphur or accelerator.—S. G.

Influence of Sugar in the Corrosion of [Tinplate by] Canned Fruits. E. F. Kohman and N. H. Sanborn (*Canner*, 1935, **80**, (9), Part 2, 111–112; *C. Abs.*, 1935, **29**, 6319).—In general, there is less container corrosion at the higher sugar syrup concentrations. Sugars in canned fruits decrease corrosion as compared with non-sugar packs. In both a citric acid–sodium citrate solution and in grape-fruit juice the addition of 25 or 50% dextrose, sucrose, or levulose definitely increased the H-ion concentration of the solution. It appears probable that sugars combine chemically with some of the fruit constituents.—S. G.

***Influence of Various Acids on Corrosion [of Tinplate] in Prepared Prunes.** E. F. Kohman and N. H. Sanborn (*Canner*, 1935, **80**, (9), Part 2, 112; *C. Abs.*, 1935, **29**, 6319).—The ability of various organic and inorganic acids to prevent or retard corrosion of tinplate by canned prunes was determined. Sufficient of each acid was added to lower the p_H from 4·05 to 3·84. Citric acid gave the best results. This acid possesses the tendency to form complex citrate ions with metals.—S. G.

***Influence of Various Acids on Corrosion [of Tinplate] in Royal Anne Cherries.** G. S. Bohart (*Canner*, 1935, **80**, (9), Part 2, 114; *C. Abs.*, 1935, **29**, 6318).—The principal acid produced by flat-sour bacteria in canned cherries is lactic acid. The acidity of the experimental pack of cherries was adjusted to p_H 3·5 by the addition of citric, lactic, phosphoric, malic, acetic, and butyric acids. The greatest loss of vacuum in the cans owing to corrosion was caused by phosphoric acid. There is a considerable natural phosphate in these cherries.—S. G.

***Corrosion Tests of Metals Used in Pea Processing.** F. L. LaQue (*Canning Age*, 1935, **16**, 385–387, 406).—Copper, nickel, tin, zinc, cast tin–bronze, 2 and 1 brass, 50 : 50 soft solder, Monel metal, and 18% nickel silver were investigated. Sets of specimens were exposed in brine tanks, pails of wet peas, and other positions in a working pea-canning plant. The effect of 2, 6, 10, 20, 30, 50, and 80 p.p.m. of the metals chromium, copper, iron, nickel, tin, and zinc on the colour and flavour of canned peas was also determined. —C. E. H.

Underground Corrosion. K. H. Logan (*Proc. Amer. Soc. Civil Eng.*, 1935, **61**, 317–329; discussion, 591–594, 919–923; *Build. Sci. Abs.*, 1935, 8).—A summary of the conclusions reached by the National Bureau of Standards (U.S.A.), as a result of the corrosion of pipes in soil (see *Met. Abs.* (*J. Inst.*

Metals), 1931, **47**, 665; *Met. Abs.*, 1934, **1**, 242) leads to a discussion of the characteristics and course of such corrosion, and the means available for reducing corrosion losses. Further research in this field is urged. 25 references are given.—S. G.

The Corrosivity of Soils. —— (*Nat. Bur. Stand. Letter Circular* No. **433**, 1935, 13 pp.).—Gives abstracts and summaries of reports relating to investigations of the corrosion of ferrous and non-ferrous materials by soils.—S. G.

Corrosion of Metals. Nathalie Goldowski (*La Nature*, **1935**, (2955), 540–542; (2957), 69–72; *C. Abs.*, 1935, **29**, 7920).—Several new machines have been developed for alternate immersion of metallic plates in test solutions. The electrochemical phenomena involved in the corrosion of metals and results of variations in oxygen contact are associated with the rate of corrosion.—S. G.

V.—PROTECTION

***Influence of the Working Conditions in Tinning on the Porosity of Tinplate.** Fritz Peter and Georges Le Gal (*Arch. Eisenhüttenwesen*, 1935–1936, **9**, 285–287; discussion, 288–291).—Numerous tests extending over a long period of large-scale tinning operations have shown that no single factor has a determining influence on the porosity of tinplate. The most important factors are absolute cleanliness of the steel, the thickness of the tin coating, the nature of the pickling process, and the purity of the flux. Absorption of hydrogen from the pickling operation does not appear to play the important part in producing porosity usually ascribed to it. The minimum thickness of tin to guarantee absolute freedom from porosity under correct working conditions is about 100 grm./m.^{2}. In the discussion *W. H. Creutzfeld* stated that before making tests for porosity all grease must be removed from the surface; this can be done most effectively by washing with trichlorethylene which has no action on the tin, whereas alkaline cleaners attack the metal and produce new pores. The best method for detecting pores consists in coating the metal with a warm (60° C.) solution of potassium ferrocyanide in 10–15% agar-agar containing 0·5–1% of sodium chloride. Other speakers produced evidence in favour of the theory that surface impurities on the iron are the chief cause of porosity in the tinplate.—A. R. P.

†Copper Wire Tinning. Ch. Bernhoeft (*Z. Metallkunde*, 1935, **27**, 264–266).—The tin coating applied to copper wire to prevent its being attacked by sulphur during vulcanization of the insulating rubber coating subsequently applied may be faulty owing to one or more of the following causes: incomplete removal of the acid used in pickling before passing the wire through the bath, too high a temperature of the tin bath which results in dissolution of 5% or more of copper, too thin a coating due to a low bath temperature or too rapid passage of the wire through the bath, or insufficient cleaning of the copper.—A. R. P.

Hot-Galvanizing. Hand Galvanizing of Small Pieces: Galvanizing by the Usual Method. A. Forny (*Galvano*, **1935**, (35), 26–27).—Describes briefly the main features of the methods used in France for galvanizing small parts by hand, condemning the empirical control and inefficient working which appear to be usual in this field. A bright finish without spangles is best for small pieces. This is obtained by adding 0·015% each of tin and aluminium to the bath, and working at about 470° C. For hot-dip galvanizing a highly experienced staff is required. The equipment is briefly outlined.—C. E. H.

Lead and Tin in Zinc Used for Galvanizing. Werner Frölich (*Illust. Zeit. Blechindustrie*, 1935, **64**, 1298–1299, 1323–1324).—Remelted zinc usually contains appreciable proportions of tin and lead, probably derived from solder: the tin content may be reduced to 0·3–0·4% by means of sulphur, but F.

considers that small additions of metals other than zinc render the material less corrodible and less susceptible to embrittlement or discoloration, *e.g.* by antimony, than is pure zinc. He recommends a composition of lead 1, tin 0·6, iron 0·12, cadmium 0·07, aluminium 0·01%, antimony a trace, and remainder zinc, for use in galvanizing baths, the temperature of which requires very careful control.—P. M. C. R.

***On the Reactions of Iron with Liquid Zinc [at Galvanizing Temperatures].** Wilhelm Püngel, Erich Scheil, and Robert Stenkhoff (*Arch. Eisenhüttenwesen*, 1935–1936, **9**, 301–304).—The attack on iron by molten zinc at galvanizing temperatures can take place in two ways, either (I) $FeZn_3$ is formed and the rate of dissolution of the iron is small and increases slightly with increase in temperature, or (II) $FeZn_7$ is the principal product of the reaction, being formed as loose masses of needle-like crystals which allow the zinc to come into contact with fresh iron surfaces, and thus attack on the iron is severe. In case (I) a dense protective layer is formed on the iron, and the reaction soon becomes very slow at constant temperature, whereas in case (II) a very thick non-protective layer is formed which sometimes assumes remarkable crystal shapes, several examples of which are illustrated. Above a certain definite temperature depending on the nature of the steel $FeZn_3$ is always formed, but below this temperature either compound may be formed according to the conditions. The presence of carbon and copper in the steel seems to favour case (II) whereas the presence of chromium and aluminium seems to favour case (I).—A. R. P.

***Metallic Cementation. VII.—Metallic Cementation [of Iron, Nickel, and Copper] by Means of Manganese Powder.** Tsutomu Kase (*Kinzoku no Kenkyu*, 1935, **12**, 478–483).—[In Japanese.] The cementation of iron, nickel, and copper by manganese in the form of the pulverized commercial product at various temperatures between 600°–1100° C. for 1, 2, 3, and 5 hrs. was investigated. The hardness and depth of penetration of the surface layer of the cemented specimens was measured, and microscopic examination, chemical analyses, and corrosion tests with strong acids were also carried out. Manganese diffuses into iron, nickel, and copper at a temperature above 600° C., the rate of diffusion increasing with increase of temperature. In the case of iron the rate of diffusion increases almost abruptly at the *A*3 point (906° C.). The relation between the increase in weight of the specimens and the absolute temperature of cementation or the length of time for the treatment is given by an exponential function as previously shown (*Met. Abs.*, 1935, **2**, 165, 385, 463, 522), The surfaces of iron and nickel cemented with manganese are easily attacked by strong acids, but that of copper is unaffected by dilute sulphuric and hydrochloric acids or concentrated hydrochloric acid.—S. G.

[Metal Spraying in] Oil-Field and Refinery Practice in Foreign Countries. William Reid (*Metallizer*, 1935, **4**, (1), 2–5, 13).—R. lists the parts of oil-refinery plant which have been successfully treated by the metal spraying process. The article deals mostly with the building up of shafts, &c., with steel, but there is also a description of some work carried out by the spraying of Monel metal, zinc, and " aluminium–bronze."—W. E. B.

Metallizing New Refinery Vessels. G. M. Jackson (*Metallizer*, 1935, **4**, (1), 11).—A description of the use of metal spraying for the protection of condensers in oil refinery. The coating is 2 lb./ft.^{2} of metal sprayed (lead), and the coating is applied both to the vapour and the water side of the condenser.—W. E. B.

Protection Against Burning-Out by Means of the " Alument " Process. —— (*Illust. Zeit. Blechindustrie*, 1935, **64**, 1389–1390).—The process consists in annealing at 900°–1100° C. the (ferrous) materials to be protected, after spraying with aluminium; a special flux is painted over the sprayed metal, which it protects from oxidation in the early stages, whilst assisting its penetration into the iron when combination occurs. A hard and resistant coating of $FeAl_3$ is said to be produced: it is claimed that treatment of an "Alument"-treated iron surface at 1000° C. for 1400 hrs. produced no appreciable alteration in structure. Thin-walled articles should be treated with special light alloys, as the brittleness of $FeAl_3$ would cause an undue decrease in strength.—P. R.

Anti-Rust Paints Containing Coal-Tar and Aluminium Powder. —— (*Ann. Ponts Chaussées*, 1935, **105**, 286–288).—An account is given of comparative tests on tar–aluminium paints and red-lead. The tests included exposure to ultra-violet radiation, salt-spray, freezing, moist and dry heat, and immersion in water. Both the durability and the covering power are stated to have proved superior in the case of the tar–aluminium paint.—P. M. C. R.

Aluminium Paints. Berthold Winter (*Petroleum Z.*, 1935, **31**, (44), 8).—Aluminium paint is stable and effective at temperatures up to 1000° C.: its high reflecting power renders it a useful protective medium for fuel tanks and containers, where a low temperature is desirable; it affords valuable protection against rust even when used in conjunction with other pigments, and it resists attack by ammonia and hydrogen sulphide. It is also recommended as a preservative for wood.—P. M. C. R.

Improved Paints Spur Attacks on Corrosion Problems. J. O. Hasson (*Steel*, 1935, **96**, (10), 30–33).—The preparation of the surface to which they are to be applied is of particular importance in connection with anti-corrosion paint coatings. Galvanized iron is best first roughened by etching with an acid solution, or by exposure to the weather for some months. A good primer for galvanized iron is a zinc dust–zinc oxide paint.—S. G.

VI.—ELECTRODEPOSITION

Faulty Chromium Plating, Its Detection and Removal. Ralph W. Harbison (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 521–522).—For chromium plate direct on iron or steel the ferroxyl test or simple immersion in copper sulphate solution rapidly detects porosity but for chromium plate on nickel, copper, or brass undercoats it is preferable to make the article the cathode in acid copper sulphate solution, copper being deposited only on the porous parts. The best method for stripping faulty chromium plate consists in dissolving the chromium anodically in 3·5–4% sodium hydroxide solution; the plating may be stripped more rapidly in hot hydrochloric acid but this produces severe etching of ferrous or copper-base metals.—A. R. P.

The New Methods of Nickel Plating. E. Staurenghi (*Industria meccanica*, 1935, **13**, 702–704; *C. Abs.*, 1935, **29**, 7821).—Present nickel plating processes are reviewed, and degreasing and cleaning methods are described. The nickel content of the bath is about 40–50 grm./litre; current density 0·3–0·4 amp./dm.^{2} while for rapid plating methods 1–3 amp./dm.^{2} are employed. The bath is stirred and the pieces are moved to obviate streaks on the deposit; p_H is 5·8–6·2. For rapid nickel plating the following bath is recommended: pure nickel sulphate 22·5 kg.; pure ammonium sulphate 2·0 kg., pure nickel chloride 0·5 kg., pure sodium perborate 0·5 kg., water 100 litres; 35°–40° C., voltage 2·75–3·5.—S. G.

Testing of Nickel Plate [on Steel]. (Liebetanz.) See p. 15.

***On the Polarization Potential in the Cathodic Deposition of Zinc from Aqueous Solutions of Zinc Sulphate.** Tomimatu Isihara, Takeo Onoda, and Katuo Umetu (*Kinzoku no Kenkyu*, 1935, **12**, 381–396).—[In Japanese.] The cathodic polarization potential, anodic overvoltage, and total polarization potential in the electrolysis of aqueous solutions of zinc sulphate of different concentrations, acidified with sulphuric acid and with the addition of various amounts of glue or gelatin, were measured by a direct method with a normal calomel electrode and a potentiometer. The anode consisted of a platinized platinum plate, but the starting cathode was a zinc-plated platinum plate having an inner layer of copper. Except the active surface of the cathode, all portions of it were covered completely with lead glass by fusion. The effects of current density and the composition of the solution on the quantities referred to above were also measured. All the experiments were carried out at 35° C. in an electric thermostat of large capacity.—S. G.

Non-Poisonous Plating Baths. K. Assmann (*Chem.-Zeit.*, 1935, **59**, 904–905).—Owing to the highly poisonous nature of the components many attempts have been made in recent years to replace cyanide plating baths with those containing non-poisonous salts. Satisfactory results have been obtained in silver- and copper-plating by the use of solutions of the iodides in concentrated alkali iodide solutions. For silver the bath contains potassium iodide 450, silver iodide 45, hydriodic acid 15, and gelatin 3–4 grm. dissolved in 800 c.c. of water, and for copper potassium iodide 550, cuprous iodide 55, hydrochloric acid 10, and gelatin 3–5 grm. in 1 litre of water. The baths are operated at 20° C. with 0·5–1·5 amp./dm.^{2} at 0·2–0·5 v. and yield fine-grained adherent deposits on copper, brass, nickel silver, and similar alloys. Much less expensive baths which yield brighter deposits than those obtained from cyanide baths are prepared by dissolving 33 grm. of silver thiocyanate or 43 grm. of cuprous thiocyanate in 1 litre of 20% sodium thiocyanate solution containing 1% of sodium sulphite. Silver has also satisfactorily been plated from nitrate solutions containing thiourea. No good non-poisonous brass plating bath has yet been developed but good cadmium and zinc deposits can be obtained from sulphate baths and good chromium deposits from solutions of violet chromic chloride using soluble chromium anodes and superimposed alternating current to overcome the passivity of the anodes.—A. R. P.

†**Bright Electrolytic Deposits.** Max Schlötter (*Z. Metallkunde*, 1935, **27**, 236–237).—Electrodeposited metals are never absolutely pure, small amounts of the anion of hydrolysis products of the salts in the electrolyte or of various addition agents being practically always included in the deposit. The structure of the deposit as regards grain-size and rate of growth is controlled chiefly by the nature of the anion, with increasing molecular volume of which the rate of grain-growth decreases and the number of crystallization nuclei increases. Under suitable electrical conditions, inclusion of anions in the lattice structure of the deposited metal may be induced and the appearance thus considerably modified. Working along these lines considerable advances have recently been made in the production of bright deposits of copper, silver, gold, nickel, and chromium. Bright nickel deposits contain inclusions of oxide, are not passive like matt deposits, and can readily be chromium plated; matt and bright deposits of nickel form a thermo-element the e.m.f. of which is $2 \cdot 5 \times 10^{-6}$ v./° C.—A. R. P.

The Importance of Regularity in the Crystal Structure of Thick Electrolytic Coatings. W. Müller (*Metallwaren-Ind. u. Galvano-Tech.*, 1935, **33**, 477–478).—The factors influencing the structure of electrolytic deposits are critically discussed and their influence on the production of thick (0·5–5 mm.) deposits with a regular structure throughout is outlined, the importance of correct bath composition, standard electrical conditions, and absolute cleanliness being stressed.—A. R. P.

VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY

(Other than Electrodeposition.)

***Polarization of Electrodes in the Deposition of Metals from Solutions of Complex Cyanides.** O. Essin and A. Matanzew (*Z. physikal. Chem.*, 1935, [A], **174**, 384–394).—Many opinions have been expressed in the literature as to the nature of electrode polarization in the deposition of metals from solutions of complex salts. Analysis of the experimental results of S. Glasstone shows that the concentration polarization caused by cyanide accumulation at the cathode leads in many cases to a relation between polarization and current density similar to the equation for hydrogen overvoltage. This relation in the case of mercury deposition from cyanide solution indicates that polarization is of a chemical nature and is induced by retarded discharge of the ions in the sense of Volmer's theory of overvoltage. No definite conclusions can, however, be drawn from the results available for cadmium and silver but in the case of copper they indicate that no chemical polarization, but rather a depolarization effect, takes place.—B. Bl.

The Hydrogen Film on a Polarized Metallic Electrode. G. Perfil'ev (*Sotzialist. Rekonstruktziya i Nauka*, **1935**, (3), 168; *C. Abs.*, 1935, **29**, 7826).—[In Russian.] The polarization capacity of the hydrogen film formed on the electrode in cathodic polarization depends on the density and frequency of the a.c. The dependence of the capacity of the mercury cathode on the potential is expressed by a curve with a sharply marked maximum. The hydrogen overvoltage diminishes with increase in the capacity and the diminution of the active resistance of the polarization condenser under the influence of the a.c.
—S. G.

VIII.—REFINING

*****Bullion Parting at the Homestake Mine.** Nathaniel Herz (*Min. and Met.*, 1935, **16**, 500–504).—The crude metal bars obtained in the extraction of the precious metals from the ore by cyaniding and amalgamation contain gold 73–82, silver 17·5–23, copper 0·5–3, lead 0·5–1·5, iron 0–0·05, and antimony 0–0·5%. The bars are melted in a small furnace and the metal transferred to clay pots brasqued with borax; a steady stream of chlorine is bubbled through the molten metal to convert all the base metals and the silver into chlorides leaving gold purer than 99·4%. The slag is melted with borax and a little soda ash to recover some of the silver and any suspended gold, while leaving most of the silver chloride unattacked; this metal is returned to the gold refining pots. The residual silver chloride is broken up and reduced to metal with iron and sulphuric acid, copper is extracted by digesting the sponge with hydrochloric acid, and the purified sponge is melted with borax and soda ash to give pure silver.—A. R. P.

IX.—ANALYSIS

Contribution to Applied Spectroscopy in Metal Working Laboratories. I.—The Spectrographic Apparatus of the M.A.N. G. Heidhausen (*Mitt. Forsch. Anst. G.H.H.-Konzern*, 1935, **4**, 59–70).—The spectrographic outfit of a German steelworks laboratory is described with reference to illustrations and wiring diagrams, and some examples of its value in the analysis of steel and cast iron are given.—A. R. P.

***p*-Homosalicylic Aldoxime as a Reagent for Copper.** C. H. Kao and K. H. Chen (*J. Chinese Chem. Soc.*, 1935, **3**, (1), 22–26).—[In English.] The reagent solution is prepared by diluting an alcoholic solution of the oxime with water, and filtering. Cu is precipitated in the presence of acetic acid and sodium acetate, the precipitate containing 17·48% Cu. Ni is quantitatively precipitated from neutral solutions: the precipitation of Co is incomplete. Methods of separating Cu from Fe''', Ni, and other metals, and of Ni from Cd, Mg, and Al are shortly described.—P. M. C. R.

Pyrocatechol as a Reagent for Titanium. Nathan R. Pike, Joseph B. Ficklen, and I. Laird Newell (*Ber. deut. chem. Ges.*, 1935, [B], **68**, (6), 1023–1026).—Pyrocatechol gives a colour with as little as 2 parts of Ti in 10^7 parts of solution, but many metals and acid radicals interfere.—P. M. C. R.

The Determination of Aluminium in Nickel-Chromium and Nickel-Chromium–Iron Alloys: A Survey of Available Methods. Fred P. Peters (*Chemist-Analyst*, 1935, **24**, (4), 4–10).—The most rapid method for removing the other metals present in these alloys consists in electrolysis of a cold nearly neutral solution of the sulphates using a Hg cathode and a Pt anode; deposition of Fe, Co, Ni, Cr, Cu, and Mo is complete in 1½–2 hrs. using 6 amp. at 9 v. If no other metals are present the Al can then be recovered from the solution by precipitation with NH_4OH, but if Ti is present the solution is treated with H_2O_2 and 8-hydroxyquinoline in $CH_3{\cdot}CO_2H$, made ammoniacal and heated until the Al precipitate is crystalline. A colorimetric method for minute amounts of Al is also described.—A. R. P.

Determination of Small Amounts of Antimony in Zinc. Frank W. Scott (*Chemist-Analyst*, 1935, **24**, (4), 16–17).—The sample (5 grm.) is dissolved in 50 c.c. of Br-water and 10 c.c. of HNO_3, 50 c.c. of HCl are then added and the solution evaporated to a syrup, diluted with H_2O, neutralized with KOH, adjusted to 10% HCl, and saturated with H_2S. The precipitate is redissolved and the Sb separated from Cu, Pb, and As as usual and from Sn by precipitation with H_2S in the presence of $H_2C_2O_4$; it is eventually precipitated as Sb_2S_5, collected in a Gooch crucible, washed successively with H_2S water, CS_2, and C_2H_5OH, dried at 105° C. and weighed.—A. R. P.

***Determination of Magnesium in Duralumin.** G. Stanley Smith (*Analyst*, 1935, **60**, 812–814).—The alloy (2 grm.) is dissolved in 10% NaOH solution and the residue collected, washed free from Al salts, and extracted with hot H_2SO_4 (*d* 1·2). The acid $MgSO_4$ solution so obtained is purified by exact neutralization with NaOH and boiling with ZnO and $KMnO_4$ to precipitate Fe, Mn, and any Al still present, the excess of $KMnO_4$ being destroyed by adding a few drops of C_2H_5OH. The filtrate from this treatment containing all the Mg and a little Cu and Ni is treated with 1 grm. of KCN and 10 c.c. of 10% NaOH solution whereby, on boiling, practically pure $Mg(OH)_2$ is precipitated. The washed precipitate is dissolved in dilute H_2SO_4 and the Mg precipitated in the usual way as $MgNH_4PO_4$ which is ignited to $Mg_2P_2O_7$ for weighing.—A. R. P.

Testing of Nickel-Plate [on Steel]. R. Liebetanz (*Metall-Woche*, **1935**, 117–118).—After Ni-plated steel has been worked and annealed removal of the plated films by the usual reagents is difficult since the intermediate layer formed by diffusion is very resistant to attack. The following procedure is recommended: the outer film is removed by dissolution in a cold 3 : 1 mixture of concentrated and fuming HNO_3 and the Cu and Ni determined by electrolysis first in dilute HNO_3, then in ammoniacal solution; the intermediate diffusion layer is dissolved in cold HCl (*d* 1·12) saturated with Br, and the Cu removed with H_2S and the Ni with dimethylglyoxime.—A. R. P.

A Contribution to the Iodometric Titration of Tin. F. L. Okell and John Lumsden (*Analyst*, 1935, **60**, 803–810; discussion, 811).—Low results in the iodometric titration of Sn are shown to be due to the presence of dissolved O_2 in the I solution; a method of preparing air-free I solution is described and boiling with Al turnings is recommended as a means of reducing Sn^{IV} to Sn^{II} for titration.—A. R. P.

***On the Precipitation of Titanium as Phosphate.** Da-Tchang Tcheng and Houong Li (*J. Chinese Chem. Soc.*, 1935, **3**, (2), 115–117).—[In English.] Titanium phosphate was precipitated from solutions of the chloride having various degrees of (HCl) acidity; when the latter does not exceed 10% precipitation is complete. A very large excess of ammonium phosphate must be employed.—P. M. C. R.

Note on the Pyrophosphate Method for the Determination of Zinc. Z. H. Pan and C. H. Chiang (*J. Chinese Chem. Soc.*, 1935, **3**, (2), 118–121).—[In English.] The conversion of zinc ammonium phosphate into zinc pyrophosphate was found to begin at 350° C., and to be complete in 2 hrs. at 370° C.: temperatures up to 520° C. produce inappreciable degrees of volatilization. The temperature usually recommended (900°–1000° C.) is therefore unnecessarily high: it also leads to volatilization.—P. M. C. R.

X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

On the Question of the Size of Photograph in Micrographic Work with the Metallurgical Microscope. Ernst Rossow (*Z. Metallkunde*, 1935, **27**, 263–264).—A large plate should be used only when a large print is required, when only a few prints are required, or when extreme sharpness of detail or specially sensitized layers (*e.g.* for the extreme infra-red) are necessary. In all other cases it is just as satisfactory and much more economical to use small films for taking photomicrographs.—A. R. P.

Surface Illuminator for Microscopes. Bausch and Lomb Optical Co., Ltd. (*J. Sci. Instruments*, 1935, **12**, 399).—An annular ring holding 6 electric light bulbs with individual reflecting surfaces is held in position over the microscope objective. The device is suitable for use with the 48-, 32-, and 16-mm. microscope objectives.—J. S. G. T.

***Microscope Tilting Stage.** W. Watson and Sons, Ltd. (*J. Sci. Instruments*, 1935, **12**, 397).—A tilting microscope stage, constructed so that objectives of low-, medium-, or high-power (including oil-immersion objectives) can be used for making stereophotomicrographs without altering the illumination employed in ordinary microscopical observation. The specimen is photographed, then rotated through 15° about an axis at right angles to the optical axis, and photographed again.—J. S. G. T.

†The Electron Microscope. Walter Henneberg (*Elektrotech. Z.*, 1935, **56**, 853–856).—The principles, present position, and sphere of usefulness of electron microscopy are discussed.—B. Bl.

The Electron Microscope and Its Applications. L. Marton (*Rev. d'Optique*, 1935, **14**, 129–145).—The electronic microscope (see *Met. Abs.*, 1934, **1**, 196) is described; its principal advantages are its high resolving power even at very low numerical apertures, and its possible use in recording emission phenomena. The metallographic and histological applications of the instrument are described and illustrated.—P. M. C. R.

The Electronic Optics of Centred Systems. Emile Henriot (*Rev. d'Optique*, 1935, **14**, 146–158).—The possibility of substituting electronic radiation for ordinary light, as in the electron microscope, points to a close analogy between the two types of radiation, a theoretical analysis of which is presented.—P. M. C. R.

***A Semi-Automatic Potentiometer for Thermal Analysis.** R. J. M. Payne (*J. Sci. Instruments*, 1935, **12**, 348–355).—A mechanically-driven potentiometer for use in conjunction with an inverse-rate recorder for making thermal curves of metals and alloys is described. The instrument operates normally as a null-method potentiometer; the galvanometer used experiences no large deflections, and errors due to creep do not occur. It is intended to make the working of the instrument wholly automatic.—J. S. G. T.

A Simple Thermo-Regulator. H. P. Bloxam (*J. Sci. Instruments*, 1935, **12**, 361–363).—A bi-metallic type of thermo-regulator, which can be made either as a portable or built-in instrument, for controlling temperatures up to 300° C., constant to within ± 3° and 0·1° C., respectively, is described.—J. S. G. T.

An Improved Thermo-Regulator and Circuit for D.C. Supply. S. J. Folley and P. L. Temple (*J. Sci. Instruments*, 1935, **12**, 392–393).—A form of d.c. electric thermo-regulator having a large surface/volume ratio of toluene bulb and a mercury seal at either end is described. The electric circuit includes a pentode valve used in conjunction with a relay to reduce sparking at the mercury surface in the regulator. A water-bath is easily maintained at ordinary temperatures to within 0·01° C.—J. S. G. T.

***A Variable Temperature X-Ray Powder Camera.** W. H. Barnes and W. F. Hampton (*Rev. Sci. Instruments*, 1935, [N.S.], **6**, 342–344).—Describes an X-ray camera, designed for obtaining X-ray diffraction patterns by the monochromatic pin-hole method at temperatures (constant to within 0·1°–0·2° C.) between about — 60° and 0° C. The crystal is mounted on a copper block, the temperature of which is controlled by circulation of pre-cooled acetone.—J. T.

Spectroscope with Prism Objective. L. Herman and (Mme.) R. Herman (*Rev. d'Optique*, 1935, **14**, 203–207).—The use of a prism objective in conjunction with an inclined spherical reflector obviates the use of a collimator and a slit screen. The optical system is described, and an account is given of the preparation of the series of mirrors employed: these were coated with platinum by cathodic projection. An example is given of the successful use of the spectroscope in metallurgical analysis.—P. M. C. R.

A Two-Crystal Spectrometer for X-Rays of Wave-Length $0\cdot030 < \lambda < 0\cdot215$ A. T. R. Cuykendall and M. T. Jones (*Rev. Sci. Instruments*, 1935, [N.S.], **6**, 356–361).—Describes a two-crystal X-ray spectrometer employing transmission and reflection of X-rays through the crystal.—J. S. G. T.

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

†The Testing of Engineering Materials. H. J. Gough and W. J. Clenshaw (*Trans. Inst. Marine Eng.*, 1935, **47**, 241–276).—A discussion of certain aspects of the testing of engineering materials deals with such subjects as the testing of materials at high temperatures, lubrication, lifting-gear components, contact corrosion, welded joints, fatigue of metals, failure of metals under complex stress distribution, corrosion-fatigue, and failures in service. Reference is made to the fatigue properties of single crystals of aluminium, iron, zinc, antimony, bismuth, and silver; to the fatigue and corrosion-fatigue of such non-ferrous alloys as Duralumin and a magnesium alloy containing 2·5% aluminium; to combined static tension–torsion tests on aluminium and copper; and to the failure of bronze condenser tubes in service.—J. W. D.

†Special Apparatus Used for Testing Aluminium Alloys. E. John Pike (*Metallurgia*, 1935, **13**, 35–37).—The testing apparatus which has been designed to give an idea of the behaviour of aluminium alloys under working conditions, such as high stresses, is discussed and includes the repeated-impact fatigue testing machine, the rotating fatigue testing machine, a machine for testing bearing and frictional properties at elevated temperatures, and the use of the X-ray spectroscope for charting internal stresses which will result not in the total elimination of internal stress or its counteraction by thickening of parts of the section, but in the use of these stresses to counteract applied stresses. Test results for the different types of testing apparatus described are given for various aluminium alloys.—J. W. D.

†General Review of the Experimental Methods of Determining the Tensile Properties of Aluminium Castings. A. von Zeerleder (*Aluminium*, 1935, **17**, 570–574).—Read before the Congrès International des Mines, de la Métallurgie, et de la Géologie Appliquée, Paris, Oct. 1935.—Methods for casting test-pieces simultaneously with the casting and the appropriate dimensions to obtain comparable results are critically discussed.—A. R. P.

Mechanical Testing Machine. Tensometer, Ltd. (*J. Sci. Instruments*, 1935, **12**, 366–367).—A testing machine in which the movement of a mercury column actuates mechanism for recording the load applied to the test-piece is described. Extensions are recorded as abscissæ on a graph in which the loads are represented by abscissæ. A simple zero-adjustment is provided.—J. T.

***Abrasion at High Temperatures [New Abrasion Tester].** Yoshiro Fujii (*Tetsu-to-Hagane* (*J. Iron Steel Inst. Japan*), 1935, **21**, 656–660).—[In Japanese.] By means of a new abrasion tester, various metals used for internal combustion engine cylinder liners and piston rings were tested in lubricating oil at 200° C. —S. G.

***On Avoiding the Effect of Sheet Thickness on the Values Obtained in the Erichsen Test.** A. von Vegesack (*Z. Metallkunde*, 1935, **27**, 227–235).—Mathematical analysis of the Erichsen test shows that the depth of penetration (T) of the standard Erichsen tool is related to the thickness of the sheet by the expression $T = T_{n1}\sqrt[4]{S/1{\cdot}0743}$ where T_{n1} is the depth of penetration of a sheet of normal thickness (1·0743 mm.), and S is the thickness of the sheet under test. This expression is in close agreement with the results obtained on soft-iron strip.—A. R. P.

RADIOLOGY.

†State and Problems of Radiology. Herbert Graf (*Elektrotech. Z.*, 1935, **56**, 1047–1050).—A review.—B. Bl.

Separate Determination of Principal Elastic Stresses by Means of X-Rays. R. Glocker and E. Osswald (*Z. tech. Physik*, 1935, **16**, 237–242).—The application of X-rays for the determination of principal component stresses in test-pieces is described. The method is illustrated by its application to the cases of a tube subjected to internal pressure and a twisted rod.—J. S. G. T.

XIII.—FOUNDRY PRACTICE AND APPLIANCES

Aluminium Fluxes. —— (*Amer. Metal Market*, 1935, **42**, (228), 5).—A very brief note of a new series of fluxes for use in casting aluminium and its alloys. They are said to be free from disadvantages such as the too rapid release of chlorine, objectionable vapours, and hygroscopicity. They consist of a mixture of zinc chloride and sodium fluoride, with or without potassium fluoride, water being present. Flux melting points of about 650° C. are claimed.—L. A. O.

The Special Brasses. —— (*Machines*, **1935**, (Nov.), 17–20).—An account of the commercially useful ranges of the copper–zinc alloys is followed by a discussion of the " zinc equivalent " of common metallic additions to brass. The pre-alloying required for the convenient introduction of such additions (nickel, manganese, aluminium, iron) is described, as is the casting, remelting, and final pouring of the desired product.—P. M. C. R.

†Recent Developments in the Manufacture and Applications of Magnesium and Magnesium Alloys. W. C. Devereux (*Metallurgia*, 1935, **13**, 47–49).—A review of recent developments in the production and use of magnesium alloys deals with the preparation of high-purity magnesium by a direct reduction and distillation process; with the use of inhibitors such as sulphur, boric acid, and ammonium bifluoride in moulding material to prevent reaction between the metal and moisture; with the exclusion of air from the mould prior to pouring; with the working of ingots at temperatures of 380°–420° C., and the effect of such working on the mechanical properties and structure; and with the extrusion of magnesium alloys. The composition and mechanical properties of various alloys in the sand-cast and die-cast conditions and as forgings, extrusions, and sheets are given, and the influence of heat-treatment on the mechanical properties of typical heat-treatable magnesium-base alloys are considered. Recent applications of magnesium alloy in aero-engine and aircraft construction, and the use of magnesium alloy sheets to replace aluminium sheets in metal-skin construction are also referred to.—J. W. D.

The Use of Synthetic Moulding Materials in Magnesium Foundry Practice. R. Jones (*Metallurgia*, 1935, **13**, 49).—A brief note on the need for using dry silica sands moulded with suitable bonding agents and inhibitors to prevent the reaction which occurs with sand and with the steam generated in green-sand moulds, when the molten metal impinges on the mould face. It is stated that 5% by weight of pure clay binder to 95% by weight of sand with addition of 4–6% of water, together with the necessary inhibitor, provides a moulding material particularly suited to the casting of magnesium and its alloys. —J. W. D.

XV.—FURNACES AND FUELS

Progress in Design and Application of Electric Furnaces. H. Knight (*Metallurgia*, 1935, **13**, 53–56).—Brief descriptions are given of some recent developments in electric melting furnaces and include a large H.-F. furnace installation, "double-furnace" melting, and the rocking-resistor furnace suitable for the melting of high melting-point alloys such as brass and bronze. Recent developments in heat-treatment furnaces both of the batch-type and continuous-type for heat-treatment and bright-annealing are also dealt with. Reference is made to a new application of H.-F. induction heating known as high-frequency hardening, and to a new high-temperature thermocouple which will withstand successfully for long periods temperatures of 1500° C. and above, and at the same time provide a thermo-electric power of measurable magnitude.—J. W. D.

†**The Importance of Large Electrical Heating Apparatus in Technique and Economy.** C. T. Buff (*Elektrotech. Z.*, 1935, **56**, 1147–1148, 1192–1195, 1221–1225, 1239–1241).—A review of the whole field of the industrial use of electric heat.—B. Bl.

†**The Development and Future Possibilities of Gas as an Industrial Fuel.** Joseph E. White (*Gas World, Indust. Gas Suppt.*, 1935, **7**, (12), 7–11; discussion, 12–13).—Read before the North-Western Section of the Institute of Fuel and the Manchester District Association of Gas Engineers. Applications of towns' gas in semi-rotary brass and aluminium melting furnaces, for rolling non-ferrous strip and sheet, for brass annealing, carburizing, flanging, and annealing locomotive boiler plates are described and illustrated.—J. S. G. T.

†**British Coals; Their Analyses and Uses.** —— (*Fuel Economist*, 1935, **11**, 82–84).—Analyses are given of seven coals and one coke marketed by Dorman, Long, and Co., Ltd.—J. S. G. T.

XVI.—REFRACTORIES AND FURNACE MATERIALS

†**Refractoriness and Its Determination.** F. H. Clews and A. T. Green (*Trans. Ceram. Soc.*, 1935, **34**, 467–499).—The subject is critically reviewed with special reference to standard German and American testing methods. A *bibliography* of 43 references is appended.—A. R. P.

***The Action of Alkalis on Refractory Material. I.—The Action of Potash Vapour on Refractory Materials at 900° and 1000° C.** F. H. Clews, A. Green, and A. T. Green (*Trans. Ceram. Soc.*, 1935, **34**, 436–455).—Aluminous fireclay brick is more readily corroded by potash vapours and absorbs more potash at 900° C. than do normal fireclay, silicious fireclay, or silica-bricks on which a viscous protective film of silicate forms.—A. R. P.

Experiments on the Grading, Porosity, and Permeability to Air of Silica Bricks. F. H. Clews and A. T. Green (*Trans. Ceram. Soc.*, 1935, **34**, 457–466).—The pressure under which silica bricks are formed affects the permeability to air considerably, values of about 0·04 being obtained with 6·75 tons/in.^{2}. Bricks made under pressures of 2·25 tons/in.^{2} are not markedly less permeable than those made by hand-tamping. Addition of 0·5% of cellulose liquor slightly reduces the permeability. Pressure has much less effect on porosity than on permeability.—A. R. P.

***The Effect of the Water Content of Silica Brick Batches on the Porosity of the Fired Brick.** T. R. Lyman and W. J. Rees (*Trans. Ceram. Soc.*, 1935, **34**, 500–506).—Numerous test results show that it is necessary to control within narrow limits the moisture content of the batch in the manufacture of silica bricks, the best results in standard practice being obtained with about 7·5% of moisture. If pressure is used in forming the bricks, the porosity and the permeability can be further reduced by using a drier batch, but naturally the weight of the fired brick will be greater.—A. R. P.

XVII.—HEAT-TREATMENT

Heat-Treatment of Aluminium Alloys. J. Towns Robinson (*Nickel Bull.*, 1935, **8**, 138–139).—The heat-treatment of the " R.R." series of aluminium alloys and of Silumin and " Y " alloy, and the structures and properties resulting from such heat-treatment are discussed.—J. H. W.

XVIII.—WORKING

On the Manufacture of Aluminium Foil. W. Frölich (*Metall-Woche*, **1935**, 157–158).—A brief account is given of modern methods of rolling aluminium ingots into foil for insulating and packing purposes.—A. R. P.

The Drawing of Square and Rectangular Aluminium Vessels. Gerhard Henker (*Illust. Zeit. Blechindustrie*, 1935, **64**, 1382–1383).—Illustrated instructions for the drawing of aluminium cups and hoods, especially of the type employed in wireless apparatus, include a discussion of the relation between size of work and number of draws, drawing speed, dimensions of plate, and probable output.—P. M. C. R.

Precautions to be Observed in Changing the Type of Oil Used in the Cutting and Plastic Deformation of Metals. K. Krekeler (*Z. Metallkunde*, 1935, **27**, 262–263).—The more expensive vegetable and animal oils previously used as lubricants in the working of metals are now being satisfactorily replaced by the cheaper mineral oils. Examples of the use of the latter are given with practical hints.—A. R. P.

The Choice of Suitable Cutting Metals. —— (*Werkstatt u. Betrieb*, 1935, **68**, 242–243, 289–290).—A table shows the approximate composition of the various groups of tool materials, and the properties of each type are discussed. Non-ferrous materials of this nature include the Stellite group, and the " carbide " materials. A description of the carbide group includes a summary of the properties of " Alloy 548," an iron–tungsten–cobalt carbide having properties similar to those of entirely metallic cutting alloys. The mechanical properties of the tool materials are tabulated and the relation between hardness and brittleness is discussed. The relative cutting speeds of 5 typical materials are tabulated for bronze, brass, copper, aluminium, and 4 steels.—P. M. C. R.

XIX.—CLEANING AND FINISHING

Cleaning Metal Surfaces Before Finishing Them. C. F. Scribner (*Indust. Finishing* (*U.S.A.*), 1934, **10**, (8), 12–14).—The uses of abrasives, solvent degreasers, acid pickling, and alkaline cleaners are discussed.—C. E. H.

***New Knowledge in the Colouring of Metals.** G. Gross (*Z. Metallkunde*, 1935, **27**, 238–241).—A common method of colouring metal surfaces comprises immersion in hot (80°–95° C.) solutions containing sodium thiosulphate 124 and lead acetate 38 grm./litre; this solution colours copper dark blue, zinc a brownish-bronze, and iron a steel-blue colour, and produces various shades on brass according to the conditions. G. has examined the effects of ageing, temperature, concentration of the constituents, and time of immersion on the colour and nature of the films produced on steel and brass. At 80° C. the time required to produce a definite tint decreases with increase in the concentration of thiosulphate when the lead content is kept constant, and with increase in lead content when the thiosulphate is kept constant. Ageing of the bath reduces the time required to about half that of a new bath and addition of argol to an old bath develops the same colour in 5 seconds as is produced in 27 seconds without argol. The most rapid action is obtained with a bath containing sodium thiosulphate 240, lead acetate 25, and argol 30 grm./litre at 80°–90° C., but equally good results can be obtained at room temperature with a longer period of immersion (12 minutes instead of 5–10 seconds); at the same time the adhesion, thickness, and resistance to corrosion of the coloured films are materially increased.—A. R. P.

Surface Colouring of Metals. Georg Buchner (*Chem.-Zeit.*, 1935, **59**, 841–843).—A general review of the principles and methods of producing artistic and protective surface films on metals.—A. R. P.

XX.—JOINING

The Packing of Socket Joints Without the Use of Lead. —— (*Illust. Zeit. Blechindustrie*, 1935, **64**, 1237–1238).—Excerpts are given from the German Standard Specification (DIN 2435 U) for packing materials to be used in place of lead in making socket joints in cast-iron or steel tubes. The use of aluminium wool is recommended, and the method of packing described.—P. R.

***Welding of Wire of Chromium–Nickel and High Heat-Resistant Alloys by Condenser Discharge.** T. Wrana (*Elektrotech. Z.*, 1935, **56**, 991–993).—Mechanical and electrical tests of the joint in wires welded by a condenser discharge indicate that this method of welding is suitable for joining resistance wires of Nichrome, Megapyr, and Kanthal.—B. Bl.

Modern Methods of Welding. R. S. Kennedy (*Trans. Inst. Marine Eng.*, 1935, **47**, 295–299).—A short description of various methods of welding, forge welding, resistance, or flash welding, spot and seam welding, gas welding, and electric welding with special reference to the electric welding of iron and steel, refers to the welding of cracks in gun-metal and aluminium by the oxy-acetylene method.—J. W. D.

XXI.—INDUSTRIAL USES AND APPLICATIONS

***Investigations on Metallic Contamination of Foods. II.—Effect of Cooking and Storage of Foodstuffs in Aluminium Vessels.** N. C. Datta (*Proc. Indian Acad. Sci.*, 1935, **2**, (3B), 322).—Aluminium vessels are well suited for the storage and boiling of milk and milk products. Fruit and vegetable juices dissolve only a small amount of aluminium from utensils during storage. The amount dissolved possibly depends on the organic acid present and the buffering capacity of the food material. The corrosive action of acid foods on aluminium is increased by the presence of salt; the amount of aluminium dissolved by tamarind solution containing salt during storage is very nearly equal to the amount of aluminium dissolved by acid and salt taken separately, so that each seems to act independently of the presence of the other. The amount of aluminium dissolved in the ordinary process of cooking is very small, but in cases when acidic foods containing salt are cooked and stored for fairly long periods in aluminium vessels, the maximum of aluminium added to the daily diet from utensils is about 50 mg. Acid foodstuffs containing salt should not be left long in the same aluminium vessel after boiling. Feeding experiments with rats show that food prepared in aluminium vessels has no harmful effect on growth, reproduction, and general well-being of the animals.—J. S. G. T.

Aluminium Caps for Milk Bottles. —— (*Light Metals Rev.*, 1935, 2, 185–186).—A development report. Describes the method of attaching the cap to the bottle, and the cost as compared with the cardboard discs previously used in sealing the bottles.—L. A. O.

The Standardization of Aluminium Bars for Electrical Switchgear. K. Kupper and F. Streiff (*Aluminium*, 1935, 17, 579–585).—Tables and graphs are given for calculating the permissible loading of aluminium bars of various dimensions with d.c. and with a.c. of various frequencies under different electrical arrangements.—A. R. P.

Light Metal Traffic Signs. Fritz Rendel (*Aluminium*, 1935, 17, 568–569).—The high reflectivity and resistance to weathering of certain aluminium alloys render them eminently suitable as bases for traffic signs. The desired lettering can be applied to anodized surfaces and does not deteriorate in brightness or colour by the action of dust and rain and the signs show clearly at night since the light of car lamps is brilliantly reflected from the bright aluminium background.—A. R. P.

Aluminium Trusses and Floor for Brooklyn Bridge. —— (*Eng. News-Record*, 1935, **114**, 547–550).—S. G.

Adhesives for Aluminium [Foil]. —— (*Light Metals Rev.*, 1935, 2, 182–185).—A development report. Discusses the types of glues most suitable for attaching various kinds of paper to aluminium foil. No adhesive has yet been found capable of permanently attaching two aluminium surfaces to each other; the most satisfactory substances for this purpose are gutta-percha (for thin foils), a mixture of beeswax and resin, bitumen, and cellulose nitrate.—L. A. O.

Copper Developments—A Review of Recent Work. —— (*Metallurgia*, 1935, **13**, 46, 57–60).—A review of some of the more recent electrical, architectural, and metallurgical developments of copper. Recent developments in the electrical applications of copper are the use of cadmium–copper conductors, steel-cored and hollow copper conductors, copper oxide rectifiers, and copper conduits. In architecture there is an extended use of copper for tubes and pipes, for sheets and strips for roofing, for copper boilers, cylinders, and tanks, and for moulding and decorative purposes. Metallurgical applications include its more general use as an alloying element both in cast and wrought steels and in cast iron, and in the manufacture of copper moulds and stools for casting steel.—J. W. D.

Copper Dampcourses. Building Research Station (*Roy. Inst. Brit. Arch. J.*, 1935, **42**, 382–383; *Build. Sci. Abs.*, 1935, **8**).—The physical and mechanical properties of soft-temper copper are considered favourable to the use of this metal for damp-proof courses. A search has been made of the literature to discover information bearing on the durability of copper from the point of view of corrosion as a damp-proof course; none bearing directly on the behaviour of copper in this respect has been obtained, but observations on the effect of lime and cement solutions on the behaviour of copper embedded in cement suggest that lime and Portland cement will not be destructive. Copper for use in damp-proof courses should be soft-temper material, complying with clause 2 of British Standard Specification No. 61, and with a minimum weight of 16 oz./ft.^{2}. Joints should be made by lapping the sheets to a distance of 3 in.—S. G.

New Use for Beryllium–Copper. —— (*Amer. Metal Market*, 1935, **42**, (207), 2).—A very brief note. The use of beryllium–copper for dies used in the manufacture of Bakelite products, has been commercially developed. The die is made by casting the alloy in a plaster mould.—L. A. O.

Gold and Gold Substitutes in Dental Practice. J. Dresel (*Metall-Woche*, **1935**, 118–119).—Suitable alloys for dental plates generally consist of 18-ct. gold containing copper and platinum or palladium, but recently several white alloys have been introduced with satisfactory results. The cheapest of these consists of gold 25, platinum 41·7, and palladium 33·3%. All dental gold alloys are wrought into the finished shape after quenching from 900° C. and are finally tempered by slow heating to 350°–400° C. followed by slow cooling. As substitutes for gold alloys various stainless steels and silver–platinum metal alloys have found increasing use.—A. R. P.

Lead and Its Uses in the Mineral Industries. Felix Edgar Wormser (*Min. and Met.*, 1935, **16**, 493–497).—The use of lead for storage battery plates, electrical cable coverings, the lining of sulphuric acid chambers, covering benches and floors in chemical works, and for the preparation of bearing metal alloys and the manufacture of pipes, &c., is briefly reviewed.—A. R. P.

The Use of Lead in Sound-Proofing. J. Mahul (*Bull. tech. Suisse Romande*, 1935, **61**, 282–285).—Lead reflects a high proportion of any incident sound-waves, the production of secondary vibrations being obviated by the low elasticity of the metal. M. describes comparative tests made by Cellerier on the sound-insulating properties of sheet lead, concrete, cement, various woods, plaster, brick, &c. It is stated that the sound-insulating power of lead sheet 1 mm. thick is equivalent to that of " cellular " concrete 100 mm. thick. The efficiency of the lead is increased by a backing of porous material: the combination has been successfully used at the National Broadcasting Station, New York, and at a factory in Paris. Both instances are described and illustrated. —P. M. C. R.

***Tungsten Alloy and the Treatment of Cancer by Radium Rays.** —— (*Science-Supplement*, 1935, [N.S.], **82**, (2133), 6–7).—A new tungsten alloy, containing 5–10% of copper or nickel, and having a density of about 17, makes possible the use of a radium bomb only about 64% as large as the lead bombs previously used for shielding large packs of radium. Patients can thus be placed closer to the source of radium rays. The alloy was invented by McLennan and Smithells.—J. S. G. T.

***A New Magnetic Alloy for Loud Speakers.** —— (*Science-Supplement*, 1935, [N.S.], **82**, (2131), 9).—A new alloy, originally developed as a heat-resisting alloy which did not deteriorate at high temperatures, composed of aluminium, cobalt, nickel, and iron, capable of lifting (by reason of its permanent magnetization) sixty times its own weight, is briefly referred to. The alloy must be cast in the required shapes and finished by grinding.—J. S. G. T.

XXII.—MISCELLANEOUS

75 Years Verein deutscher Eisenhüttenleute 1860–1935. —— (*Stahl u. Eisen*, 1935, **55**, 1253–1450).—The entire number is an account of the inception, history, and work of the Verein deutscher Eisenhüttenleute, to celebrate the seventy-fifth year of its existence.—L. A. O.

New Research Laboratory of the London, Midland and Scottish Railway Company. —— (*Iron Coal Trades Rev.*, 1935, **131**, 987).—Includes a plan showing the general lay-out of the laboratory.—L. A. O.

Research and Technical Development in the Tin Industry. —— (*Metallurgia*, 1935, **13**, 61–62).—Recent research work on tin includes investigation into the manufacture and properties of tinplate and other tin coatings, and into certain advances in electrodeposition. Investigations are also in progress to improve tin-base bearing metals, to overcome porosity in bronze, and to develop new tin-base alloys which may be improved by heat-treatment. Technical developments include an extended use of solder, a revival in the use of pewter, the application of pure solid tin in the form of pipe in the food and fine chemical industries and for the manufacture of foil and collapsible tubes. In the form of tin oleate, tin has recently been added to the extent of 0·1% to lubricating oil for motor-cars as an anti-oxidant.—J. W. D.

Material Problems of the Last Twenty-Five Years and Their Solution in Railway Practice. R. Kühnel (*Glasers Ann.*, 1935, **117**, 135–137).—The development of the uses of bearing metals, red brass, bronze, and copper on the German railways since 1919 is discussed.—B. Bl.

The Electrical Equipment of Schools and Research Institutes. H. Hader and W. Jaeckel (*Elektrotech. Z.*, 1935, **56**, 993–996).—B. Bl.

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